FEAR OF FALLING AND BALANCE CONFIDENCE
IN OLDER ADULTS WITH DIABETES MELLITUS

by

Patricia Amy Hewston

A thesis submitted to the Graduate Program in Rehabilitation Science
in conformity with the requirements for
the degree of Doctor of Philosophy

Queen’s University
Kingston, Ontario, Canada
(September, 2016)

Copyright © Patricia Amy Hewston, 2016

This work is licensed under a Creative Commons Attribution 4.0 International License
Abstract

Several determinants of fear of falling (FoF) and low balance confidence overlap with the consequences/complications of diabetes mellitus (DM). FoF is strongly associated with low balance confidence, and balance confidence mediates the relationship between FoF and balance and physical function. The purpose of this thesis was two-fold: (1) to examine the prevalence, severity and determinants of FoF in older adults (aged≥65) with DM, and (2) to evaluate the validity of the short version of the Activities-specific Balance Confidence scale (ABC-6) and its association with balance and postural control in older adults with DM. Three separate studies were conducted of older adults with DM (DM-group) and without DM (noDM-group). Study I revealed that although FoF prevalence adjusted for age and sex was not different between-groups, the DM-group had 8.8% fewer participants in the low and 8.4% more in the high Falls-Efficacy Scale International categories when compared to the noDM-group. Higher FoF severity in the DM-group was associated with poor physical performance, being female, fall history and clinical depressive symptoms. Study II provided evidence of convergent, discriminant and concurrent validity of the ABC-6 for use in older adults with DM with and without diabetic peripheral neuropathy (DPN). Notably, the ABC-6 was more sensitive in detecting subtle differences in balance confidence between the DM-group and noDM-group when compared to the original ABC scale (ABC-16), and can be administered in less time. Study III explored balance confidence (ABC-6) and its association with balance and postural control in older adults with DM. Subtle differences in axial segmental control (i.e., lower trunk roll velocity and higher head-trunk correlations) while walking and lower balance confidence were apparent in the DM-group, even in the
absence of DPN, when compared to the noDM-group. Balance confidence partially explained the variance in head-trunk stiffening between-groups, and consequently low balance confidence in older adults with DM may contribute to the dependence on postural control strategies that are normally only utilized in high-risk situations. Findings from this thesis will help to guide the development of protocols for screening and intervention recommendations of patient education and targeted rehabilitation programs for older adults with DM.

**Keywords:**

Diabetes Mellitus; Fear of Falling; Balance Confidence; Balance; Postural Control
Co-Authorship and Contributions to the Literature

This thesis presents the doctoral research conducted by Patricia Hewston under the supervision of Dr. Nandini Deshpande. The sum of this work resulted in the following contributions to the literature with the intended authorship as follows:

**Manuscripts included in this thesis:**

**CHAPTER 3: STUDY I**

P. Hewston, A. Garcia, B. Alvarado, and N. Deshpande. Prevalence, severity, and determinants of fear of falling in older adults with diabetes mellitus: The International Mobility in Aging Study (IMIAS).

**CHAPTER 4: STUDY II**

P. Hewston and N. Deshpande. The short version of the activities-specific balance confidence scale for older adults with diabetes mellitus: convergent, discriminant and concurrent validity. (In Revisions: Canadian Journal of Diabetes).

**CHAPTER 5: STUDY III**

P. Hewston and N. Deshpande. Head and trunk control while walking in older adults with diabetes mellitus: effects of balance confidence. (In Revisions: Journal of Motor Behavior).

**Related published manuscripts:**

P. Hewston and N. Deshpande. Falls and balance impairments in older adults with type 2 diabetes: Thinking beyond diabetic peripheral neuropathy. Canadian Journal of Diabetes, 2016;40: 6-9. (Mini-review based on Comprehensive Exam). This manuscript was selected by the Primary Care Committee for reprint in the Fall 2016 issue of the Canadian Journal of Diabetes – Primary Care Edition.

Acknowledgements

Sincere thanks to,

Dr. Nandini Deshpande, my thesis supervisor, for your endless support, enthusiasm and excellent mentorship throughout the research outlined in this thesis,

Dr. Marcia Finlayson and Dr. Angeles Garcia, my thesis advisory committee members, for their insight and suggestions that have enriched this thesis,

Dr. Maria Victoria Zunzunegui, Dr. Beatriz Alvarado and the IMIAS team members, universities and institutes for their warm welcome and support,

Dr. Sandra Olney for your advice and encouragement over the past four years,

Dr. Etienne Bisson, Ms. Grace Lui, Ms. Lindsay DeLima and Ms. Alison Aldred for their assistance with data collection and, my fellow graduate students, for their friendship,

All the support staff in the School of Rehabilitation Therapy for their timely assistance,

All the participants for their time and willingness,

and

my parents, brother and grandparents for their unconditional support.

This work would not have been possible without the support of several funding agencies:

• STUDY I: CIHR (Grant # 108751, PI: Dr. Maria Victoria Zunzunegui)
• STUDY II: CIHR (Grant # 112214, PI: Dr. Nandini Deshpande)
• STUDY III: Senate Advisory Research Committee (SARC Grant # 129290, PI: Dr. Nandini Deshpande)

• This thesis was also further supported by the Canadian Occupational Therapy Foundation, Ontario Graduate Scholarship Program (Ontario Graduate Scholarships; Queen Elizabeth II Scholarship in Science and Technology), Queen’s University (Franklin Bracken Fellowship; Health Sciences Graduate Growth Funding; Queen’s Graduate Awards) doctoral scholarships to Patricia Hewston.
Table of Contents

Abstract .................................................................................................................................................. ii
Co-Authorship and Contributions to the Literature ................................................................. iv
Acknowledgements ............................................................................................................................. v
Table of Contents .................................................................................................................................. vi
List of Figures ....................................................................................................................................... xi
List of Tables ........................................................................................................................................ xii
List of Abbreviations .......................................................................................................................... xiii

CHAPTER 1
Introduction ................................................................................................................................................ 1
1.1. Fear of Falling ............................................................................................................................... 2
1.2. Balance Confidence ....................................................................................................................... 2
1.3. Balance and Postural Control ....................................................................................................... 3
1.4. Purpose and Structure of Thesis ................................................................................................. 5
1.5. References ..................................................................................................................................... 6

CHAPTER 2
Literature Review..................................................................................................................................... 11
2.1. Diabetes Mellitus .......................................................................................................................... 11
2.1.1. Definition ................................................................................................................................... 11
2.1.2. Prevalence and Classification .................................................................................................. 12
2.1.3. Diagnostic Criteria and Treatment .......................................................................................... 13
2.2. Falls-related Psychological Concerns .......................................................................................... 14
2.2.1. Fear of Falling .......................................................................................................................... 15
2.2.2. Falls-related Self-efficacy ......................................................................................................... 16
2.2.3. Balance Confidence ................................................................................................................. 17
2.2.4. Relationship with Balance and Physical Function ..................................................................... 18
2.3. Falls-related Psychological Concerns in Older Adults with Diabetes Mellitus... 20
2.3.1. Prevalence and Severity .......................................................................................................... 20
2.3.2. Determinants ........................................................................................................................... 22
CHAPTER 3
Prevalence, severity, and determinants of fear of falling in older adults with diabetes mellitus: The IMIAS Study (Study I) .......................................................... 49

3.1. Abstract ........................................................................................................... 50
3.2. Introduction ...................................................................................................... 51
3.3. Research Design and Methods ....................................................................... 52
  3.3.1. Participants and Sampling Strategy ............................................................ 52
  3.3.2. Outcome Measures .................................................................................... 52
  3.3.3. Statistical Analysis .................................................................................... 54
3.4. Results ............................................................................................................. 55
  3.4.1. Fear of Falling Prevalence and Severity .................................................... 55
  3.4.2. Fear of Falling Determinants .................................................................... 56
3.5. Discussion ....................................................................................................... 57
3.6. Study Limitations ............................................................................................ 60
3.7. Clinical Implications ....................................................................................... 60
3.8. Conclusions .................................................................................................... 61
3.9. References ...................................................................................................... 62
3.10. Tables ............................................................................................................ 66
3.11. Figures ........................................................................................................... 68

CHAPTER 4
The short version of the activities-specific balance confidence scale for older adults with diabetes mellitus: convergent, discriminant, and concurrent validity (Study II) ................................................................. 70

4.1. Abstract .......................................................................................................... 71
4.2. Introduction .................................................................................................... 72
CHAPTER 5
Head and trunk control while walking in older adults with diabetes mellitus:
effects of balance confidence (Study III) ................................................. 96
  5.1. Abstract ..................................................................................... 97
  5.2. Introduction ............................................................................. 98
  5.3. Methods .................................................................................. 99
    5.3.1. Participants ......................................................................... 99
    5.3.2. Participant Characteristics .................................................. 100
    5.3.3. Experimental Procedures ...................................................... 100
    5.3.4. Primary Outcome Measures ............................................... 101
    5.3.5. Statisical Analysis ................................................................. 102
  5.4. Results ...................................................................................... 103
    5.4.1. Primary Outcome Measures ............................................... 103
CHAPTER 6

General Discussion .................................................. 122

6.1. Discussion of Major Findings .................................... 123
6.2. Clinical Implications ............................................... 130
    6.2.1. Protocols for Screening ..................................... 131
    6.2.2. Patient Education and Targeted Rehabilitation Programs ...... 132
6.3. Conclusions .......................................................... 134
6.4. References ............................................................ 135

APPENDICES

Appendix A: Ethics Approvals ........................................... 139
    A.1. Study I ........................................................... 140
    A.2. Study II .......................................................... 143
    A.3. Study III ......................................................... 144

Appendix B: Primary Study Designs and Sample Sizes ................. 145
    B.1. Studies I-111 .................................................... 146

Appendix C: FoF and Balance Confidence Questionnaires ............ 151
    C.1. Falls-Efficacy Scale International (FES-I) ........................ 152
    C.2. Activities-specific Balance Confidence Scale (ABC-16; ABC-6) ...... 153
Appendix D: Clinical Assessments in the Physical Domain ......................... 154

D.1. Short Physical Performance Battery (SPPB) .................................. 155
D.2. Human Activity Profile (HAP) ...................................................... 157
D.3. Modified Timed-up and Go (mTUG) ............................................. 161
D.4. Modified Clinical Test of Sensory Integration and Balance (mCTSIB) .... 162
D.5. Frailty and Injuries: Cooperative Studies of Intervention Techniques (FICSIT-4) 163

Appendix E: Clinical Assessments in the Psychological Domain ................ 165

E.1. Centre for Epidemiological Studies Depression Scale (CES-D) .......... 166
E.2. Montreal Cognitive Assessment (MoCA) ......................................... 167
E.3. Trail Making Test – Part B (TMT-B) ............................................... 168

Appendix F: Sample Advertisements ...................................................... 170
List of Figures

CHAPTER 2
Figure 2.1: Schematic diagram of the correlations between fear of falling, balance confidence and functional ability................................................................. 48

CHAPTER 3
Figure 3.1: Fear of falling prevalence in older adults with and without diabetes mellitus ....68
Figure 3.2: Fear of falling severity in older adults with and without diabetes mellitus ....69

CHAPTER 4
Figure 4.1: Convergent validity: ABC-6 and ABC-16 ........................................... 93
Figure 4.2: Discriminant validity: ABC-6 and ABC-16 between study-groups.............. 94
Figure 4.3: Supplemental figure of discriminant validity between study-groups.......... 95

CHAPTER 5
Figure 5.1a: Experimental setup: Instrumentation ................................................... 116
Figure 5.1b: Experimental setup: 6-meter walking path .......................................... 117
Figure 5.2: Walking speed between groups in 4 experimental conditions ................. 118
Figure 5.3: Head control between groups in 4 experimental conditions ................. 119
Figure 5.4: Trunk control between groups in 4 experimental conditions ............. 120
Figure 5.5: Representative graphs of head-trunk correlations ............................... 121
List of Tables

CHAPTER 2
Table 2.1: Fear of falling prevalence in older adults with diabetes mellitus ....................... 46
Table 2.2: Balance confidence and fear of falling severity in older adults with diabetes mellitus ......................................................................................................................... 47

CHAPTER 3
Table 3.1: Fear of falling determinants in older adults with and without diabetes mellitus ................................................................................................................................. 66
Table 3.2: Determinants of higher fear of falling severity in older adults with diabetes mellitus ................................................................................................................................. 67

CHAPTER 4
Table 4.1: Participant characteristics between study-groups .................................................. 90
Table 4.2: Physical and psychological assessments between study-groups ......................... 91
Table 4.3: Concurrent validity: Comparison of correlation coefficients of both ABC scales with physical and psychological clinical assessments in the DM study-groups............. 92

CHAPTER 5
Table 5.1: Participant characteristics between study-groups ................................................. 115
## List of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2hPG</td>
<td>2-hour plasma glucose</td>
</tr>
<tr>
<td>ABC-16</td>
<td>Activities-specific Balance Confidence Scale (Original – 16 items)</td>
</tr>
<tr>
<td>ABC-6</td>
<td>Activities-specific Balance Confidence Scale (Shortened – 6 items)</td>
</tr>
<tr>
<td>ANCOVA</td>
<td>Analysis of covariance</td>
</tr>
<tr>
<td>ANOVA</td>
<td>Analysis of variance</td>
</tr>
<tr>
<td>BMI</td>
<td>Body mass index</td>
</tr>
<tr>
<td>CBT</td>
<td>Cognitive Behavioural Therapy</td>
</tr>
<tr>
<td>CDA</td>
<td>Canadian Diabetes Association</td>
</tr>
<tr>
<td>CI</td>
<td>Confidence interval</td>
</tr>
<tr>
<td>CES-D</td>
<td>Centre for Epidemiological Studies Depression Scale</td>
</tr>
<tr>
<td>DM</td>
<td>Diabetes mellitus</td>
</tr>
<tr>
<td>DM-group</td>
<td>Older adults with diabetes mellitus</td>
</tr>
<tr>
<td>DPN</td>
<td>Diabetic peripheral neuropathy</td>
</tr>
<tr>
<td>DPN-group</td>
<td>Older adults with diabetes mellitus and diabetic peripheral neuropathy</td>
</tr>
<tr>
<td>ETDRS</td>
<td>Early Treatment Diabetic Retinopathy Study Tumbling E Chart</td>
</tr>
<tr>
<td>FES</td>
<td>Falls-Efficacy Scale</td>
</tr>
<tr>
<td>FES-I</td>
<td>Falls-Efficacy Scale International</td>
</tr>
<tr>
<td>FICSIT-4</td>
<td>Frailty and Injuries: Cooperative Studies of Intervention Techniques</td>
</tr>
<tr>
<td>FoF</td>
<td>Fear of falling</td>
</tr>
<tr>
<td>FPG</td>
<td>Fasting plasma glucose</td>
</tr>
<tr>
<td>FrPC</td>
<td>Falls-related psychological concerns</td>
</tr>
<tr>
<td>GDM</td>
<td>Gestational diabetes mellitus</td>
</tr>
<tr>
<td>GLM</td>
<td>General linear model</td>
</tr>
<tr>
<td>HAP</td>
<td>Human Activity Profile</td>
</tr>
<tr>
<td>HAP-AAS</td>
<td>Human Activity Profile – Activity adjusted score</td>
</tr>
<tr>
<td>HbA1c</td>
<td>Glycated hemoglobin</td>
</tr>
<tr>
<td>HRp-p</td>
<td>Peak-to-peak head roll angular displacement</td>
</tr>
<tr>
<td>HRvel</td>
<td>Head roll velocity</td>
</tr>
<tr>
<td>H-T</td>
<td>Head-trunk</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>-------------</td>
</tr>
<tr>
<td>H-Tcorr</td>
<td>Head-trunk roll correlation</td>
</tr>
<tr>
<td>Icon-FES</td>
<td>Iconographical Falls-efficacy Scale</td>
</tr>
<tr>
<td>IFCC</td>
<td>International Federation of Clinical Chemistry and Laboratory Medicine</td>
</tr>
<tr>
<td>IMIAS</td>
<td>International Aging in Mobility Study</td>
</tr>
<tr>
<td>IMIAS-SNSS</td>
<td>International Aging in Mobility Study – Social Networks and Social Support</td>
</tr>
<tr>
<td>IRED</td>
<td>Infrared emitting diode</td>
</tr>
<tr>
<td>LCT</td>
<td>Leganes Cognitive Test</td>
</tr>
<tr>
<td>LDL</td>
<td>Low-density lipoprotein</td>
</tr>
<tr>
<td>mCTSiB</td>
<td>modified Clinical Test of Sensory Integration for Balance</td>
</tr>
<tr>
<td>MoCA</td>
<td>Montreal Cognitive Assessment</td>
</tr>
<tr>
<td>mTUG</td>
<td>modified Timed-up-and-Go</td>
</tr>
<tr>
<td>noDM-group</td>
<td>Older adults without diabetes mellitus</td>
</tr>
<tr>
<td>NGSP</td>
<td>National Glycohemoglobin Standardized Program</td>
</tr>
<tr>
<td>No-SS3</td>
<td>No Serial Subtraction by 3’s</td>
</tr>
<tr>
<td>OR</td>
<td>Odds ratio</td>
</tr>
<tr>
<td>PR</td>
<td>Prevalence Ratio</td>
</tr>
<tr>
<td>ProFANE</td>
<td>Prevention of Falls Network Europe</td>
</tr>
<tr>
<td>SAFE</td>
<td>Survey of Activities and Fear of Falling in the Elderly</td>
</tr>
<tr>
<td>SD</td>
<td>Standard deviation</td>
</tr>
<tr>
<td>SPPB</td>
<td>Short Physical Performance Battery</td>
</tr>
<tr>
<td>SPSS</td>
<td>Statistical Package for the Social Sciences</td>
</tr>
<tr>
<td>SS3</td>
<td>Serial Subtraction by 3’s</td>
</tr>
<tr>
<td>T1D</td>
<td>Type 1 diabetes</td>
</tr>
<tr>
<td>T2D</td>
<td>Type 2 diabetes</td>
</tr>
<tr>
<td>TMT-B</td>
<td>Trail Making Test Part B</td>
</tr>
<tr>
<td>TRp-p</td>
<td>Peak-to-peak trunk roll angular displacement</td>
</tr>
<tr>
<td>TRvel</td>
<td>Trunk roll velocity</td>
</tr>
<tr>
<td>TUG</td>
<td>Timed-up and Go</td>
</tr>
</tbody>
</table>
CHAPTER 1: INTRODUCTION

Diabetes mellitus (DM) is a chronic metabolic condition that affects 415 million adults worldwide and is projected to increase to 642 million (or 1 in 10 adults) by 2040 (1). DM is highly prevalent in older adults (≥65 years of age) (2). Older adults with DM are 2.73-times (95% CI:1.61-4.63) more likely to experience multiple falls (3) and 1.70-times (95% CI:1.30-2.20) more likely to have a hip fracture (4) when compared to older adults without DM. Given the devastating consequences of falls, it is not surprising that older adults with DM report falls-related psychological concerns of fear of falling (FoF) (5–15) and low balance confidence (16,17).

Falls-related psychological concerns are reported in both fallers and non-fallers and can potentially be more debilitating than a fall itself (18). FoF and loss of confidence in the ability to maintain balance can lead to a vicious cycle of self-imposed activity restriction, deconditioning, postural instability, and social isolation which can expedite the pathway to disability (18,19). It is known higher FoF severity is strongly associated with low balance confidence (20–22) and balance confidence mediates the relationship between FoF and worse balance and physical function (20,23). However, falls-related psychological concerns can have differential effects on different populations due to the complex interaction between pathology, FoF and an individuals perceived control in their ability to maintain balance (23–25). Therefore, if protocols for screening and intervention recommendations for patient education and targeted rehabilitation programs are to be developed for older adults with DM, it is first critical to understand the current state of knowledge, severity, determinants, assessments, and potential influence of falls-related psychological concerns in older adults with DM.
1.1. Fear of Falling

FoF is a lasting concern about falling that can lead an individual to avoid activities that he/she remains capable of performing (26). FoF is more prevalent in older adults with DM (69%) than those without DM (49%) (8). However, FoF has been primarily assessed with a single dichotomous question enquiring about FoF prevalence in older adults with DM (5–11) which provides no information on FoF severity. In contrast, the *Falls-efficacy Scale International* (FES-I) standardized questionnaire has established cut-off points of low, moderate and high concern about falling (27). The FES-I quantifies FoF severity to help clinicians identify those who are in need of FoF interventions (28).

FoF has been primarily attributed to poor physical performance, particularly, mobility and balance impairments in older adults with DM (8-10). However, several other determinants for developing FoF overlap with the consequences/complications of DM, including but not limited to, falls, muscle weakness, diabetic peripheral neuropathy (DPN), depression and cognitive decline (29–31). Therefore, it is possible that the cumulative effect of these DM-related consequences may contribute to higher FoF severity in older adults with DM. However, no studies could be cited that investigated if FoF is more severe in older adults with DM when compared to those without DM, and also which determinants may contribute to higher FoF severity in older adults with DM.

Therefore, the specific objectives of the first study in this thesis were to compare the prevalence and severity of FoF in older adults with and without DM, and identify which FoF determinants contribute to FoF severity in older adults with DM.

1.2. Balance Confidence

Balance confidence is defined as an individual’s belief in their ability to maintain
balance during activities of daily living (32). The most commonly used measure of balance confidence is the Activities-specific Balance Confidence Scale (ABC-16). Of the limited evidence available, balance confidence (ABC-16) has been reported to be 11% lower in older adults with DM without diagnosed DPN who were fallers than non-fallers (16) and low in older adults with DPN (ABC-16: 71.42%) (17). However, balance confidence (ABC-16) has been documented to be similar between older adults with and without DM despite subtle but clear DM-related degradation of sensory functions (visual; vestibular; somatosensory) and worse balance performance (16). Emerging evidence suggests the short version of the ABC Scale (ABC-6), with its narrower continuum of activity difficulty, is more sensitive to detect subtle differences in balance confidence than the ABC-16 (33). Therefore, it is possible the ABC-6 may detect subtle differences in balance confidence between older adults with and without DM that are undetected by the ABC-16. Furthermore, the ABC-6 is advantageous in busy clinical or research settings as it can be administered in considerably less time than the ABC-16. Although the psychometric properties of the ABC-6 are reported in community-dwelling older adults (33,34) and those with chronic conditions (e.g., Parkinson’s Disease, high-level gait disorders) (34), no studies have investigated the validity of the ABC-6 in older adults with DM. Therefore, the specific objective of the second study in this thesis is to evaluate the convergent, discriminant and concurrent validity of the ABC-6 in older adults with DM with and without diagnosed DPN.

1.3. Balance and Postural Control

FoF and/or low balance confidence can result in the misappraisal of risk, anticipatory anxiety, and ultimately, the dependence on postural control strategies that are
normally only utilized in high-risk situations (35). FoF has been associated with conservative gait (e.g., slower gait speed, slower stride velocity and shorter stride length) in older adults with DM (12–14). However, investigations have primarily focused on global control and lower limb gait parameters. Yet, approximately two-thirds of the body’s mass is attributed to the upper body (36) and precise head and trunk control are critical to maintain an upright posture and balance while walking (37). FoF and low balance confidence are strongly associated with a head-trunk stiffening strategy in older adults (38–40) and Deshpande and Patla (41) reported head-trunk stiffening as a generalized postural control strategy adopted by older adults during gait that was not present in young adults. Older adults with DM have been documented to stiffen their upper body during standing balance under challenging conditions (42) possibly in an attempt to simplify postural control (i.e., reduce degrees of freedom in the head-neck control) and improve head stabilization to maintain balance. However, no studies have explored the relationship between balance confidence and head-trunk stiffening during gait under challenging conditions in older adults with DM. Yet, low balance confidence is theorized to result in an internal focus of attention (40). Therefore, concurrent execution of a postural control strategy may result in inadequate attentional resources for optimal task performance (40). Furthermore, it is unknown if tasks that are known to increase challenge to postural control while walking affects head and trunk control more in older adults with DM than those without DM. Therefore, the specific objectives of the third study in this thesis were to examine the relationship between balance confidence (ABC-6) and head-trunk stiffening, as well as, head and trunk control individually during gait under challenging conditions in older adults with and without DM.
1.4. Purpose and Structure of Thesis

The purpose of this thesis was two-fold: (1) to examine the prevalence, severity and determinants of FoF in older adults with DM, and (2) to evaluate the validity of the ABC-6 and its association with balance and postural control in older adults with DM. To identify the gaps in the literature, a comprehensive literature review was undertaken to portray the current state of knowledge (Chapter 2). Study I compares the prevalence and severity of FoF (FES-I) in older adults with and without DM, and identifies which FoF determinants contribute to FoF severity in older adults with DM (Chapter 3). Study II evaluates if the ABC-6 is a valid assessment tool of balance confidence in older adults with DM with and without diagnosed DPN (Chapter 4). Study III explores the relationship between balance confidence (ABC-6) and head-trunk stiffening under challenging walking conditions in older adults with and without DM (Chapter 5). This thesis will conclude with an overall general discussion, future directions and clinical implications (Chapter 6).
1.5. References


CHAPTER 2: LITERATURE REVIEW

This chapter is a literature review composed of three main sections. Section I provides a brief overview of the definition, prevalence, classification, diagnostic criteria and treatment of diabetes mellitus (DM). Section II reviews the key constructs and commonly used assessment tools for the falls-related psychological concerns of fear of falling (FoF), falls-related self-efficacy and balance confidence. Section III synthesizes what is known about falls-related psychological concerns and their association with balance, mobility and postural control in older adults with DM. Lastly, the conclusion provides a critical appraisal of the available literature, identifies the gaps in the literature and presents the rationale for each study in this thesis.

2.1. Diabetes Mellitus

2.1.1. Definition

Areteaus of Cappadocia, an Ancient Greek Physician, first used the term diabetes (Greek, ‘to syphon’) to describe a condition that seemed to drain fluids rapidly from affected individuals. John Rollo, a British Surgeon-General, first used the adjective mellitus (Latin, ‘honey’) to distinguish diabetes (mellitus) with sweet urine and blood from the other diabetes (insipidus) with tasteless urine (1). The definition of DM has evolved with advancements in pathophysiology research and most notably the discovery (1921) and clinical use (1922) of insulin by Banting, Best, Macleod and Colip (1). Currently, the Canadian Diabetes Association (CDA) Clinical Practice Guidelines defines DM as a “metabolic disorder characterized by the presence of hyperglycemia due to defective insulin secretion, defective insulin action or both” (2).
2.1.2. Prevalence and Classification

An estimated 415 million adults currently have DM worldwide, a number that is projected to increase to 642 million (or 1 in 10 adults) by 2040 (3). In Canada, the prevalence of DM is currently estimated to be 3.4 million (9.3%) individuals (4). DM is significantly more prevalent in older adults (≥65 years), males (55%), and in individuals of certain ethnic groups (i.e., those of Aboriginal, Hispanic, Asian, South or Southeast Asian or African descent) (3–5).

There are three main types of DM: type 1 diabetes (T1D), type 2 diabetes (T2D), and gestational diabetes mellitus (GDM). T1D, previously referred to as insulin dependent diabetes or juvenile-onset diabetes, primarily results from a cellular-mediated autoimmune destruction of the beta cells in the pancreas and absolute insulin deficiency (2). T1D often develops suddenly in children and accounts for 5-10% of all individuals diagnosed with DM. T2D, previously referred to as non-insulin dependent diabetes or adult-onset diabetes, is characterized by insulin resistance and often relative insulin deficiency (2). The development of T2D occurs primarily in older adults and accounts for 90-95% of all individuals with DM. Although the exact cause of T2D is unknown, several modifiable risk-factors have been identified which include: obesity defined as a body mass index (BMI) ≥30kg/m², physical inactivity and poor nutrition (3). Lastly, GDM is characterized by glucose intolerance that is first detected during pregnancy. GDM significantly increases the risk of developing T2D after childbirth. Although there are three distinct classifications of DM, which do not have the same cause, DM-related complications and consequences have been documented to be analogous (6).
2.1.3. Diagnostic Criteria and Treatment

The majority of epidemiological research studies classify DM as a dichotomous variable (yes/no) based on self-report or blood glucose levels (3). A DM diagnosis can be determined by fasting plasma glucose (FPG≥7.0 mmol/L, with fasting not >8 hours), 2-hour plasma glucose (2hPG≥11.1 mmol/L) in a 75g oral glucose tolerance test or glycated hemoglobin (HbA1c≥6.5%, in the absence of factors that affect the accuracy of HbA1c values) (2). Of these diagnostic tests, the FPG and 2hPG have high established standards and can accurately predict the onset of microvascular complications (e.g., retinopathy) but are highly susceptible to day-to-day variability (2). In contrast, the HbA1c test can predict long-term glucose concentration over the past three months but may be misleading in those with certain complications (e.g., underestimate glucose levels in those with haemolytic anemia or B12 deficiency, and overestimate glucose levels in those with iron deficiency anemia, chronic liver disease, etc) (7,8). Therefore, the CDA Clinical Practice Guidelines recommends that the decision of which diagnostic test to use be based on clinical judgment and individual factors (2).

In Canada, HbA1c is reported using the National Glycohemoglobin Standardized Program (NGSP) units as a percentage (8). Therefore, throughout this thesis HbA1c will be written in NGSP units (%). However, these HbA1c (%) can be converted to the International Federation of Clinical Chemistry and Laboratory Medicine (IFCC) SI units (mmol/mol) with the following formula: [IFCC = 10.93(NGSP) - 23.50] (9). The CDA Clinical Practice Guidelines recommends optimal glycemic control at HbA1c≤7% for vascular protection from macrovascular (e.g., coronary artery, peripheral arterial, and cerebrovascular diseases) and microvascular (e.g., nephropathy, diabetic peripheral
neuropathy [DPN], diabetic retinopathy) complications in individuals with DM (10). However, less stringent HbA1c targets between 7.1-8.5% may be more appropriate for older adults, those with longer diabetes duration or a history of severe hypoglycemia (10). Lifestyle modifications is the first line of treatment for most patients diagnosed with T2D. If glycemic targets are not met, pharmacological therapy is used with treatment individualized using different classes of anti-hyperglycemic medications each with a different mechanism of action. In those with T1D first line treatment is to establish an insulin therapy administered by syringe, pen or pump (11). However, glycemic control is only the “A” in the ABCDEs for vascular protection outlined in the CDA Clinical Practice Guidelines, and is followed by “B” for blood pressure control (<130/80 mmHg), “C” for cholesterol management (low density lipoprotein [LDL] ≤2.0 mmol/L), “D” for drugs to protect the heart, “E” for exercise, and “S” for smoking cessation (12).

2.2. Falls-Related Psychological Concerns

Falls-related psychological concerns is an umbrella term that encompasses the constructs of FoF, falls-related self-efficacy and balance confidence (13). Falls-related psychological concerns can potentially be more debilitating than a fall itself, as fear and loss of confidence can lead to self-imposed activity avoidance, deconditioning, postural instability, and social isolation which can expedite the pathway to disability (14). However, distinguishing between these constructs has become increasingly problematic as they are often used interchangeably in the literature (13) and the construct of FoF has been used incorrectly as an umbrella term for all falls-related psychological concerns (15). In order to develop clarity and consistency within this evidence base, it is critical that individual constructs are clearly defined (13). Therefore, the constructs of FoF, falls-
related self-efficacy, and balance confidence will be defined below.

### 2.2.1. Fear of Falling

In 1982, Murphy and Isaacs first mentioned the concept of FoF after observations that older adults who fell had severe anxiety that affected their ability to stand or walk unsupported, and documented this as post-fall syndrome (16). FoF can reflect a realistic appraisal of reduced functional abilities which can lead to appropriate cautious behaviour to avoid falls. However, FoF can also be irrational, excessive, and a persistent vicious cycle of reduced balance confidence, activity avoidance, deconditioning, postural instability, and social isolation which in turn can increase fall-risk and exacerbate FoF (17). Tinneti and Powell defined FoF “as a lasting concern about falling that can lead an individual to avoid activities that he/she remains capable of performing” (18). This definition is widely used and recognizes FoF as a significant health concern of both fallers and non-fallers.

The simplest way to assess FoF is with the single question, “Are you afraid of falling?” (15). Although this approach is informative, this question may underestimate FoF prevalence and does not provide a measure of FoF severity. In contrast, the Survey of Activities and Fear of Falling in the Elderly (SAFE) is a standardized questionnaire that quantifies FoF prevalence and severity during the performance of 11 activities and also provides an index of activity restriction as a result of FoF (19). The SAFE is a valid and reliable assessment of FoF with excellent internal consistency (Cronbach’s $\alpha=0.91$) in older adults (19). Drawing from the SAFE and healthcare professionals’ experience, the Prevention of Falls Network Europe (ProFaNE) developed the Falls-Efficacy Scale International (FES-I). The FES-I is a standardized questionnaire that assesses concern
about falling, rather than falls-efficacy as suggested by its name which was retained to acknowledge the historical development of the scale (15,20), within 16 physical and social activities at home and the community. FES-I items are rated on a four-point scale (1[not at all concerned] to 4[very concerned]) and total scores range from 16-64 (20). FES-I total scores can be further classified based on FoF severity with clinical cut-off points of no (score=16), low (score=17-19), moderate (score=20-27) and high (score≥28) concern about falling (21). The FES-I has excellent reliability and validity across many different languages and cultures (20,22) as well as excellent internal consistency (Cronbach’s α=0.96) in older adults (20). Limitations of the FES-I include the encouragement of hypothetical answers even if an individual does not currently engage in an activity, ambiguous environmental contexts, and inconsistent findings in those with cognitive impairment. As a result, the Iconographical Falls-efficacy Scale (Icon-FES) was recently developed to precisely describe environmental circumstances of each activity and the use of pictures for visual cues (23). Further, the Icon-FES may be more suitable to assess FoF in older adults with cognitive impairments (24).

2.2.2. Falls-related Self-efficacy

Falls-related self-efficacy is defined as an individual’s “confidence in their ability to undertake activities of daily living without falling” (25). The most common measure of falls-related self-efficacy is the Falls-Efficacy Scale (FES) which preceded the FES-I and was the first instrument to expand on the conceptualization of FoF as a dichotomous entity (25). The FES is a standardized 10-item questionnaire that measures confidence to perform a series of activities without falling (25). The FES is a valid and reliable assessment of falls-related self-efficacy with excellent internal consistency.
(Cronbach’s $\alpha=0.96$) in older adults (25). However, the FES assesses confidence during basic activities of daily living and may be less sensitive to identify low self-efficacy in active community-dwelling older adults during challenging physical and social activities (20).

2.2.3. Balance Confidence

Balance confidence is conceptually similar to falls-related self-efficacy as both constructs measure an individual’s confidence to perform daily activities (15). However, balance confidence refers to situation-specific self-efficacy regarding balance performance (13). Specifically, balance confidence is defined as “an individual’s belief in their ability to maintain balance while performing activities of daily living” (26).

The most commonly used measure of balance confidence is the Activities-specific Balance Confidence Scale (ABC-16). The ABC-16 is a standardized 16-item questionnaire that measures balance confidence during activities that occur both at home and in the community during both static and mobility challenges with or without perturbations (26). Balance confidence is measured on a continuum of 0% (no confidence) to 100% (completely confident) for 16 activities of daily living and reported as a percentage based on the mean of all 16-items for the ABC-16 (26). Higher scores indicate higher balance confidence and a cut-off score of <67% has been used to classify older adults who are at risk of falling (27). The ABC Scale is a valid and reliable assessment of balance confidence with excellent internal consistency (Cronbach’s $\alpha=0.96$) in older adults (26). However, in order to reduce the time to administer the ABC-16 in busy clinical or research settings, the short version of the ABC Scale (ABC-6) was derived from the identification of six items (items 5, 6, 13-16) with
the lowest balance confidence on the ABC-16 in older adults with Parkinson’s Disease and high-level gait disorders (28). The ABC-16 and ABC-6 have similar psychometric properties and are strongly correlated (r=0.95; p<0.001) when assessed in community-dwelling older adults (28,29) and those with chronic conditions (e.g., Parkinson’s Disease, high-level gait disorders) (28,30). However, the ABC-16 may potentially inflate balance confidence scores and decrease the ability to distinguish between fallers and non-fallers in community-dwelling older adults when compared to the ABC-6 (29). Therefore, the ABC-6 may be a more useful measure of balance confidence than the ABC-16 in community-dwelling older adults.

2.2.4. Relationship with balance and physical function

FoF and/or low balance confidence can lead to activity avoidance and consequently declines in functional abilities (balance and physical function) (17). However, FoF and balance confidence are distinct constructs which raises the question: what is the relationship between FoF, balance confidence and functional abilities?

Drawing from related psychology literature, Bandura defined the term **self-efficacy** as an individual’s belief about his or her capabilities to successfully complete an action (31,32). Bandura’s Self-Efficacy Theory demonstrates that self-efficacy mediates the relationship between thoughts/actions and behaviour/performance (31). In general, individuals with low self-efficacy avoid the performance of activities that are viewed as personal threats (31). However, the limitations of Bandura’s Self-Efficacy Theory include the ambiguity of the definition and assessment of self-efficacy, and its unidimensional view of self-efficacy to mediate the relationship between thoughts/actions and behaviour/performance (33). To address these concerns, within the falls-literature, FoF
has been defined as falls-related self-efficacy which can be assessed on the FES-I and is viewed as one of many determinants that can lead to changes in physical function (behaviour/performance) (15).

Tinetti et al. (34) reported falls-related self-efficacy to be a robust significant correlate of functional abilities, even after adjusting for relevant covariates, in older adults (N=1103, age≥72 years). In constrast, FoF was only marginally correlated with functional abilities in the same cohort (34). However, few studies have investigated how balance confidence (situation-specific self-efficacy) is associated with FoF and functional abilities. Figure 2.1 is a schematic diagram of what is currently known about the relationships between: (a) FoF and balance confidence, (b) FoF and functional ability, and (c) balance confidence and functional ability. FoF is moderately-to-strongly correlated with balance confidence (r=-0.33, p<0.001) in community-dwelling older adults and those with chronic conditions (dizziness: FES-I and ABC-16; r=-0.84, p<0.001 (35); Parkinson’s disease: FES-I and ABC-16; r=-0.80, p<0.001 (36)). However, the strength of the correlates of FoF and balance confidence with functional ability appears to be different. Specifically, Li et al. (37) reported the functional abilities of community-dwelling older adults (N=256, age≥70) to have none-to-weak correlations with FoF but be moderately correlated with balance confidence (r=0.25–0.54, p<0.001). Consequently, balance confidence has been described as a cognitive mechanism that mediates the relationship between FoF (thoughts/actions) and functional abilities (behaviour/performance) in older adults (37).

Hadjistavropoulos, Delbaere and Fitzgerald (15) also included the mediating role of balance confidence in a new theoretical model of FoF and falls for community-
dwelling older adults. Furthermore, balance confidence has been documented as a better predictor of future falls than FoF (38,39). Overall, these studies provide converging evidence that FoF and balance confidence are distinct constructs, and that balance confidence may have a stronger relationship with functional abilities than FoF.

### 2.3. Falls-Related Psychological Concerns in Older Adults with Diabetes Mellitus

To identify what is known about falls-related psychological concerns in older adults with DM, a systematic search of the literature was conducted. The search strategy involved a two-step process: (1) a primary search of CINAHL, EMBASE, PubMed and Google Scholar electronic databases, and (2) secondary search of article reference lists and citation tracking. The search included MeSH terms and key terms of: ‘diabetes’ AND ‘fear’ OR ‘falls AND self-efficacy’ OR ‘balance confidence’. Dates were from database inception and limited to English. The final searches were completed in May 2016. Based on the criteria above, a total of 13 research articles (11 FoF; 0 falls-related self-efficacy; 2 balance confidence) were identified that examined falls-related psychological concerns in individuals with DM. Findings from these articles, in addition to related literature, will be discussed below to identify what is known about the prevalence, severity and determinants of falls-related psychological concerns, as well as its influence on balance, mobility and postural control in older adults with DM.

#### 2.3.1. Prevalence and Severity

Table 2.1 summarizes the evidence of the prevalence FoF in individuals with DM. FoF prevalence, assessed with a single dichotomous question, ranged from 5-69% in individuals with DM (40–45). However, the large variance in FoF prevalence may be
attributed to subtle differences in methodology. Specifically, low prevalence of FoF was found when participants were asked, “Do you have FoF?” (5%) (43) when compared to the lay question “Are you afraid of falling” (66%) (46). FoF prevalence significantly increased with DM-related complications (noDM-group: 5%; DPN-group: 20%; DPN-Pain-group: 64%) (43) and was higher in older adults with DM when compared to those without DM (44,45). Furthermore, consistent with the literature (47,48), FoF prevalence was significantly higher in females (67.8%) than males (56.3%) in older adults with DM when compared to those without DM (45). Therefore, FoF is a significant health concern in some older adults with DM than those without DM.

Table 2.2 summarizes the evidence of balance confidence and FoF severity in older adults with DM. Balance confidence (ABC-16) has been reported to be 11% lower in older adults with DM without overt DPN who were fallers than non-fallers (49) and low in older adults with DPN (ABC-16: 71.42%) (50). However, balance confidence (ABC-16) was not significantly different between older adults with and without DM despite subtle but clear degradation of sensory functions (visual; vestibular; somatosensory) and worse balance in the DM-group when compared to the noDM-group (49). Consequently, it is possible that the ABC-16 may not be sensitive enough to detect subtle differences in balance confidence between-groups. Therefore, the exploration of more sensitive assessment tools (ABC-6) is required in older adults with DM without overt DPN.

Of the few studies available, FoF severity has been documented to range from no (FES-I total score = 16) to high (FES-I total score = 46) concern about falling in older adults with DM (51,52). However, despite this broad range, moderate-to-high FoF
severity has been reported in 82% of older adults with DM, regardless of overt DPN (53). This is of particular importance as higher concerns of FoF may lead to excessive activity restriction (54) that can potentially cause physical deconditioning, postural instability, and falls (15). However, no studies could be cited that investigated whether FoF is more severe in older adults with DM when compared to those without DM. Yet, this information is required to determine if additional protocols for screening are needed for older adults with DM in addition to existing falls-prevention programs for older adults.

2.3.2. Determinants

FoF has been primarily attributed to poor physical performance, particularly, mobility and balance impairments in older adults with DM (42–44,55). However, several other determinants for developing falls-related psychological concerns overlap with the consequences/complications of DM, including but not limited to, falls, sensory impairments, muscle weakness, cognitive decline and depression (48,56,57). Therefore, it is possible that the cumulative effect of these DM-related consequences may contribute to higher FoF severity and subsequently greater activity restriction and deconditioning in older adults with DM. This sub-section aims to explore which determinants may contribute to higher FoF severity and lower balance confidence in older adults with DM.

2.3.2.1. Physical Domain

The most robust determinants of falls-related psychological concerns in older adults have been identified within the physical domain (47,48). Fall history is a significant determinant of FoF in older adults who have experienced at least one fall in the past year (OR=2.96; 95% CI:2.46–3.56) (58) or recurrent falls (OR=5.72; 95% CI:4.40–7.43) (59). However, emerging evidence indicates that balance confidence may
be a better predictor of future falls than FoF in older adults (38,39). Furthermore, balance impairments are a significant determinant of both moderate (OR=1.75; 95% CI:1.21-2.55) and high (OR=4.44; 95% CI:2.15-9.17) FoF in older adults (60). As well, older adults with mobility impairments who used a walking aid have been shown to be 5.71-times (95% CI:2.51-8.05) more likely to report FoF when compared to those who do not use a walking aid (61). Low balance confidence is significantly correlated with worse standing balance (tandem stance, r=0.592, p<0.01; unipedal stance, r=0.686, p<0.01) and mobility (Timed-up and Go, r=0.606, p<0.01) (62). Overall, all of these physical determinants of falls-related psychological concerns have been identified as DM-related consequences/complications, and will be discussed below.

Falls are highly prevalent in older adults with DM with annual incidence rates of 39% (63). Older adults with DM are 2.73-times (95% CI:1.61-4.63) more likely to experience multiple falls (64) and 1.70-times (95% CI:1.30-2.20) more likely to experience a hip fracture (65) when compared to those without DM. Although several risk factors are associated with falls, one of the most commonly identified determinant is impaired balance (66). Balance requires the integration of multiple sensorimotor and cognitive processes (67,68). Therefore, it is not surprising that emerging evidence suggests that DM-related sensorimotor and cognitive impairments may contribute to increased fall-risk in older adults with DM (68). However, no studies could be cited that investigated if DM-related declines in multiple sensory systems (somatosensory, visual and vestibular), as well as muscular and cognitive functions, required for balance and postural control may contribute to higher FoF severity and lower balance confidence in older adults with DM than those without DM.
DPN (38.4%), diabetic retinopathy (26.3%) (5) and vestibular dysfunction (57.9%) (69) are highly prevalent in individuals with DM. Long-term hyperglycemia can lead to DPN, which is characterized by a distal to proximal nerve damage of the feet and hands (70). DPN affects the largest and most rapidly conducting sensory fibers of the somatosensory system which include 1a afferents from muscle spindles, as well as 1b afferents from golgi tendon organs and cutaneous mechanoreceptors (71). Consequently, DPN disrupts the ability to detect changes in muscle length (muscle spindles), muscle tension (golgi tendon organs), and vibration and pressure sensations (cutaneous mechanoreceptors) which provide critical information for balance and postural control. Long-term hyperglycemia can also affect the circulatory system of the retina and consequently diabetic retinopathy (72). Specifically, diabetic retinopathy can cause macular edema which distorts central vision, damage to small blood vessels (non-proliferative diabetic retinopathy) or the accumulation of scar tissue (proliferative diabetic retinopathy) which can reduce visual-contrast sensitivity (72). Furthermore, diabetic retinopathy is the leading cause of legal blindness (73). Collectively, these visual changes can impair the ability to safely navigate through the natural environment particularly under dimly lit conditions or in the presence of low contrast tripping hazards (e.g. sidewalk curb). In addition to DPN and diabetic retinopathy, long-term hyperglycemia can result in vestibular dysfunction of the highly active metabolic vasculature of the inner ear (74). Vestibular dysfunction can disrupt the ability to rapidly relay information about the head’s position and orientation in space which is crucial for maintaining gaze stabilization and overall balance (74). Lastly, sub-clinical declines in sensory function of one or more sensory system(s) reduces the sensory redundancy
available to the central nervous system which can also adversely affect balance and mobility in older adults with DM without overt complications (49,68).

Long-term hyperglycemia can also affect mechanical and metabolic muscle and cognitive functions in older adults with DM. Progressive declines in lower leg muscle mass and strength (75), as well as reduced grip strength (used as an indicator of total muscle strength) (55), have been documented in older adults with DM than those without DM. Subsequently, these declines in overall muscle strength can result in difficulty performing activities of daily living (e.g., sit-to-stand) or the ability to recover balance after perturbations. As well DM-related declines in cognitive functions can reduce the ability to integrate and re-weight sensory information needed to maintain balance and postural control. Therefore, the cumulative effect of DM-related sensorimotor and cognitive deficits, which can lead to balance and mobility impairments, may contribute to higher FoF severity and lower balance confidence in older adults with DM than those without DM.

2.3.2.2. Psychological and Social Domains

Significant determinants of falls-related psychological concerns in older adults have been identified within the psychological and social domains (47,48). In addition to the role of cognition in sensory integration, cognitive impairment has been identified as a significant determinant of FoF (OR=2.20; 95% CI:1.40-3.45) (61). However, inconsistent findings have been found in individuals with moderate cognitive impairment who report high concern of FoF (76) compared to those with Alzheimer’s disease who report low FoF prevalence (77), this may be attributed to the inability to comprehend items or report subjective states (24). In contrast, depressive symptoms and anxiety have been reported
in those with FoF and low balance confidence (61,78). As well psychotropic medications and heightened anxiety levels can alter the responsiveness and sensitivity of the central nervous system to control balance (78,79). Depression and anxiety can also erode one’s sense of independence and confidence to perform activities of daily living, and consequently lead to activity restriction and social isolation (80). Furthermore, older adults who live alone were 2-times (95% CI:1.69-4.47) more likely to have high concern of FoF when compared to older adults who did not live alone (60). This may be attributed to fear of being unable to get up and call for help in the event of an injurious fall, and/or deconditioning as a result of activity curtailment as a strategy to avoid falling and maintain an independent living status (81). Of all these psychological and social determinants, the majority have been identified as DM-related consequences/complications, and will be discussed below.

Within the psychological domain, long-term hyperglycemia has been associated with mitochondrial dysfunction, the accumulation of plaque (Amyloid Precursor Protein) and oxidative stress on brain tissue (82,83). Consequently, the co-morbidities of Alzheimer’s disease and vascular dementia as well as cortical (prefrontal) and subcortical abnormalities, are highly prevalent in older adults with DM (84). Furthermore, DM-related consequences of clinical depression (11%) and generalized anxiety disorder (14%) are more prevalent in individuals with DM when compared to those without DM (85–87). The possible mechanism behind the interplay between DM and these psychiatric conditions is hypothesized to be reciprocal susceptibility due to physical inactivity, obesity, and/or elevated cortisol release (85). Within the social domain, a diagnosis of DM may be psychologically taxing for an individual and their family members due to
“unpredictable symptoms, the need for continual monitoring and treatment, persistent concerns about complications and the potential erosion of personal and professional relationships” (85). Despite multiple DM-related consequences/complications which can occur within the psychological and social domains, there is limited evidence of the relationship between psychological and social determinants of falls-related psychological concerns in older adults with DM. Of the limited evidence available, Moreira et al. (88) revealed older women with DM who had higher FoF severity (FES-I total score ≥23) had more depressive symptoms when compared to those with lower FoF severity (FES-I total score <23). However, no studies have investigated the relative contributions of psychological determinants in comparison to other domains in older adults with DM.

2.3.2.3. Demographic Domain

In the demographic domain, several determinants have been associated with increased falls-related psychological concerns. Specifically, the non-modifiable determinants of older age and being female are strongly associated with FoF (47,48) and low balance confidence (46). Although FoF prevalence has been documented to be significantly higher in female (67.8%) than male (56.3%) older adults with DM when compared to those without DM (45), it is unknown if FoF severity is also higher in females with DM. Body mass index (BMI) is a significant determinant of FoF in older adults (60), and individuals with DM have significantly higher BMI than those without DM (64). Furthermore, low education, illiteracy or lack of education beyond reading/writing skills (OR=1.50; 95% CI:1.10-2.10) (89), and low socioeconomic status, below the poverty level (OR=1.40; 95% CI:1.13-1.73) (90), are both significant determinants of falls-related psychological concerns, and are more prevalent in
individuals with DM (91). The association of falls-related psychological concerns and low socioeconomic status may be attributed to limited healthcare access in an event of an injurious fall. Overall, the cumulative effect of higher BMI, low education and socioeconomic status may contribute to higher FoF severity and lower balance confidence in older adults with DM when compared to those without DM.

**2.3.3. Association with Balance, Mobility, and Postural Control**

Staab, Balaban, and Furman (92) conceptualized falls-related psychological concerns as fearful cognitive processes (cortex-amygdala) that can result in motor, physiological and/or endocrine alternations (93). Specifically, in animal models, fear has been associated with activation of the ascending projections of the central gray matter that elicits motor freezing as well as autonomic responses from the lateral hypothalamic projections of increased heart rate, blood pressure, temperature or respiration (92,94). Furthermore, the amygdala-driven fear response can result in changes in postural control and increased muscle activity during the “fight-or-flight response” activated by the sympathetic nervous system (92). Therefore, drawing from research in animal models of the neuro-anatomical links between falls-related psychological concerns and postural control, it is not surprising that postural threat responses are activated in the presence of fear. Specifically, the presence of FoF and/or low balance confidence can result in the misappraisal of risk, anticipatory anxiety, and ultimately, the dependence on postural control strategies that are normally only utilized in high-risk situations (92).

Despite the high prevalence of FoF and low balance confidence in older adults with DM, a limited number of studies have investigated their association with balance, mobility and postural control in older adults with DM. However, understanding how
these falls-related psychological concerns influence postural control in older adults with DM will provide direction for the development of targeted balance and mobility interventions. Therefore, this sub-section aims to summarize what is currently known about the relationship between falls-related psychological concerns and balance, mobility and postural control in older adults with DM and secondly, to draw from related literature of upper body control and postural threat to provide direction for future investigations.

It is now established that older adults with DM have altered gait patterns (95,96) and worse balance (97) when compared to those without DM, regardless of overt DPN. Of the limited evidence available, higher FoF severity has been associated with cautious gait patterns of reduced walking speed, slower stride velocity, shorter stride length and increased step variability in older adults with DM (51–53,88). As well Moreira et al. (88) reported older adults with DM with higher FoF severity (FES-I≥23) had worse mobility performance on the Timed-up and Go and 5-Times Sit-to-Stand clinical assessments when compared to those with lower FoF severity (FES-I<23). Similarly, older adults with DM who reported FoF (single question) had worse mobility performance, as indicated by increased time to climb eight flights of stairs, when compared to those without FoF (41). However, no studies could be cited that compared the influence of falls-related psychological concerns on balance, mobility and postural control between older adults with and without DM.

Investigations of falls-related psychological concerns in older adults with DM have primarily focused on global control and lower limb gait parameters. Yet, approximately two-thirds of the body’s mass is attributed to the upper body (98). The inverted pendulum model indicates that precise control of the head and trunk segments
over one’s base of support is required to maintain an upright posture and balance (99). Specifically, the progressive reduction of oscillations from the lower body allow the head to move in a straight line at a constant speed (100). However, head control declines with age, and reduced head stabilization disrupts the ability to maintain a stable field of vision and accurately interpret vestibular inputs required for balance (101). The trunk, the largest and heaviest body segment, plays a dynamic role to attenuate head accelerations and displacement, and ensure the maintenance of an upright posture (98) through passive mechanical dampening and feed-forward control of the paraspinal muscles (102). Furthermore, loss of trunk control in the mediolateral direction can be extremely hazardous and may even contribute to the high incidence of hip fractures in older adults with DM (103). Of the limited evidence available of head and trunk control, older adults with diagnosed DPN have been reported to have smaller head and pelvis accelerations and less rhythmic control (i.e., higher harmonic ratios) while walking when compared to healthy controls (104). These erratic acceleration patterns suggest that older adults with DPN may have difficulty controlling momentum and displacement of the trunk (104) which can impair head control and overall balance (105). However, no studies have examined upper body control and falls-related psychological concerns during gait in older adults with DM.

An essential component to falls-related psychological concerns is the perceived appraisal of risk, especially under conditions of postural threat (e.g., walking at increase heights, on a slippery surface or while performing secondary tasks) (92,106). Maki and colleagues (107) suggested that the adoption of postural control strategies is adjusted based on anticipated levels of postural threat. Foundational work by Carpenter et al. (108)
demonstrated that young adults (mean age = 23.5 years) had higher frequency postural sway and reduced amplitude variability while standing on a high platform (0.81 meters) when compared to the low platform (0.19 meters). These results suggest that a stiffening strategy was employed at the ankle joint in an attempt to achieve tighter control of the center of mass within a smaller area (i.e., generating faster movements of the center of pressure through smaller amplitude displacements) under conditions of postural threat (108). Similarly, Adkin et al. (109) reported that a tighter control of posture was adopted in young adults (mean age = 20.3 ± 1.3 years) under conditions of increased postural threat while standing on a platform at low (0.40 meters), medium (1.0 meter) and high (1.60 meters) surface heights. As well, subsequent aging research revealed that both young (mean age = 24.6 ±2.8 years) and older (mean age = 69.4 ±7.3 years) adults employed similar stiffening strategies while standing at progressively higher surface heights which provoked greater levels of anxiety and lower balance confidence (110).

FoF and low balance confidence are also strongly associated with a head-trunk stiffening in older adults (106,108,111). Head-trunk stiffening may be advantageous to simplify postural control (i.e., reduce degrees of freedom in the head-neck control) and improve head stabilization when the trunk is stabilized. However, head-trunk stiffening may be maladaptive under conditions of more pronounced trunk movement (106). Additionally, low balance confidence is theorized to result in an internal focus of attention and may result in inadequate attentional resources for optimal task performance (106). Deshpande and Patla (112) reported mediolateral head-trunk stiffening to be a generalized strategy adopted by older adults that was not present in young adults. Although this study did not quantify FoF or balance confidence, head-trunk stiffening
may have been related to FoF and/or low balance confidence in older adults and the dependence on postural control strategies that are normally only utilized in high-risk situations (92). Older adults with DM have been documented to stiffen their upper body during standing balance under challenging conditions (113). However, no studies have explored the relationship between falls-related psychological concerns and head-trunk stiffening while walking in older adults with DM.

2.4. Conclusions

Overall, FoF is a significant health concern in some older adults with DM. Several determinants for developing falls-related psychological concerns overlap with the consequences/complications of DM, and the cumulative effect may contribute to higher falls-related psychological concerns in older adults with DM when compared to those without DM. However, no studies could be cited that investigated how these factors may contribute to FoF severity in older adults with DM. Therefore, the specific objective of the first study in this thesis was to compare the prevalence and severity of FoF (FES-I) in older adults with and without DM, and identify which FoF determinants contribute to FoF severity in older adults with DM. Research of falls-related psychological concerns appears to be primarily driven by the construct of FoF and its assessment as a single question (e.g., are you afraid of falling?). Isolated studies have documented low balance confidence in older adults with DM and those with DPN. However, lack of significant differences in balance confidence between those with and without DM may be attributed to lack of sensitivity of the ABC-16 when compared to the ABC-6. Therefore, specific objective of the second study in this thesis is to evaluate the convergent, discriminant and concurrent validity of the ABC-6 in older adults with DM with and without diagnosed
DPN. Lastly, despite the high prevalence of FoF and low balance confidence in older adults with DM, limited studies have investigated their influence on balance, mobility and postural control in older adults with DM. Of the limited evidence, FoF has been associated with conservative gait patterns in older adults with DM. However, no studies have investigated the relationship between balance confidence and upper body control. Therefore, the specific objectives of the third study in this thesis were to explore the relationship between balance confidence (ABC-6) and head-trunk stiffening, as well as, head and trunk control individually during gait under challenging conditions in older adults with and without DM.

Overall addressing these gaps in the literature will provide direction for the development of protocols for screening and intervention recommendations of patient education and targeted rehabilitation programs for older adults with DM. Specifically, this thesis will determine if falls-related psychological concerns differ between older adults with and without DM (Studies I-III), identify which determinants lead to higher FoF severity in older adults with DM (Study I), if the ABC-6 is a valid assessment tool of balance confidence in older adults with DM with and without diagnosed DPN (Study II), and if low balance confidence is associated with the dependence on postural control strategies that are normally only utilized in high-risk situations (ie. head-trunk stiffening; Study III) in older adults with DM.
2.5. References


39. Landers MR, Oscar S, Sasaoka J, Vaughn K. Balance confidence and fear of falling avoidance behavior are most predictive of falling in older adults: Prospective analysis. Phys Ther. 2015 [ePub Ahead of Print].


44. Bruce D, Hunter M, Peters K, Davis T, Davis W. Fear of falling is common in patients with type 2 diabetes and is associated with increased risk of falls. Age Ageing. 2015;687–90.


47. Denkinger MD, Lukas A, Nikolaus T, Hauer K. Factors associated with fear of falling and associated activity restriction in community-dwelling older adults:


### Table 2.1.
Fear of falling prevalence in older adults with diabetes mellitus

<table>
<thead>
<tr>
<th>Citation</th>
<th>FrPc Construct</th>
<th>Participants Per Group</th>
<th>Age (Years)</th>
<th>Evidence of FrPC</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Powell et al. (2006)</td>
<td>FoF</td>
<td>252 DPN-group</td>
<td>75.4±6.6</td>
<td>FoF prevalence significantly reduced with monochromatic near-infrared photoenergy treatment (FoF prevalence before 66%; after:14%, p&lt;0.001)</td>
</tr>
<tr>
<td>(2) van Sloten et al. (2011)</td>
<td>FoF</td>
<td>100 DM-group</td>
<td>64.5±9.4</td>
<td>FoF prevalence was 24% in the DM-group. FoF prevalence was significantly associated with time to climb 8 flights of stairs (p&lt;0.05).</td>
</tr>
<tr>
<td>(3) Munshi et al. (2012)</td>
<td>FoF</td>
<td>145 DM-group</td>
<td>77.0±5.0</td>
<td>FoF prevalence was 47% in the DM-group.</td>
</tr>
<tr>
<td>(4) Roman de Metteline et al. (2013)</td>
<td>FoF</td>
<td>104 DM-group 95 noDM-group</td>
<td>78.4±8.7 75.1±9.9</td>
<td>FoF prevalence was significantly higher in the DM-group (66.3%) than the noDM-group (48.4%; p=0.01).</td>
</tr>
<tr>
<td>(5) Lalli et al. (2013)</td>
<td>FoF</td>
<td>20 DM-group 20 DPN-group 22 DPN-Pain-group</td>
<td>58.8±11.7 60.2±13.6 62.6±9.5</td>
<td>FoF prevalence significantly increased with DM-complications (DM-group 5%; DPN-group 20%; DPN-Pain-group 64%, p&lt;0.01).</td>
</tr>
<tr>
<td>(6) Bruce et al. (2015)</td>
<td>FoF</td>
<td>186 DM-group 186 noDM-group</td>
<td>70.2±10.2 70.3±10.1</td>
<td>FoF prevalence was significantly higher in the DM-group (24.2%) than the noDM-group (15.1%; p&lt;0.05).</td>
</tr>
<tr>
<td>(7) Chang et al. (2016)</td>
<td>FoF</td>
<td>544 DM-group 3279 noDM-group</td>
<td>≥65</td>
<td>FoF prevalence was significantly higher in the DM-group (male: 56.3%; female 67.8%) compared to the noDM-group (male: 44.4%; female: 62.2%; p≤0.05).</td>
</tr>
</tbody>
</table>

**Note.** FrPC: Falls-related psychological concerns; FoF: Fear of falling; BC: Balance confidence; ABC Scale: Activities-specific Balance Confidence Scale; DM: diabetes mellitus; noDM: individuals without diabetes mellitus; DPN: diabetic peripheral neuropathy.
### Table 2.2.
Balance confidence and fear of falling severity in older adults with diabetes mellitus

<table>
<thead>
<tr>
<th>Citation</th>
<th>FrPc Construct</th>
<th>Participants Per Group</th>
<th>Age (Years)</th>
<th>Evidence of FrPC</th>
</tr>
</thead>
<tbody>
<tr>
<td>(8) Deshpande et al. (2015)</td>
<td>BC ABC-16</td>
<td>35 DM-group, 25 noDM-group</td>
<td>70.6±4.7, 74.6±5.4</td>
<td>BC was not significantly different between the DM- and noDM-group (p=0.151). In the DM-group, fallers (n=7) had 11% lower BC than no-fallers (n=28; p=0.03).</td>
</tr>
<tr>
<td>(9) Alshahrani et al. (2016)</td>
<td>BC ABC-16</td>
<td>13 DPN-Intervention</td>
<td>65.1±7.5</td>
<td>BC in the DPN-group did not improve following a 10-week intra-neural intervention (before: 71.42 ± 25.78; after: 78.02±17.01).</td>
</tr>
<tr>
<td>(10) Allet et al. (2009)</td>
<td>FoF FES-I</td>
<td>76 DM</td>
<td>63.0±9.6</td>
<td>Increased FoF severity was significantly associated with reduced walking speed (p&lt;0.05).</td>
</tr>
<tr>
<td>(11) Allet et al. (2010)</td>
<td>FoF FES-I</td>
<td>35 DM-Intervention, 36 DM-Control</td>
<td>63.0±7.8, 64.0±8.9</td>
<td>FoF severity significantly reduced with the balance intervention in the DM-Intervention group at both the program completion (12-weeks, p&lt;0.05) and follow-up (6-weeks, p&lt;0.05) and was significantly lower than DM-Control (p&lt;0.05).</td>
</tr>
<tr>
<td>(12) Kelly et al. (2013)</td>
<td>FoF FES-I</td>
<td>18 DM-group, 16 DPN-group</td>
<td>62.0±7.0, 73.0±8.0</td>
<td>Moderate-to-high FoF severity was reported in 82% of participants. Higher FoF severity was significantly associated with both slower stride velocity (p&lt;0.05) and shorter stride length (p&lt;0.05).</td>
</tr>
</tbody>
</table>

2.7. Figures

Figure 2.1.
Schematic diagram of the correlations between fear of falling, balance confidence and functional ability – adapted from Li et al. 2002

![Diagram showing correlations between fear of falling, balance confidence, and functional ability.](image)

Note. This figure is a schematic diagram of correlations between (a) fear of falling (FoF) and balance confidence, (b) FoF and functional ability, and (c) balance confidence and functional ability.

FoF was moderately to strongly correlated with balance confidence ($r = -0.33$, $p<0.001$) in community-dwelling older adults those with chronic conditions (dizziness: FES-I and ABC-16; $r=-0.84$, $p<0.001$ (14); Parkinson’s disease: FES-I and ABC-16; $r=-0.80$, $p<0.001$ (15)). Functional ability displayed none-to-weak correlations with FoF but was moderately correlated with balance confidence ($r=0.25–0.54$, $p<0.001$) in community-dwelling older adults (16). Consequently, balance confidence has been described as a cognitive mechanism that mediates the relationship between FoF (thoughts/actions) and functional abilities (behaviour/ performance) in older adults (38).
CHAPTER 3: STUDY I

Prevalence, severity, and determinants of fear of falling in older adults with diabetes mellitus: The IMIAS Study
3.1. Abstract

**Background:** Several determinants of developing fear of falling (FoF) overlap with the consequences of diabetes mellitus (DM). We compared the prevalence, severity and determinants of FoF in older adults with and without DM, and identified which FoF determinants contribute to FoF severity in older adults with DM. **Methods:** Community-dwelling older adults (n=799; Age:65-74, 52.8% women) were recruited. DM was ascertained by HbA1c≥6.5% or self-reported physician's diagnosis. FoF was quantified with Falls Efficacy Scale International (FES-I). FoF determinants were evaluated in demographic/health-related, physical, psychological and social domains. **Results:** 141 older adults were identified with DM (DM-group; age:68.88±2.80 years) and 620 without DM (noDM-group; age:68.81±2.68 years). Although FoF prevalence adjusted for age and sex was not different between-groups (p=0.449), the DM-group had 8.8% fewer participants in the low (p=0.025) and 8.4% more in the high (p=0.002) FoF categories. In those who reported FoF, FoF severity adjusted for age and sex was significantly higher overall (p<0.001) and in 10 of 16 FES-I items in the DM-group than the noDM-group (all p<0.05). In the DM-group, moderate-to-high FoF was significantly more likely in those with poor physical performance [PR=2.00; p<0.001], women [PR=1.70; p=0.002], fall history [PR=1.54; p=0.012] and clinical depressive symptoms [PR=1.48; p=0.047] than no-low FoF category. **Conclusions:** High concern of FoF was more prevalent and FoF was of higher severity in 10 of 16 activities in older adults with DM compared to no-DM. Therefore, protocols for screening and intervention recommendations for physical performance, women, fall history and those with clinical depressive symptoms, and tailored interventions may help to reduce FoF severity in older adults with DM.
3.2. Introduction

Fear of falling (FoF) is a lasting concern about falling that can lead to a vicious cycle of reduced balance confidence, activity avoidance, deconditioning, postural instability, and falls (1). FoF is more prevalent in older adults with diabetes mellitus (DM; 66.3%) than those without DM (48.4%) (2). However, FoF has been primarily assessed with a single dichotomous question enquiring prevalence, “Are you afraid of falling?” in older adults with DM (2–6) providing no information on FoF severity. FoF has been primarily attributed to poor physical performance, particularly, mobility and balance impairments in older adults with DM (2–5). However, several other determinants for developing FoF overlap with the consequences/complications of DM, including but not limited to, falls, muscle weakness, sensory impairments, depression and cognitive decline (7–9). Therefore, it is possible that the cumulative effect of these DM-related consequences may contribute to higher FoF severity and subsequently greater activity restriction and deconditioning in older adults with DM. However, no studies could be cited that investigated how these factors contribute to FoF in older adults with DM. This information is critical for the protocols outlining screening and tailored interventions to help break the vicious cycle of FoF and improve physical function and quality of life in older adults with DM.

Therefore, this study compared the prevalence, and severity of FoF in older adults with and without DM, and identified which FoF determinants contribute to FoF severity in older adults with DM. It is hypothesized that FoF will be more prevalent and of higher severity overall in older adults with DM than those without DM and the difference in the severity will be particularly higher for activities that may impose greater challenges on
postural control. Further, FoF determinants in older adults with DM will be identified in more than just the physical domain.

### 3.3. Research Design and Methods

#### 3.3.1. Participants and sampling strategy

The International Mobility in Aging Study (IMIAS) is an ongoing multisite longitudinal study aimed to better understand how to prevent or slow down the loss of mobility in older adults. The Canadian IMIAS sample consists of 799 age- and sex-matched community-dwelling older adults (aged 65-74) from Kingston, Ontario (n=398) and Saint-Hyacinthe, Quebec (n=401). For initial recruitment, participants were excluded if they had >4 errors on Leganes Cognitive Test (LCT) orientation scale (10) due to potential inability to complete study procedures. Ethics was approved by respective university ethics boards in accordance with the Declaration of Helsinki. Additional details of study design are included in previous publications (11,12).

For the present study, baseline data collected in 2012 were used. Participants were excluded for possible dementia (LCT≤22) and incomplete FoF questionnaires. Blood samples were provided by 78% of the Canadian IMIAS sample at a local hospital to obtain glycated hemoglobin (HbA1c) values. DM was ascertained by HbA1c≥6.5% (13) or self-reported physician's diagnosis when HbA1c<6.5% or HbA1c values were not available.

#### 3.3.2. Outcome measures

##### 3.3.2.1. FoF prevalence and severity

FoF was assessed with the Falls Efficacy Scale International (FES-I) questionnaire of 16-activities measured on a 4-point Likert scale [1(not concerned at all)
to 4(very concerned)] and summed for total FES-I score (range:16-64). FES-I scores were classified as no (FES-I score=16), low (FES-I=17-19), moderate (FES-I=20-27) and high (FES-I≥28) concern about falling (14).

3.3.2.2. FoF determinants

3.3.2.2.1. Demographic and health-related domain

Demographic factors of age, sex and body mass index (BMI; kg/m²) were recorded. Co-morbidity was the total number of chronic conditions (range:0-7; hypertension, cancer, chronic lung disease, heart disease, stroke, arthritis, osteoporosis). Total years of education and fall history in the past year were obtained.

3.3.2.2.2. Physical domain

Physical performance was assessed with the Short Physical Performance Battery (SPPB) which includes: a hierarchical test of standing balance, a 4-meter walk, and 5-repeated chair stands (15). SPPB total scores range from 0-12, and <8 is an established cut-off for poor physical performance (15). Use of a walking aid to walk a quarter mile was recorded (yes/no). Visual acuity was assessed binocularly with usual corrective lenses using the ETDRS Tumbling E Chart placed at a distance of 2-meters. Total number of correctly identified E’s was recorded. Maximum grip strength (kg) was measured with a Jamar handheld dynamometer (Promedics, Blackburn) of the self-reported dominant hand in a seated position with 90 degrees of elbow flexion over 3-trials.

3.3.2.2.3. Psychological domain

Depressive symptoms were evaluated with the Centre for Epidemiological Studies Depression Scale (CES-D). Total CES-D scores range from 0-60 with higher scores
indicating more depressive symptoms and ≥16 clinical depressive symptoms (16).
Cognitive function was evaluated with the Montreal Cognitive Assessment (MoCA).
Total MoCA scores range from 0-30, higher scores indicating better cognitive function (17).

3.3.2.2.4. Social Domain

Social support from spouse, children, family (i.e., brothers, sisters, nephews, nieces and/or grandchildren) and friends was quantified on respective sub-scales of the IMIAS Social Network and Social Support (IMIAS-SNSS) (18). Each sub-scaled included 6-items scored on a 5-point Likert scale [0(never) to 5(always)] and higher scores indicating higher levels of social support. Living arrangement was recorded (living alone / not living alone) as a measure of proximity of help or assistance if a fall was to happen at home.

3.3.3. Statistical analysis

Data with skewed distributions were log10 transformed and back-transformed for data presentation, as appropriate. Missing data were replaced with overall mean (visual acuity, n=2; grip strength, n=9) and median (use of assistive device, n=5) values. Logistic regression adjusted for age and sex were used to examine differences in FoF prevalence overall (yes/no) and by FES-I category between the DM-group and noDM-group. In those who reported FoF, separate general linear models (GLMs) adjusted for age and sex were used to examine differences in FoF severity overall and each FES-I item between the DM-group and noDM-group. Separate GLMs and chi-square analysis were used to examine differences in FoF determinants between the DM-group and noDM-group.
Preliminary analyses were conducted to determine a FES-I category threshold (low, moderate or high) where FoF determinants became significantly different than those classified with no FoF. FoF determinants were not significantly different between no and low FoF (all p>0.05); however, significant differences were found between no and moderate FoF (p<0.05; data not shown). Therefore, FES-I categories were collapsed into no-low and moderate-high categories for the subsequent analyses. Separate GLMs and logistic regressions adjusted for age and sex were used, as appropriate, to explore differences in FoF determinants between older adults with DM who had no-low and moderate-to-high FoF. FoF determinants at the p<0.10 level were included as independent variables in a multiple linear regression model adjusted for age and sex of FoF severity in the DM-group. Poisson regression was conducted as a post hoc analysis to estimate prevalence ratios (PR) of moderate-to-high FoF compared to no-low FoF for the significant FoF determinants in the DM-group. Associations with P<0.05 were considered as statistically significant (SPSS-V.22)

3.4. Results

Of the 799 participants in the Canadian IIMIAS sample, 7 were excluded for possible dementia (LCT≤22) and 31 were excluded for incomplete FES-I questionnaires. Of the remaining 761 participants, 141 (83 with HbA1c≥6.5%, 37 with HbA1c<6.5% with physicians diagnosis, and 21 with physicians diagnosis only) were identified with DM (DM-group) and 620 without DM (noDM-group).

3.4.1. FoF prevalence and severity

Overall FoF prevalence adjusted for age and sex was not significantly different between-groups (DM-group:84.4%; noDM-group:84.1%, p=0.449). However, FoF
prevalence adjusted for age and sex revealed the DM-group had significantly fewer participants in the low (8.8%; p=0.025) and more in the high (8.4%; p=0.002) FES-I categories than noDM-group (Figure-3.1). In those who reported FoF, FoF severity adjusted for age and sex was significantly higher overall (DM-group: 22.75±7.80; noDM-group: 20.70±5.31, p<0.001) and in 10 of 16 FES-I items in the DM-group than noDM-group (all p<0.05; Figure-3.2). The largest group-differences were identified in item-9, item-14 and item-15. Separate post hoc GLMs revealed large reductions in power and effect sizes of the group-differences in FoF severity overall (Δobserved power=0.870, Δηp²=0.02), item-9 (Δobserved power=0.278, Δηp²=0.024), item-14 (Δobserved power=0.722, Δηp²=0.015) and item-15 (Δobserved power=0.708, Δηp²=0.011) after further adjustment for the FoF determinants that were significantly different between-groups outlined in Table-3.1 (BMI; chronic conditions; years of education; HbA1c (%), SPPB total score; use of walking aid; MoCA total score) in addition to age and sex. Only SPPB total score and use of walking aid were significant covariates (all p<0.001).

3.4.2. FoF determinants

Table-3.2 outlines differences in FoF determinants adjusted for age and sex in the DM-group between those with no-low and moderate-high FoF. Determinants that were considerably different between these 2-groups (p<0.20) were included as independent variables in a multiple linear regression adjusted for age and sex of FoF severity in the DM-group. Being female (p=0.005), fall history (p=0.038), poor physical performance (p<0.001), more depressive symptoms (p=0.008) were significant determinants of FoF severity. To gain further insight into these findings, physical performance (SPPB<8, poor physical performance; SPPB≥8 good physical performance) and depression (CES-D>16
clinical depression; CES-D≤16 no-depression) scores were also dichotomized. Poisson regression with robust variance was used as a post hoc analysis to estimate the PR of moderate-to-high FoF. In the DM-group, moderate-to-high FoF was significantly more likely in those with poor physical performance [PR=2.00, 95%CI=1.44-2.74, p<0.001], women [PR=1.70, 95%CI=1.21-2.38, p=0.002], fall history [PR=1.54, 95%CI=1.10-2.15, p=0.012] and clinical depressive symptoms [PR=1.48, 95%CI=1.01-2.18, p=0.047] when compared to the no-low FoF category.

3.5. Discussion

To our knowledge, this is the first study that conducted an in-depth investigation of FoF prevalence, severity and determinants in older adults with DM. FoF in the high concern FES-I category was more prevalent in the DM-group than noDM-group. Of those who reported FoF, FoF was of higher severity overall and in 10 of 16 FES-I activities in the DM-group than the noDM-group. Significant determinants of moderate-to-high FoF in the DM-group were poor physical performance, being female, fall history in the past year and clinical depressive symptoms.

*High concern of falling was more prevalent in older adults with DM than those without noDM*

FoF was highly prevalent in older adults with DM (84.4%). Although the overall FoF prevalence was not significantly different between-groups, the DM-group had significantly 8.8% fewer participants in low and 8.4% more in the high concern FES-I categories than the noDM-group. Therefore, the use of overall FoF prevalence in older adults with DM may be misleading, and FES-I categorization may be more useful to identify those with high concerns of FoF. High concerns of FoF may lead to excessive
activity restriction (19) that can potentially cause physical deconditioning, loss of independence and reduced quality of life (20,21).

**FoF was of higher severity in 10 of the 16 FES-I activities in older adults with DM than noDM**

FoF severity was significantly higher in 10 of the 16 FES-I activities in the DM-group than noDM-group. The largest group-differences were identified as reaching for something above your head or on the ground (item-9), walking on an uneven surface (item-14) and walking up or down a slope (item-15). The DM-group had worse physical performance, and more participants used a walking aid than the noDM-group. DM-related declines in multiple sensorimotor and cognitive systems responsible for balance can lead to postural instability, poor physical performance and mobility-related declines (22) and subsequently may contribute to increased FoF severity (23). For example, long-term hyperglycemia can cause inflammation and reduced sensitivity of the highly active metabolic vasculature in the inner ear (24) which may contribute to postural instability during rapid head movements while reaching. Furthermore, DM-related declines in one or more sensory system(s) also reduces the sensory redundancy available to the central nervous system which may lead to postural instability during activities that may impose greater challenges on postural control such as walking on an uneven surface or up/down a slope (3). Interestingly, the group-difference in FoF severity while walking on a slippery surface (item-11) was not as large and may suggest this activity is perceived as highly challenging by both older adults with and without DM.
Poor physical performance, being female, fall history and clinical depression were significant determinants of higher FoF severity in older adults with DM

As expected poor physical performance (SPPB<8) and being female were identified as the primary determinants of higher FoF severity in the DM-group. Older adults with DM with poor physical performance were 2-times more likely to have moderate-to-high FoF than no-low FoF, and 90.5% of those with poor physical performance had moderate-to-high FoF. Higher FoF severity in females is consistently reported in the literature (7,25). Females were 1.7-times more likely to have moderate-to-high FoF than no-low FoF, and moderate-to-high FoF was identified in 58.7% of females and 41.3% of males in the DM-group. However, DM is more prevalent in males than females (26) and males may feel inhibited to express FoF due to the perceived stigma attached to the admission of fear on their masculinity (23). Therefore, FoF should not be overlooked in males with DM.

Falls can lead to increased FoF severity as a result of previous injury, loss of independence and/or social embarrassment (7,23). Older adults with DM who fell in the past year were 1.54-times more likely to have moderate-to-high FoF than no-low FoF, and 63% of fallers had moderate-to-high FoF. However, longitudinal investigation is warranted to understand the temporal relationship between FoF and falls in older adults with DM.

The prevalence of clinical depressive symptoms (CES-D≥16) in the DM-group (10%) was double that of those with no co-morbidities (4.1%). It is known depression can erode one’s self-confidence to perform activities which may lead to activity restriction
and subsequently FoF (23). However, this is the first study to identify clinical depression in older adults with DM as a significant FoF determinant. Older adults with DM with clinical depression were 1.48-times more likely to have moderate-to-high FoF than no-low FoF, and 78% with clinical depression were classified with moderate-to-high FoF. Therefore, older adults with DM with clinical depression may also benefit from FoF interventions.

3.6. Study Limitations

A major limitation of this study is the cross-sectional design. A longitudinal study is warranted to validate casual relationships. Participants with possible dementia were excluded as the FES-I has not been validated in this population. Evaluation of sensory functions were not available and therefore only theoretical postulations could be made. Furthermore, anxiety and personal mastery are known FoF determinants but were unavailable in this dataset.

3.7. Clinical Implications

In community-dwelling older adults, FoF in the high concern FES-I category was more prevalent and of higher severity in those with DM than noDM. Early detection is critical to break the vicious cycle of FoF. Therefore, additional protocols for screening and tailored interventions may be necessary for older adults with DM. Our results suggest that protocols for screening that include physical performance, women, fall history and those with clinical depressive symptoms may be advantageous. Glycemic control was not a significant FoF determinant in older adults with DM in this study-group possibly because from the available HbA1c values, only 11% of older adults were identified to have glycemic control not at target (HbA1C>8%) (27).
3.8. Conclusions

FoF in the high concern FES-I category was more prevalent, and FoF was of higher severity overall and in 10 of 16 FES-I activities in older adults with DM than those without DM. Therefore, protocols for screening and tailored interventions for physical performance, women, fall history and those with clinical depression and tailored interventions may help to reduce FoF severity in older adults with DM.
3.9. References


18. Ibrahim T, Alvarado B, Zunzunegui M. Psychometric properties and validation of a social networks and social support measurement tool for use in international ageing research: The International Mobility in Ageing Study. Age Soc. [In Press].


Available from: http://www.mayoclinic.org/tests-procedures/a1c-test/basics/results/prc-20012585
3.10. Tables

Table 3.1.
Fear of falling determinants in older adults with and without diabetes mellitus

<table>
<thead>
<tr>
<th>Demographics and health-related domain</th>
<th>noDM-group (n=620)</th>
<th>DM-group (n=141)</th>
<th>F or x²</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>68.81±2.68</td>
<td>68.89±2.80</td>
<td>0.073</td>
<td>0.787</td>
</tr>
<tr>
<td>Sex (% of males)</td>
<td>46.00</td>
<td>54.60</td>
<td>3.440</td>
<td>0.046*</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>28.42±13.79</td>
<td>31.99±18.76</td>
<td>6.668</td>
<td>0.010*</td>
</tr>
<tr>
<td>Chronic conditions (0-7)</td>
<td>1.54±1.17</td>
<td>2.02±1.23</td>
<td>18.85</td>
<td>&lt;0.001**</td>
</tr>
<tr>
<td>Years of education</td>
<td>14.16±4.35</td>
<td>13.06±4.45</td>
<td>7.245</td>
<td>0.007*</td>
</tr>
<tr>
<td>Fell in the past year (% of participants)</td>
<td>30.30</td>
<td>32.60</td>
<td>0.302</td>
<td>0.583</td>
</tr>
<tr>
<td>HbA1c (%)a</td>
<td>5.66±0.29</td>
<td>6.95±0.96</td>
<td>611.759</td>
<td>&lt;0.001**</td>
</tr>
</tbody>
</table>

Physical domain

| Physical performance (SPPB total score) | 10.39±1.56 | 9.70±2.10 | 20.05 | <0.001** |
| Use of a walking aid (% of participants) | 4.90       | 10.30     | 5.90  | 0.015* |
| Visual Acuity (# of correct E’s)     | 50.04±7.80  | 48.80±8.93 | 2.75  | 0.098 |
| Maximum grip strength (kg)           | 35.05±16.29 | 38.01±37.81 | 2.147 | 0.143 |

Psychological domain

| Depressive symptoms (CES-D total score) | 6.62±7.39 | 7.12±7.43 | 0.534 | 0.465 |
| Cognitive Function (MoCA total score)  | 26.41±2.82 | 25.77±3.04 | 5.735 | 0.017* |

Social domain

| Spouse social support (IMIAS-SNSS score)b | 24.01±2.62 | 24.17±2.14 | 0.274 | 0.601 |
| Children social support (IMIAS-SNSS score)c | 22.90±3.06 | 22.49±3.27 | 1.743 | 0.187 |
| Family social support (IMIAS-SNSS score) | 20.05±4.75 | 20.23±4.29 | 0.178 | 0.673 |
| Friends social support (IMIAS-SNSS score) | 20.65±5.21 | 19.90±5.75 | 2.339 | 0.127 |
| Living alone (% of participants)        | 27.60       | 31.90      | 1.062 | 0.303 |

Note. The DM-group had significantly more males (p=0.046), higher BMI (p=0.010), more chronic conditions (p<0.001), less education (p=0.007), higher HbA1c (p<0.001), poor physical performance (p<0.001) and lower cognition (p=0.017) than noDM-group. Data are means (SD) unless described otherwise. *p<0.05, **p<0.001

BMI: Body Mass Index; HbA1c: glycated hemoglobin; SPPB: Short Physical Performance Battery; CES-D: Centre for Epidemiological Studies Depression Scale; MoCA: Montreal Cognitive Assessment; IMIAS-SNSS: International Aging in Mobility Study – Social Networks and Social Support. aHbA1c was available in 591/761 participants. Only participants with a spouse (n=510)b and children (n=669)c were included in these analyses.
Table 3.2.
Determinants of higher fear of falling severity in older adults with diabetes mellitus

<table>
<thead>
<tr>
<th>Demographics and health-related domain</th>
<th>No-Low FoF (n=78)</th>
<th>Moderate-High FoF (n=63)</th>
<th>F or x²</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>68.64±2.78</td>
<td>69.17±2.83</td>
<td>1.264</td>
<td>0.263</td>
</tr>
<tr>
<td>Sex (% of males)</td>
<td>65.40</td>
<td>41.30</td>
<td>8.236</td>
<td>0.005*</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>28.63±5.39</td>
<td>36.16±26.99</td>
<td>5.09</td>
<td>0.026*</td>
</tr>
<tr>
<td>Chronic conditions (0-7)</td>
<td>1.59±1.04</td>
<td>2.56±1.23</td>
<td>20.060</td>
<td>&lt;0.001**</td>
</tr>
<tr>
<td>Years of education</td>
<td>13.24±4.45</td>
<td>12.84±4.46</td>
<td>0.100</td>
<td>0.753</td>
</tr>
<tr>
<td>Fell in the past year (% of participants)</td>
<td>21.79</td>
<td>46.03</td>
<td>8.927</td>
<td>&lt;0.003*</td>
</tr>
<tr>
<td>HbA1c (%)</td>
<td>6.89±0.75</td>
<td>7.02±11.18</td>
<td>0.812</td>
<td>0.369</td>
</tr>
</tbody>
</table>

**Physical domain**

| Physical performance (SPPB total score) | 10.45±1.22        | 8.76±2.55                | 24.592  | <0.001** |
| Use of a walking aid (% of participants) | 1.28             | 20.63                    | 13.347  | <0.001** |
| Visual Acuity (# of correct E’s)       | 50.37±7.01        | 45.90±10.67              | 2.651   | 0.106 |
| Maximum grip strength (kg)             | 42.24±48.22       | 31.11±16.57              | 0.693   | 0.406 |

**Psychological domain**

| Depressive symptoms (CES-D total score) | 4.97±5.21         | 9.78±8.83                | 14.885  | <0.001** |
| Cognitive Function (MoCA total score)  | 25.60±2.90        | 25.97±3.22               | 0.452   | 0.503 |

**Social domain**

| Spouse social support (IMIAS-SNSS score) | 24.46±2.16        | 23.67±2.06               | 1.156   | 0.285 |
| Children social support (IMIAS-SNSS score) | 22.50±3.18        | 22.48±3.41               | 0.000   | 0.988 |
| Family social support (IMIAS-SNSS score) | 20.15±4.21        | 20.33±4.42               | 0.115   | 0.735 |
| Friends social support (IMIAS-SNSS score) | 19.67±5.52        | 20.19±5.75               | 0.027   | 0.780 |
| Living alone (% of participants)        | 21.79             | 44.44                    | 12.429  | 0.006* |

**Note.** Falls Efficacy Scale International (FES-I) categories were merged to no-low (FES-I score=16-19) and moderate-high (FES-I score ≥20) concern about falling in older adults with diabetes mellitus (DM-group). Fear of falling determinants adjusted for age and sex that were identified to be significantly different (p>0.20) between the no-low and moderate-high FES-I categories were included in the linear regression analysis. Data are means (SD) unless described otherwise. *p<0.05, **p<0.001.

BMI: Body Mass Index; HbA1c: glycated hemoglobin; SPPB: Short Physical Performance Battery; CES-D: Centre for Epidemiological Studies Depression Scale; MoCA: Montreal Cognitive Assessment; IMIAS-SNSS: International Aging in Mobility Study – Social Networks and Social Support. aHbA1c was available in 120 of the 141 participants. Only participants with a spouse (n=90)b and children (n=122)c were included in these analyses.
3.11. Figures

Figure 3.1.
Fear of falling prevalence in older adults with and without diabetes mellitus

Fear of falling (FoF) prevalence adjusted for age and sex between-groups in the Falls Efficacy Scale International (FES-I) categories of no (FES-I score=16), low (FES-I score=17-19), moderate (FES-I score=20-27) and high (FES-I score≥28) concern about falling. DM-group had significantly 8.8% fewer participants in the low (p=0.025) and 8.4% more in the high (p=0.002) FES-I categories than noDM-group. *p<0.05.
Figure 3.2.
Fear of falling severity in older adults with and without diabetes mellitus

| Item | FoF severity adjusted for age and sex between-groups and across the 16 Falls Efficacy Scale International (FES-I) items. FoF severity was significantly higher in 10 of 16 FES-I items in the DM-group than noDM-group. *p<0.05. †p<0.001. |
CHAPTER 4: STUDY II

The short version of the activities-specific balance confidence scale for older adults with diabetes mellitus: convergent, discriminant, and concurrent validity
4.1. Abstract

Objective: To examine the convergent, discriminant and concurrent validity of the short version of the Activities-specific Balance Confidence scale (ABC-6) in older adults with diabetes mellitus (DM) with and without diagnosed diabetic peripheral neuropathy (DPN). The ABC-6 is advantageous in busy clinical or research settings as it can be administered in significantly less time than the original 16-item Activities-specific Balance Confidence scale (ABC-16). Methods: Thirty older adults (aged ≥65) were age- and sex-matched in 3-groups: 10 with DM (DM-group), 10 with diagnosed DPN (DPN-group), and 10 without DM (noDM-group). Balance confidence was quantified with the ABC-16 which includes the six items of the ABC-6. Potential correlates were evaluated in physical and psychological domains. Results: The ABC-6 and ABC-16 balance confidence scores were strongly correlated (r=0.969, p<0.001; convergent validity). The ABC-6 revealed significant differences in balance confidence between the noDM- and DM-groups (p<0.001; discriminant validity) whereas the ABC-16 did not (p>0.05). The ABC-6 was moderately but significantly correlated with physical activity level (r=0.528, p=0.017), mobility (r=-0.520, p=0.027), balance (r=0.633, p=0.003) and depressive symptoms (r=-0.515, p=0.020) in the DM study-groups (concurrent validity). Conclusions: The ABC-6 and ABC-16 had excellent convergent validity and both ABC-scales had similar concurrent validity. However, the ABC-6 was more sensitive to detect subtle differences in balance confidence in older adults with diabetes without diagnosed DPN than the ABC-16. Overall the ABC-6 is a valid assessment tool that may provide a means for early detection of balance and mobility-related declines in older adults with DM without diagnosed DPN.
4.2. Introduction

Balance confidence is defined as an individual’s belief in their ability to maintain balance while performing activities of daily living (1). Low balance confidence is associated with activity avoidance, physical deconditioning, declines in mobility and balance, clinical depression and falls (2–4). The most commonly used measure of balance confidence is the Activities-specific Balance Confidence Scale (ABC-16). However, to reduce the time to administer the ABC-16 in busy clinical or research settings, the short Activities-specific Balance Confidence Scale (ABC-6) was derived from the identification of six items with the lowest balance confidence on the ABC-16 in older adults with Parkinson’s Disease and high-level gait disorders (5). The psychometric properties of the ABC-6 were similar to the ABC-16 when assessed in community-dwelling older adults (5,6) as well as individuals with Parkinson’s Disease and high-level gait disorders (5,7).

Of the limited evidence available, balance confidence (ABC-16) has been reported to be 11% lower in older adults with DM who were fallers than non-fallers (8), and low in older adults with diabetic peripheral neuropathy (DPN; ABC-16: 71.42%) (9). However, balance confidence (ABC-16) has also been reported to be similar between older adults with and without DM despite subtle but clear DM-related degradation of sensory functions (visual; vestibular; somatosensory) and worse balance performance (8). Emerging evidence suggests that the ABC-6, with its narrower continuum of activity difficulty, is more sensitive to detect subtle differences in balance confidence than the ABC-16 (6). Therefore, it is possible the ABC-6 may detect subtle differences in balance confidence in older adults with and without DM that are undetected by the ABC-16. However, it is unknown whether the ABC-6 is a valid assessment tool in older adults.
with DM. Therefore, this study builds upon previous psychometric testing of the ABC-6 and assesses its validity in older adults with DM with and without diagnosed DPN. The specific study objectives were: (i) to evaluate the **convergent validity** of the ABC-6 to assess balance confidence, compared to the ABC-16, in older adults with DM with and without diagnosed DPN, (ii) to compare the **discriminant validity** of the ABC-6 and ABC-16 in their ability to discriminate between older adults with DM, with and without DPN, compared to older adults without DM, and (iii) to explore the **concurrent validity** of the ABC-6 with physical and psychological clinical assessments in older adults with DM with and without diagnosed DPN.

It is hypothesized that the ABC-6 will have excellent convergent validity with the ABC-16, and the ABC-6 will be more sensitive to detect subtle differences in balance confidence in older adults with DM without diagnosed DPN when compared to the ABC-16. Lastly, we hypothesized balance confidence on the ABC-6 would be significantly correlated with both physical and psychological clinical assessments in older adults with DM with and without diagnosed DPN.

### 4.3. Methods

#### 4.3.1. Participants

Thirty community-dwelling older adults (aged ≥65) were age- and sex-matched in 3-groups: 10 with DM (DM-group, age: 72.00 ± 5.44 years; 7 males), and 10 with DPN (DPN-group, age: 71.70 ± 5.14 years; 7 males), and 10 without DM (noDM-group, age: 74.50 ± 3.54 years; 7 males). Inclusion criteria were DM ≥5 years. Exclusion criteria included: (1) foot open sores or ulcers, (2) other neurological conditions (e.g., Parkinson's Disease, Stroke, Multiple Sclerosis, etc.), (3) painful lower limb arthritis, (4) use of a
mobility device, (5) self-reported mobility disability (defined as the inability to walk a quarter mile without resting or climb a flight of stairs unsupported) and (6) cognitive impairment (Montreal Cognitive Assessment [MoCA] score<26) (10). Participants provided written informed consent and the protocol was approved by the Institutional Ethics Review Board.

4.3.2. Outcome measures

4.3.2.1. Participant Characteristics

Age, sex, height, and weight were recorded. Body mass index (BMI; kg/m²) was calculated and used to classify obesity (BMI≥30). Glycated hemoglobin (HbA1c) values were obtained at a local hospital from blood samples within one week of the testing session. Diabetes duration (years), possible co-morbidities (e.g., diabetic retinopathy, cataracts, glaucoma) and current medications were recorded. Number of falls were self-reported in the past year (0 falls = non-faller; ≥1 fall = faller). Lower-limb somatosensory function was assessed with a 5.07 Semmes-Weinstein Monofilament (North Coast Medical Inc., USA) on the plantar surface of the first metatarsal head of each foot. The 5.07 monofilament provides 10g of force, and the inability to sense 10g on either foot was recorded as loss of protective sensation (11).

4.3.2.2. Balance Confidence

Balance confidence was quantified with the ABC-16 questionnaire which requires participants to rate their balance confidence on a continuum of 0% (no confidence) to 100% (completely confident) for 16 activities of daily living. Balance confidence was reported as a percentage based on the mean of all 16-items for the ABC-16 (1), and the mean of 6-items (items 5, 6, 13-16) for the ABC-6 as identified by Peretz et al. (5)
(Please refer to Appendix C.2. for the ABC Scales). Higher scores indicate higher balance confidence.

4.3.2.3. Physical Domain

Physical activity level was quantified with the Human Activity Profile (HAP) which consists of 94 activities of increasing metabolic demands from self-care to strenuous exercise (12) (Please refer to Appendix D.2 for the questionnaire). The HAP adjusted activity score (HAP-AAS) was calculated as the highest activity the participant is still doing minus the total number of activities that the participant has stopped doing (maximum score = 94).

Mobility was assessed with the modified Timed-up-and-Go (mTUG) on a compliant foam surface wearing blurring goggles (13) (Please refer to Appendix D.3 for detailed procedure). The mTUG requires participants to stand up from a seated position (arms folded across the chest), walk straight ahead 3-meters, turn around, walk back to the chair and sit-down. The mTUG is more demanding than the TUG (14) and was used to avoid possible ceiling effects in community-dwelling older adults (13). The mTUG total time (seconds) was recorded. A “loss of balance” was recorded if a participant stabilized him/herself by grasping for support. If the “loss of balance” occurred, the magnitude assigned to the performance was calculated as the group mean + 3SD [n=2 in DPN-group].

Balance was assessed with the modified Clinical Test of Sensory Integration for Balance (mCTSIB) (15) (Please refer to Appendix D.4 for detailed procedure) and the Frailty and Injuries: Cooperative Studies of Intervention Techniques (FICSIT-4) (16) (Please refer to Appendix D.5 for full assessment). The mCTSIB assesses sensory
integration for maintaining balance and the ability of the central nervous system to compensate for unreliable sensory information under four conditions, with eyes open or closed, on a firm or compliant foam surface. Each condition was completed twice, and participants were evaluated on whether they could maintain balance for 30 seconds in each condition (yes/no). Total time standing in each condition was recorded, and summed for the mCTSIB total time (seconds). The FISCIT-4 assessed the ability to maintain balance, with eyes open or closed, with additional challenges of the feet positioned in parallel, semi-tandem, tandem, and one-legged stances. Item scores were summed for FISCIT-4 total score (maximum=28), and higher scores indicate better balance.

4.3.2.4. Psychological Domain

Depressive symptoms were evaluated with the Centre for Epidemiological Studies Depression Scale (CES-D; Please refer to Appendix E.1. for the full questionnaire). CES-D total scores range from 0-60 with higher scores indicating more depressive symptoms and ≥16 clinical depressive symptoms (17). Cognitive function was evaluated with the MoCA (Please refer to Appendix E.2. for full assessment). Total MoCA scores range from 0-30, higher scores indicating better cognitive function (10).

4.3.3. Statistical Analysis

Data were transformed to address unequal variances (square root: ABC-6; ABC-16; mTUG total time; mCTSIB total time; FISCIT-4 total score) or skewed distributions (log10: MoCA total scores) and back-transformed for data presentation. Separate general linear models, chi-square, and Fishers exact tests were used, as appropriate, to explore possible group-differences in participant characteristics, and the physical and psychological clinical assessments. Bivariate Pearson correlations were used to evaluate
the convergent validity between the ABC-6 and ABC-16 overall and in each study-group. A two-way mixed factor ANOVA [2(ABC Scale) x 3(Group)] was used to examine the discriminant validity of the ABC-6 to distinguish between study-groups compared to the ABC-16. Post hoc analysis were performed as required. Bivariate Pearson correlations were used to evaluate the concurrent validity of the ABC-6, compared to the ABC-16, with physical and psychological clinical assessments in the DM study-groups. \( P \leq 0.05 \) was considered statistically significant (SPSS V22).

4.4. Results

Age, sex, height, weight, BMI-category and fall history were not significantly different between-groups [all \( p > 0.05 \); Table 4.1]. DM descriptors were similar between the DM-group and DPN-group [all \( p > 0.05 \)]. One participant reported diagnosed diabetic retinopathy in the DM-group. Assessment of lower limb somatosensory functions revealed loss of protective sensation was significantly higher in the DPN-group (\( n=8 \)) than both the DM-group (\( n=0 \)) and noDM-group [\( n=0; \; p < 0.001 \)].

4.4.1. Physical and Psychological Domains

Table 4.2 displays physical and psychological clinical assessments between study-groups. Physical activity level (HAP-AAS) was significantly different between-groups [\( F_{(1,27)} = 5.841, \; p = 0.008 \)]. Post hoc analysis revealed HAP-AAS was significantly lower in the DPN-group compared to the noDM-group [\( t_{(18)} = 4.549, \; p = 0.047 \)] but similar between the other study-groups [all \( p > 0.05 \)]. Mobility (mTUG) was significantly different between-groups [\( F_{(1,27)} = 5.829, \; p = 0.008 \)]. Post hoc analyses revealed mTUG total time was greater in the DPN-group compared to the noDM-group [\( t_{(18)} = -2.699, \; p = 0.024 \)] and DM-group [\( t_{(18)} = -2.385, \; p = 0.034 \)]; however, similar between the noDM- and DM-groups.
Balance performance on the mCTSIB was significantly different between-groups \( [F(1,27)=2.704, p=0.05] \). Post hoc analysis revealed mCTSIB total time was significantly lower in the DPN-group compared to the noDM-group \( [t(18)=2.225, p=0.047] \) but similar between the other study-groups [all \( p>0.05 \)]. Balance performance on the FISCIT-4 was not significantly different between-groups when analyzed with the FISCIT-4 total score \( [F(1,27)=0.284, p=0.284] \) or within individual FISCIT-4 items [all \( p>0.05 \)].

Depression symptoms (CES-D total score) were significantly different between-groups \( [F(1,27)=3.99, p=0.030] \). Post hoc analysis revealed depressive symptoms were of higher severity in the DPN-group compared to the noDM-group \( [t(18)=-2.543, p=0.023] \) but similar between the other study-groups [all \( p>0.05 \)]. Additionally, three participants had clinical depressive symptoms (CES-D>16) in the DPN-group. Cognitive function (MoCA total score) was not significantly different between-groups \( [F(1,27)=0.48, p=0.953] \).

### 4.4.2. Convergent and Discriminant Validity

The ABC-6 and ABC-16 total scores were strongly correlated overall \( [r(27)=0.969, p<0.001] \) and within each study-group [noDM-group: \( r(8)=0.990, p<0.001 \); DM-group: \( r(8)=0.974, p<0.001 \); DPN-group: \( r(8)=0.964, p<0.001 \); Figure 4.1]. Balance confidence was significantly lower on the ABC-6 than the ABC-16 \( [F(1,27)=60.99, p<0.001] \) and significantly different across study-groups \( [\text{noDM}>\text{DM}>\text{DPN}; F(2,27)=9.32, p=0.001; \text{Figure 4.2}] \). Post hoc analysis of the \textit{ABC Scale x Group} interaction revealed both the ABC-6 \( [t(18)=4.249, p=0.001] \) and ABC-16 \( [t(18)=4.396, p=0.001] \) significantly differentiated between the noDM-group and DPN-group. However, only the ABC-6
significantly differentiated between the noDM-group and DM-group \([t_{(18)}=4.249, p=0.001]\). A post hoc item analysis of all 16 items on the ABC Scales revealed only item-6 (i.e., standing on a chair and reaching for something above head) was able to discriminate between the noDM and DM-groups \([t_{(18)}=7.108, p=0.016; \text{Figure 4.3.}]\).

### 4.4.3. Concurrent Validity

Table 4.3 displays correlation coefficients of both ABC scales with the physical and psychological clinical assessments in the DM study-groups \((n=20)\). Within the physical domain, the ABC-6 was moderately correlated with physical activity level \([\text{HAP-AAS: } r_{(18)}=0.528, p=0.017]\), mobility \([\text{mTUG total time: } r_{(18)}=-0.520, p=0.027]\) and one balance assessment \([\text{FISCIT-4 total score: } r_{(18)}=0.633, p=0.003]\). However, the ABC-6 was not significantly correlated with \(m\text{CTSIB total time: } r_{(18)}=0.351, p=0.130\). Within the psychological domain, the ABC-6 was moderately correlated with depressive symptoms \([\text{CES-D total score: } r_{(18)}=-0.515, p=0.020]\) but not with cognitive function \([\text{MoCA total score: } r_{(18)}=0.140, p=0.556]\).

### 4.5. Discussion

To our knowledge, this is the first study that examined the convergent, discriminant, and concurrent validity of the ABC-6 in older adults with DM with and without DPN. The ABC-6 had excellent convergent validity with the ABC-16. However, the ABC-6 can be administered in less time and was more sensitive to detect subtle differences in balance confidence in older adults with DM without diagnosed DPN when compared to the ABC-16. Both ABC scales had moderate concurrent validity with physical activity level, mobility, balance and depressive symptoms in the DM study-groups.
Excellent convergent validity between the ABC-6 and ABC-16

Consistent with previous studies in other populations (5,6), the ABC-6 had excellent convergent validity with the ABC-16 in older adults with DM with and without DPN (r:0.964-0.974) despite significantly lower balance confidence scores on the ABC-6 than ABC-16. Lower balance confidence on the ABC-6 may be attributed the narrower continuum of activity difficulty and systematic removal of items that could possibly inflate the overall confidence levels (5,6).

ABC-6 was more sensitive to discriminate between subtle differences in balance confidence in the noDM-group and DM-group than the ABC-16

We examined the discriminant validity of both ABC versions between community-dwelling older adults in 3-groups: noDM-group, DM-group, and DPN-group. Both the ABC-6 and ABC-16 were able to detect significant differences in balance confidence between the noDM-group and DPN-group [group-differences: ABC-6=24.85%; ABC-16=17.11%]. These findings are consistent with Peretz et al. (5) where large differences in balance confidence were detected by both ABC Scales between community-dwelling older adults when compared to individuals with Parkinson's disease [group-differences: ABC-6=23.80%; ABC-16=15.3%] or high-level gait disorders [group-differences: ABC-6=47.2%; ABC-16=36.2%]. However, only the ABC-6 was able to detect subtle differences in balance confidence between the noDM-group and DM-group [group-difference: ABC-6=15.00%]. Of the limited evidence available, Schepens et al. (6) also reported similar findings that only the ABC-6 was able to differentiate between subtle differences in balance confidence between older adults who were fallers and non-fallers [group-difference: ABC-6=14.23%]. The increased
sensitivity of the ABC-6 was primarily driven by item-6 (i.e., standing on a chair and reaching for something above your head) which was the only item on either ABC scale to independently discriminate balance confidence between the noDM- and DM-group. It is known standing on a chair and reaching increases postural threat as the consequences of losing balance becomes more detrimental at increased heights (18) as well as the restricted ability to utilize a stepping strategy to recover balance (19). However, the higher sensitivity of this item in older adults with DM may be attributed to the effects of long-term hyperglycemia on the highly active metabolic vasculature in the inner ear (20) which may contribute to postural instability during rapid head movements while reaching. Overall, although both ABC versions could discriminate between the noDM-group and the DPN-group, the ABC-6 was more sensitive to detect subtle differences in balance confidence in older adults with DM without diagnosed DPN when compared to the ABC-16.

*Moderate concurrent validity was found between the ABC-6 and physical activity level, mobility, balance and depressive symptoms in the DM-study groups*

We explored the concurrent validity of the ABC-6 with physical and psychological clinical assessments in older adults with DM with and without diagnosed DPN. Our findings demonstrated moderate concurrent validity between the ABC-6 and physical activity level, mobility, balance and depressive symptoms in the DM-study groups. The significance of the correlation coefficients did not differ between either ABC versions nor were their magnitudes reduced substantially by narrowing the continuum of
activity difficulty. The relationships between balance confidence and each of these physical and psychological clinical assessments will be discussed below.

4.5.1. Physical Domain

It is well-established that physical activity is a key component to the management of DM and its complications (21). Our results indicated the DPN-group reported significantly lower physical activity levels (HAP-AAS) when compared to the noDM-group, and low physical activity level was moderately correlated with low balance confidence in the DM study-groups. Although physical activity level may reflect the functional status of an individual, reduced confidence in the ability to perform activities can lead to activity restriction and consequently lower physical activity levels (4,22). However, longitudinal investigation is warranted to understand the temporal relationship between physical activity level, activity restriction and balance confidence in older adults with DM.

Both mobility (mTUG total score) and balance (mCTSIB total score) performance were worse in the DPN-group than noDM-group when assessed under conditions of reduced vision and somatosensory inputs. These group-differences may be attributed to loss of protective sensation (n=8) and lower limb numbness (n=10) in the DPN-group which can affect the ability of the central nervous system to compensate for multimodal sensory loss (23). Under reduced sensory conditions, balance confidence was moderately correlated with mobility performance (ie. longer time to complete the mTUG) but not the mCTSIB. However, the mTUG assesses balance during four mobility components (i.e., sit-to-stand, walk, turn and stand-to-sit) whereas the mCTSIB only assesses balance during standing. Consequently, the mTUG may better reflect balance challenges
encountered during activities of daily living which are assessed on the ABC Scale (e.g., walking around the house (item-1); step on and off an escalator while holding onto parcels such that you cannot hold onto the railing (item-15), etc.). Group-differences were not observed in the FICSIT-4 balance test possibly as sensory information from two of the three sensory systems (vestibular; somatosensory) were always available. However, the FICSIT-4 balance test was found to be significantly correlated with balance confidence in the DM study-groups. Therefore, similar to the mTUG, the additional balance challenges (ie., reduced base of support from altered foot positions) may better reflect the balance challenges assessed on the ABC Scale (e.g., stand on a chair and reach for something (item-6)) when compared to standing balance assessed in one position on the mCTSIB.

4.5.2. Psychological Domain

Clinical depression has been reported to be roughly double in older adults with DM (11%) when compared to the general population (5%) and associated with increased DM-related complications (24). It is known depressive symptoms can erode one’s self-confidence to perform activities which may lead to reduced balance confidence (25). However, this is the first study to provide evidence that increased depressive symptoms (CES-D total score) are moderately correlated with low balance confidence in older adults with DM with and without DPN. Additionally, the three participants in the DPN-group with clinical depressive symptoms (CES-D>16) were found to be 3 of the 4 participants with the lowest balance confidence in their group (Figure 4.1, ABC-6 = 46.67%, 48.33% and 60.00%). Therefore, older adults with DM with sub-clinical
depressive symptoms, as well as clinical depression, may benefit from balance confidence interventions.

Long-term hyperglycemia can result in oxidative and proinflammatory stress on brain tissue (26) and is associated with DM-related declines in cognitive function (26,27). No studies could be cited that investigated the relationship between cognitive function and balance confidence. Fear of falling is strongly associated with low balance confidence (28–30), and older adults with mild cognitive impairment report high levels of fear of falling (31). Therefore, it is reasonable to hypothesize that mild cognitive impairment is associated with low balance confidence. However, our study did not demonstrate balance confidence to be significantly correlated with cognitive function (MoCA total score) in the DM study-groups likely as participants were excluded with cognitive impairment (MoCA<26).

4.6. Study Limitations

Balance confidence scores for the ABC-6 were calculated from the ABC-16. It is possible participants may have rated their balance confidence differently if they were only asked the six questions on the ABC-6. Participants with possible cognitive impairment were excluded (MoCA<26) as the ABC-6 has not yet been validated in this population, and cognitive impairment may influence item comprehension and the ability to report subjective states (32).

4.7. Clinical Implications

Subtle differences in balance confidence were found between the noDM-group and DM-group despite similar performance on all the physical and psychological clinical assessments. Therefore, the ABC-6 may provide a means for early detection of balance
and mobility-related declines in older adults with DM without diagnosed DPN. Deterioration of one or more sensory system(s) reduces the sensory redundancy available to the central nervous system which may adversely affect balance performance and/or confidence (23). Therefore, it is not surprising that the one participant who reported diagnosed diabetic retinopathy was observed to have the lowest balance confidence in their group (Figure 4.1; ABC-6: 50.0%; ABC-16: 73.13%) and similar to those with diagnosed DPN. No-group differences were found in fall history, and the one participant in the DPN-group who was identified as a frequent faller had the highest balance confidence in their group (ABC-6: 90%; ABC-16: 90%). Furthermore, the ABC-6 may be advantageous for use in busy clinical or research settings as it can be administered in considerably less time than the ABC-16.

4.8. Conclusions

The ABC-6 had excellent convergent validity with the ABC-16, and both ABC scales had moderate concurrent validity with physical activity level, mobility, balance and depressive symptoms in the DM study-groups. However, the ABC-6 can be administered in less time and was more sensitive to detect subtle differences in balance confidence in older adults with DM without diagnosed DPN when compared to the ABC-16. Overall this study provided evidence that the ABC-6 is a valid assessment tool for use in older adults with DM with and without DPN.
4.9. References


88


### 4.10. Tables

**Table 4.1.**
Participant characteristics between study-groups

<table>
<thead>
<tr>
<th>Demographics</th>
<th>noDM-group (n=10)</th>
<th>DM-group (n=10)</th>
<th>DPN-group (n=10)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>74.50 (3.54)</td>
<td>72.00 (5.44)</td>
<td>71.70 (5.13)</td>
<td>0.369</td>
</tr>
<tr>
<td>Sex (# of males)</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>1.000</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.71 (0.09)</td>
<td>1.71 (0.11)</td>
<td>1.75 (0.07)</td>
<td>0.628</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>78.30 (18.76)</td>
<td>87.07 (15.36)</td>
<td>94.32 (16.38)</td>
<td>0.124</td>
</tr>
<tr>
<td>BMI ≥30 (n)</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>0.876</td>
</tr>
<tr>
<td>DM Descriptors</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HbA1c (%)</td>
<td>7.70 (1.20)</td>
<td>7.30 (1.20)</td>
<td></td>
<td>0.480</td>
</tr>
<tr>
<td>HbA1c &gt;8% (n)</td>
<td>--</td>
<td>4</td>
<td>2</td>
<td>0.329</td>
</tr>
<tr>
<td>DM duration (years)</td>
<td>15.50 (7.43)</td>
<td>16.00 (6.95)</td>
<td></td>
<td>0.878</td>
</tr>
<tr>
<td>Self-reported diabetic retinopathy (n)</td>
<td>--</td>
<td>1</td>
<td>0</td>
<td>1.000</td>
</tr>
<tr>
<td>DM Treatment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Antihyperglycemic therapy (n)</td>
<td>-</td>
<td>3</td>
<td>4</td>
<td>0.795</td>
</tr>
<tr>
<td>- Insulin therapy (n)</td>
<td>-</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>- Antihyperglycemic &amp; insulin therapy (n)</td>
<td>-</td>
<td>2</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>- No antihyperglycemic or insulin therapy (n)</td>
<td>-</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Fall History</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At least one fall in the past year (n)</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>0.668</td>
</tr>
<tr>
<td>More than one fall in past year (n)</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1.000</td>
</tr>
<tr>
<td>Lower Limb Somatosensory Function</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loss of protective sensation (n)</td>
<td>0</td>
<td>0</td>
<td>8</td>
<td>0.001**</td>
</tr>
</tbody>
</table>

*Note.* Data represented are means (SD) unless described otherwise. DM: diabetes mellitus. DPN: diabetic peripheral neuropathy., BMI: body mass index, HbA1c: Glycated hemoglobin, **P≤0.001.
**Table 4.2.**
Physical and psychological clinical assessments between study-groups

<table>
<thead>
<tr>
<th></th>
<th>noDM-group (n=10)</th>
<th>DM-group (n=10)</th>
<th>DPN-group (n=10)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Physical domain</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical Activity HAP-AAS</td>
<td>77.80 (9.64)</td>
<td>69.40 (10.54)</td>
<td>59.00 (11.23)</td>
<td>0.008*</td>
</tr>
<tr>
<td>Mobility mTUG total time (s)^a</td>
<td>12.16 (1.11)</td>
<td>12.71 (4.12)</td>
<td>22.32 (12.35)</td>
<td>0.008*</td>
</tr>
<tr>
<td>Balance mCTSIB total time (s)^a</td>
<td>231.50 (17.95)</td>
<td>211.10 (30.53)</td>
<td>194.40 (37.23)</td>
<td>0.050*</td>
</tr>
<tr>
<td>Balance FISCIT-4 total score^a</td>
<td>24.70 (2.79)</td>
<td>23.00 (3.80)</td>
<td>22.10 (4.15)</td>
<td>0.284</td>
</tr>
<tr>
<td><strong>Psychological domain</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depressive Symptoms CES-D total score</td>
<td>4.00 (4.64)</td>
<td>8.60 (4.50)</td>
<td>11.40 (6.49)</td>
<td>0.030*</td>
</tr>
<tr>
<td>Clinical Depressive Symptoms</td>
<td>CES-D total score ≥16</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Cognitive Function MoCA total score^b</td>
<td>28.90 (1.66)</td>
<td>28.70 (1.42)</td>
<td>28.70 (1.42)</td>
<td>0.953</td>
</tr>
<tr>
<td>Cognitive Impairment MoCA total score&lt;26</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>---</td>
</tr>
</tbody>
</table>

*Note.* Data represented are means (SD) unless described otherwise. ^a^square root and ^b^log10 transformed for data analysis and back transformed for data presentation. *p<0.05.

Table 4.3. Concurrent validity: Comparison of correlation coefficients of both ABC scales with physical and psychological clinical assessments in the DM study-groups

<table>
<thead>
<tr>
<th></th>
<th>Physical Activity</th>
<th>Mobility</th>
<th>Balance</th>
<th>Balance</th>
<th>Depression</th>
<th>Cognition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HAP-AAS</td>
<td>mTUG total time (s)</td>
<td>mCTSIB total time (s)</td>
<td>FICSIT-4 total score (s)</td>
<td>CES-D total score</td>
<td>MoCA total score</td>
</tr>
<tr>
<td>ABC-6 total scorea</td>
<td>r=0.528, p=0.017*</td>
<td>r=-0.520, p=0.027*</td>
<td>r=0.351, p=0.130</td>
<td>r=0.633, p=0.003*</td>
<td>r=-0.515, p=0.020*</td>
<td>r=0.140, p=0.556</td>
</tr>
<tr>
<td>ABC-16 total scorea</td>
<td>r=0.568, p=0.009*</td>
<td>r=-0.503, p=0.033*</td>
<td>r=0.400, p=0.081</td>
<td>r=0.607, p=0.005*</td>
<td>r=-0.569, p=0.009*</td>
<td>r=0.127, p=0.594</td>
</tr>
</tbody>
</table>

Note. a square root and b log10 transformed for data analysis and back transformed for data presentation. *p<0.05.

4.11. Figures

Figure 4.1.
Convergent validity: ABC-6 and ABC-16

Note. The short Activities-Specific Balance Confidence Scale (ABC-6) had excellent convergent validity with the original Activities-Specific Balance Confidence Scale (ABC-16; p<0.001).

Participants with clinical depressive symptoms (denoted with sub-script a) and diagnosed diabetic retinopathy (denoted with sub-script b) had the lowest balance confidence scores.
**Figure 4.2.**
Discriminant validity: ABC-6 and ABC-16 between study-groups

<table>
<thead>
<tr>
<th></th>
<th>noDM-group</th>
<th>DM-group</th>
<th>DPN-group</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ABC-16</strong></td>
<td>97.083</td>
<td>89.305</td>
<td>79.976</td>
</tr>
<tr>
<td><strong>ABC-6</strong></td>
<td>93.180</td>
<td>78.667</td>
<td>68.330</td>
</tr>
</tbody>
</table>

*Note.* Balance confidence was significantly lower on the ABC-6 than the ABC-16 \([p<0.001]\) and significantly different across study-groups \([\text{noDM} > \text{DM} > \text{DPN}; p=0.001]\). Post hoc analysis of the *ABC Scale x Group* interaction revealed both the ABC-6 \([p=0.001]\) and ABC-16 \([p=0.001]\) significantly differentiated between the noDM-group and DPN-group. However, only the ABC-6 significantly differentiated between the noDM-group and DM-group \([p=0.001]\). Data are displayed as means and standard error.
This figure depicts balance confidence on the Activities-specific Balance Confidence Scale (ABC-16; all 16 items) and shortened ABC Scale (6-items shaded in light grey). Item-6, standing on a chair and reaching for something above your head, was the only item to be significantly different between the noDM-group and DM-group (p=0.016). Whereas all 16-items where significantly different between the noDM-group and DPN-group (p<0.05).
CHAPTER 5: STUDY III

Head and trunk control while walking in older adults with diabetes mellitus: effects of balance confidence
5.1. Abstract

Introduction: Investigations of gait in older adults with diabetes mellitus (DM) have been primarily focused on lower limb biomechanical parameters. However, the upper body accounts for two-thirds of the body’s mass, and head and trunk control are critical for balance. We examined head and trunk control during fast and dual-task walking and the relationship between balance confidence and potential head-trunk stiffening strategies in older adults with DM without diagnosed diabetic peripheral neuropathy (DPN).

Methods: Twelve older adults with DM without diagnosed DPN (DM-group) and 12 without DM (noDM-group) were recruited. Walking speed, peak-to-peak head (HRp-p) and trunk (TRp-p) roll displacement, head (HRvel) and trunk (TRvel) roll velocity, and head-trunk correlation (H-Tcorr) were measured while walking at a self-selected comfortable or fastest possible speed with or without a secondary cognitive task. The short version of the Activities-specific Balance Confidence scale (ABC-6) measured balance confidence. Results/Conclusions: Subtle group-differences in axial segmental control (lower TRvel; higher H-Tcorr) were apparent in older adults with DM even in the absence of DPN. Balance confidence was 19% lower in the DM-group than noDM-group, and partially explained (34%) group-difference in head-trunk stiffening. These results emphasize the need for proactive monitoring of postural control and balance confidence before the onset of DPN.
5.2. Introduction

It is now established that older adults with diabetes mellitus (DM) have worse balance (1) and altered gait patterns (e.g., slower walking speed, shorter stride length and increased double support) (2,3) when compared to those without DM, regardless of diabetic peripheral neuropathy (DPN). These differences are more apparent while walking with added challenges such as faster speed (2) or with an additional cognitive task (4).

Investigations of gait in older adults with DM have been primarily focused on lower limb biomechanical parameters. Yet, approximately two-thirds of the body’s mass is attributed to the upper body (5). Therefore, precise head and trunk control are critical to maintain an upright posture and balance while walking. Of the limited evidence available, older adults with diagnosed DPN have been reported to have smaller head and pelvis accelerations and less rhythmic control (i.e., higher harmonic ratios) while walking when compared to healthy controls (6). These erratic acceleration patterns suggest that older adults with DPN may have difficulty controlling momentum and displacement of the trunk (6) which can impair head control and overall balance (7). Furthermore, when evaluated in standing, mediolateral postural control was worse than in the anteroposterior direction in older adults with DM (8). However, no studies could be cited that examined mediolateral axial postural control while walking in older adults with DM without DPN compared to those without DM. Secondly, it is not known if tasks known to increase challenge to postural control while walking affect head and trunk control more in older adults with DM without DPN than those without DM.

In older adults with DM, fear of falling (FoF) has been associated with balance
impairments (9) and conservative gait (e.g., slower walking speed, shorter stride length and slower stride velocity) (9–11). FoF and low balance confidence are strongly associated with a head-trunk stiffening in older adults (12–14). Head-trunk stiffening may be advantageous to simplify postural control (i.e., reduce degrees of freedom in the head-neck control) and improve head stabilization when the trunk is stabilized. However, head-trunk stiffening may be maladaptive under conditions of more pronounced trunk movement. Additionally, low balance confidence is theorized to result in an internal focus of attention and may result in inadequate attentional resources for optimal task performance (14). Older adults with DM have been documented to stiffen their upper body during standing balance under challenging conditions (15). However, no studies have explored the relationship between balance confidence and head-trunk stiffening under challenging walking conditions in older adults with DM.

This study examined head and trunk control during fast and dual-task walking and the relationship between balance confidence and potential head-trunk stiffening in older adults with DM without diagnosed DPN compared to those without DM. It is hypothesized that diabetes-related complications in multiple sensorimotor and cognitive systems required for postural control will impair head and trunk control and lead to a greater impact on fast and dual-task walking in older adults with DM than those without DM. Furthermore, it is hypothesized that lower balance confidence will lead to head-trunk stiffening in older adults with DM.

5.3. Methods

5.3.1. Participants

Twelve older adults with DM for ≥5 years without self-reported physician
diagnosed DPN (DM-group, age: 70.5±5.1 years; 7 males) and 12 age- and sex-matched older adults without DM (noDM-group, age: 72.0±5.5 years; 7 males) were recruited. Exclusion criteria included: (1) foot open sores or ulcers, (2) other neurological conditions (e.g., Parkinson's Disease, Stroke, Multiple Sclerosis, etc.), (3) painful lower limb arthritis, (4) mobility device, (5) self-reported mobility disability (defined as the inability to walk a quarter mile without resting or climb a flight of stairs unsupported) and (6) cognitive impairment (Montreal Cognitive Assessment Score<26) (16). Participants provided written informed consent and the protocol was approved by the Institutional Ethics Review Board.

5.3.2. Participant Characteristics

Age, sex, height, and weight were recorded. Body mass index (BMI) was calculated and used to classify obesity (BMI≥30). Glycated hemoglobin (HbA1c) values, measured within the past 3 months, and diabetes duration (years) were recorded in DM-group. Trail Making Test Part-B (TMT-B; Please refer to Appendix E.3. for full assessment) assessed executive functions (17). Number of falls were self-reported in the past year (0 falls=non-faller; ≥1 fall=faller).

5.3.3. Experimental Procedures

Participants walked along a 6-meter path, first at a comfortable self-selected walking speed and then at their fastest possible walking speed. On randomly selected trials, within each speed condition, participants performed a secondary cognitive task of serial subtraction by 3’s (SS3) from a randomized number <100 given at the beginning of the trial. Each trial was performed twice [2(Speed Condition) x 2(Cognitive-Task) x 2(Trials)].
An Optotrak 3020 camera bank (Northern Digital Inc., Canada) tracked the position of 8-infrared emitting diodes (IREDs) on the midline of the occiput, above each ear, on each acromion process, seventh cervical vertebra, twelfth thoracic vertebra, and second sacral vertebra (Figure 5.1a). Data were collected at a sampling rate of 50Hz and filtered with a low-pass Butterworth filter at 6Hz (C-Motion, USA) (18).

5.3.4. Primary Outcome Measures

All kinematic outcome measures were calculated during steady state walking (2-4 meters; Figure 5.1b). Steady state walking was analyzed to strategically eliminate the acceleration and deceleration phase of walking, and consistent IRED visibility eliminated the need for data interpolation.

Walking speed (m/s) was computed using the anterior progression of the second sacral vertebra IRED. Head and trunk control were calculated in the mediolateral direction using gravitational vertical as the reference value. Peak-to-peak head roll angular displacement (HRp-p; degrees) was computed using IRED data from the occiput and seventh cervical vertebra. Peak-to-peak trunk roll angular displacement (TRp-p; degrees) was computed using the IRED data from the seventh cervical vertebra and second sacral vertebra. Head (HRvel; degrees/s) and trunk (TRvel; degrees/s) roll velocity was calculated as the average root mean square of the first derivative of respective instantaneous angular displacement data. To assess head-trunk (H-T) stiffening, the correlation between the instantaneous displacement of head and trunk roll angles were calculated (H-Tcorr; Pearson’s r). Cognitive performance was calculated as the total number of correctly verbalized serial subtractions.

The Activity-specific Balance Confidence Scale (ABC-6), which is valid and
reliable in community-dwelling older adults, measured balance confidence which reflects an individual’s perceived level of confidence that they will not lose their balance or become unsteady (Please refer to Appendix C.2. for questionnaire). The ABC-6 includes the six most challenging activities of the ABC-16 and is strongly correlated with balance performance (19). Higher total scores indicated higher balance confidence.

5.3.5. Statistical Analysis

Data were examined for normality and log10 transformed as appropriate (HRp-p; TRp-p). Fisher’s r to z transformation was performed for all correlation values before analysis. No statistical differences were found between trials 1 and 2; therefore, were analyzed as the average of both trials.

One-way ANOVAs and chi-square analyses were used, as appropriate, to examine between-group differences in participant characteristics. Separate 3-way mixed factor ANOVAs [2(Group) x 2(Speed Condition) x 2(Cognitive-Task)] of walking speed, HRp-p, TRp-p, HRvel, TRvel and HTCorr were used to examine head and trunk control between groups and the effects of fast walking and the additional cognitive task. A 2-way mixed factor ANOVA [2(Group) x 2(Speed Condition)] was used to analyze cognitive performance between groups and the effect of fast walking. A one-way ANOVA [2(Group)] of ABC-6 was used to examine balance confidence between groups. Bivariate Pearson correlations were conducted for each experimental condition between H-Tcorr and ABC-6 to explore the relationship between head-trunk stiffening and balance confidence. H-Tcorr was further analyzed in the experimental condition(s) that revealed significant H-Tcorr and ABC-6 correlations (p<0.05) with separate one-way ANCOVAs [2(Group)], controlling for ABC-6. P<0.05 was considered statistically significant (SPSS
5.4. Results

Age, sex, height, weight, BMI-category, executive functions (TMT-B) and the number of fallers were not significantly different between-groups (all p>0.05; Table 5.1). Those with glycemic control not at target (n=3; HbA1c>8%) (20) or longer DM duration (4th quantile; ≥15 years) were not identified as outliers in any analysis.

5.4.1. Primary Outcome Measures

The DM-group walked marginally slower than the noDM-group \(F_{(1,22)}=3.429, p=0.078\). In both groups, walking speed significantly increased during the fastest speed condition \(F_{(1,22)}=185.062, p<0.001\) and reduced with SS3 \(F_{(1,22)}=85.08, p<0.001\;\text{Figure 5.2}\). Post hoc analysis of the Speed Condition x Cognitive Task interaction revealed walking speed significantly reduced almost twice as much with SS3 during the fastest speed when compared to the effect of SS3 during the self-selected comfortable speed \(t_{(23)}=-5.598, p<0.001\). In both groups, less serial subtractions were recited at the fastest (3.04±1.42 total correct SS3) than at the self-selected comfortable (3.71±1.67 total correct SS3) speed condition \(F_{(1,22)}=7.46, p=0.012\).

HRp-p increased with SS3, regardless of the speed condition or group \(F_{(1,22)}=11.62, p=0.002;\text{Figure 5.3a}\). HRvel increased during the fastest speed condition, regardless of SS3 or group \(F_{(1,22)}=17.78, p<0.001;\text{Figure 5.3b}\). In both groups, TRp-p increased with SS3 \(F_{(1,22)}=5.377, p=0.033\). Post hoc analysis of a Speed Condition x Cognitive-Task interaction revealed TRp-p significantly increased (27%) with S33 at the self-selected comfortable \(t_{(23)}=-3.278, p=0.003\) but not during the fastest speed condition \(t_{(23)}=-0.933, p=0.361;\text{Figure 5.4a}\). Overall TRvel was significantly lower in
DM-group than noDM-group \( [F_{(1,22)}=4.476, \ p=0.046] \). In both groups, TRvel significantly increased during the fastest speed condition \( [F_{(1,22)}=39.510, \ p<0.001] \) and reduced with SS3 \( [F_{(1,22)}=46.291, \ p=0.001] \). Post hoc analysis of a Speed Condition x Cognitive-Task interaction revealed TRvel significantly reduced with SS3 only at the fastest speed condition \( [t_{(23)}=4.854, \ p<0.001; \ Figure \ 5.4b] \). DM-group had higher overall H-Tcorr than the noDM-group, regardless of SS3 or speed condition \( [F_{(1,22)}=8.302, \ p=0.009; \ Figure \ 5.5] \).

ABC-6 total scores were 19% lower in DM-group than noDM-group \( (p=0.007) \). H-Tcorr was only significantly correlated with ABC-6 at the self-selected comfortable pace with no-SS3 (control condition; \( r=-0.564, p=0.004 \)) but no other experimental condition \( (p>0.05) \). Further analysis of H-Tcorr during the control condition revealed a large reduction \( (\Delta \eta p^2=0.338) \) in effect size and observed power \( (\Delta \text{observed power}=0.466) \) of H-TCorr group-differences after adjusting for ABC-6: which accounted for 34% of the variance between-groups. ABC-6 was also a significant covariate in this analysis \( (p=0.036) \).

5.5. Discussion

To our knowledge, this is the first study that examined head and trunk control during fast and dual-task walking and the relationship between balance confidence and potential head-trunk stiffening in older adults with DM without diagnosed DPN. Subtle group-differences in axial segmental control (i.e., lower trunk roll velocity and higher head-trunk correlations) and lower balance confidence (19%) were apparent in older adults with DM even in the absence of DPN and mobility disability. Balance confidence partially explained (34%) the variance in head-trunk stiffening between older adults with
and without DM.

**Despite overall slower walking speed in older adults with DM, the ability to increase walking speed on demand and the effect of the secondary task was similar between-groups**

Consistent with previous studies (4,6), the DM-group walked overall slower than the noDM-group which is a known compensatory strategy to increase overall stability (21). Both groups self-selected comfortable walking speed was within the ‘normal’ range, 0.90–1.43m/s for community-dwelling older adults (DM-group range:1.03-1.44m/s; noDM-group range:1.02-1.60m/s) (22,23). However, despite overall slower walking speeds in the DM-group, the ability to draw upon a functional reserve to increase walking speed on demand during the fast walking conditions was similar between-groups. Yet, on average, fast walking speeds of the DM-group (1.43±0.34m/s) did not exceed the normative range for self-selected walking speed (22,23) contrary to the noDM-group (1.61±0.35m/s). In summary, overall slower walking speeds were found in older adults with DM even before complications of DPN or mobility disability when compared to those without DM.

In both groups, walking speed reduced with the secondary cognitive task (SS3) and can be attributed to increased attentional demands (24). Walking speed significantly reduced almost twice as much with SS3 during the fastest speed when compared to the effect of SS3 during the self-selected comfortable speed condition. These findings, similar to previous aging studies, suggest that attention-demanding tasks compromise the ability to maintain a fast walking speed (25). Further, both groups self-selected comfortable walking speed with SS3 (DM-group: 0.90±0.24m/s; noDM-group:
1.04±0.23m/s) was lower than 1.2m/s recommended for safe community ambulation (26). However, on average, fast walking speeds with SS3 exceeded 1.2m/s in the noDM-group (1.40±0.30m/s) but not in the DM-group (1.14±0.24m/s) despite walking in a predictable lab environment. Therefore, it is possible that the addition of a secondary task may impede safe community mobility in the older adults with DM.

**Subtle group-differences in axial segmental control**

Subtle group-differences in trunk control revealed that the DM-group had overall significantly lower trunk roll velocity than the noDM-group. Adjusting for average walking speed, there was a large reduction in effect size ($\Delta \eta_p^2=0.066$) and observed power ($\Delta \text{observed power}=0.208$). Therefore, similar to findings in aging research (27), slower walking speed contributed to overall lower trunk roll velocity in older adults with DM. Furthermore, it is possible slower walking speed was required to strategically reduce trunk velocity and improve mediolateral control of the trunk, the largest and heaviest body segment, while walking.

In both groups, the ability to control mediolateral trunk displacement became increasingly challenging with SS3. Consequently, both groups reduced their walking speed and trunk roll velocity with increased attentional demands of SS3 possibly in an attempt to reduce trunk momentum during increased trunk displacement. However, further analysis of the *Speed Condition x Cognitive-Task* interaction revealed with SS3 TRp-p only increased at the self-selected comfortable speed condition. Surprisingly, there was no further increase in trunk roll angular displacement with SS3 during the fastest speed condition, and therefore, it is possible both groups stiffened their trunk to maintain postural stability. Further analysis of the *Speed Condition x Cognitive-Task* interaction
revealed trunk velocity also reduced with SS3 during the fastest speed condition possibly as an additional mechanism to maintain postural stability during trunk stiffening.

In both groups, similar to the trunk segment, mediolateral head control became increasingly challenging with SS3. As well, in both groups, head roll velocity increased at the fastest speed condition which may be explained by increased body movement at higher walking speeds. These results suggest that the DM-group appear to have similar head control to the noDM-group even under conditions of an additional cognitive task or faster walking speed. However, overall slower walking speed and lower trunk roll velocity may have provided a stable base for head stabilization in the DM-group. Therefore, the ability for older adults with DM to control their head similar to those without DM may have required additional “bottom-up” control from the trunk segment.

*Higher H-Tcorr in older adults with DM reflects a potential need for head-trunk stiffening to simplify postural control and was partially explained by balance confidence*

Greater head-trunk stiffening in older adults with DM may be advantageous to improve head stabilization when the trunk is stabilized (i.e., reduce the degrees of freedom in the head-neck control) but maladaptive under conditions of more pronounced trunk movement (28). Further, the noDM-group who had lower head-trunk correlations were able to independently stabilize their head segment to the same extent as those with DM; which may represent a higher degree of functional variability and adaptability within the central nervous system (29). Significant group-differences in head-trunk stiffening remained even after adjusting for average walking speed.
The significant negative linear relationship between balance confidence on the ABC-6 and head-trunk stiffening (H-Tcorr) revealed that older adults with lower balance confidence tended to have greater head-trunk stiffening while walking at their self-selected comfortable speed with no-SS3 (control condition). Balance confidence on the ABC-6 was 19% lower in DM-group than noDM-group, and partially explained (34%) the variance in head-trunk stiffening between-groups during the control condition. These findings are consistent with the literature as low balance confidence is theorized to result in an internal focus of attention and may result in inadequate attentional resources for optimal task performance (14). Therefore, head-trunk stiffening may be advantageous to simplify postural control to compensate an internal focus of attention in those with low balance confidence. Given that older age and being female are strongly associated with lower balance confidence (30), the relationship between H-Tcorr and ABC-6 was further explored post hoc controlling for age and sex. Results indicated that only ABC-6 was a significant covariate (p=0.05), and age and sex did not further explain the variance in H-Tcorr between-groups likely as the groups were age- and sex-matched.

5.5.1. Potential Role of Participant Characteristics

Group-differences in axial segmental control, lower balance confidence, and head-trunk stiffening occurred even when no participants were frequent fallers (>1 fall in the past year). Analysis of the effect of obesity on upper body control revealed no significant differences between older adults with DM who were obese (n=6; BMI≥30) and non-obese (n=6; BMI<30). Additionally, the 3 participants with glycemic control not at target (HbA1c>8%) and those with longer diabetes duration (4th quantile; ≥15 years) were not identified as outliers in any analysis. No significant group-differences in
executive function (TMT-B) were found and those with cognitive impairment (MoCA<26) were excluded, which suggests good cognitive health. Therefore, this may be why our results differed from previous research where older adults with DM had significantly lower cognition than those without DM (4).

5.6. Study Limitations

No group-differences in the ability to increase walking speed along the 6-meter walking path were found. However, given DM-complications can affect functional reserves of multiple body systems, it is possible that group-differences would occur at longer distances with increased metabolic demands. Secondly, although arithmetic tasks are commonly used as quantifiable and non-subjective secondary tasks, they may not reflect the type and perceived complexity of the tasks encountered in the natural environment (e.g., cognitive dual-task of walking-while-talking; visuomotor reaction time dual-task while crossing the street at a stoplight) (31,32)

5.7. Clinical Implications

Subtle group-differences in axial segmental control were apparent in older adults with DM even in the absence of DPN and mobility disability. Similar to our previous work that demonstrated degradation of multiple sensory systems, critical for postural control, affected balance and mobility in older adults with DM even in the absence of DPN (33). Head-trunk stiffening while walking at a self-selected speed may occur in response to lower balance confidence in older adults with DM. Therefore, proactive monitoring should begin much before overt diabetes complications to detect subtle changes in postural control and provide pre-habilitation balance and fear of falling interventions to delay potential adverse outcomes, such as falls, in older adults with DM.
5.8. Conclusions

This study demonstrated that older adults with DM without diagnosed DPN had subtle differences in axial segmental control and head-trunk stiffening in older adults with DM may be partially explained by reduced balance confidence, even in the absence of DPN and mobility disability. Findings from this study enhance our understanding of upper body control in older adults with DM without diagnosed DPN and emphasize the need for proactive monitoring of postural control and balance confidence before the onset of DPN.
5.9. References


## 5.10. Table

**Table 5.1.**
Participant characteristics between study groups

<table>
<thead>
<tr>
<th>Outcome measure</th>
<th>DM-group (n=12)</th>
<th>noDM-group (n=12)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Demographics</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>70.50 (5.12)</td>
<td>72.00 (5.52)</td>
<td>0.498</td>
</tr>
<tr>
<td>Sex (# of males)</td>
<td>7</td>
<td>7</td>
<td>1.000</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>164.71 (7.89)</td>
<td>168.17 (13.05)</td>
<td>0.441</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>82.91 (19.36)</td>
<td>72.64 (17.65)</td>
<td>0.188</td>
</tr>
<tr>
<td>BMI ≥30 (n)</td>
<td>6</td>
<td>2</td>
<td>0.193</td>
</tr>
<tr>
<td><strong>Diabetes Descriptors</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HbA1c (%)</td>
<td>7.67 (1.20)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>HbA1c &gt;8% (n)</td>
<td>3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Diabetes duration (years)</td>
<td>12.96 (5.15)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Executive Function</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TMT-B (s)</td>
<td>87.31 (37.67)</td>
<td>83.81 (33.58)</td>
<td>0.812</td>
</tr>
<tr>
<td><strong>Balance Confidence and Falls</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ABC-6 (total score)</td>
<td>72.08 (7.07)</td>
<td>91.11 (9.09)</td>
<td>0.007*</td>
</tr>
<tr>
<td>Falls (# of fallers)</td>
<td>3</td>
<td>2</td>
<td>0.500</td>
</tr>
</tbody>
</table>

**Note:** Data represented are means (SD) unless described otherwise. DM: diabetes mellitus. BMI: body mass index, HbA1c: Glycated hemoglobin, TMT-B: Trial Making Test Part B, ABC-6: Activities-Specific Confidence Scale. *P≤0.05.
Participants were instrumented with 8-infrared emitting diodes (IREDs) on the midline of the occiput (IRED-1), left ear (IRED-2), right ear (IRED-3), left acromion process (IRED-4), seventh cervical vertebra (IRED-5), right acromion process (IRED-6), twelfth thoracic vertebra (IRED-7), and second sacral vertebra (IRED-8). Each IRED was secured on a Styrofoam block adhered to each anatomical landmark with 3M medical tape. Participants wore a tight fitted toque to attach Styrofoam blocks to the head.
This figure depicts the experimental setup of the 6-meter walking path including the position and orientation of the Optotrac 3020 camera bank. All kinematic outcome measures were calculated during steady state walking (2-4 meters).
Walking speed (m/s) between-groups while walking in the self-selected comfortable or fastest speed condition with serial subtraction by 3’s (SS3) or no additional cognitive challenge (no-SS3). DM-group walked marginally slower than noDM-group (p=0.078). In both groups, walking speed reduced almost twice as much with SS3 in the fastest speed than the self-selected comfortable speed condition (p<0.001). Data are displayed as means and standard error. *p<0.05. **p<0.001.
Head roll peak-to-peak angular displacement (HRp-p; Figure 5.3-a) and velocity (HRvel; Figure 5.3-b) between-groups in the self-selected comfortable or fastest speed condition with serial subtraction by 3’s (SS3) or no additional cognitive challenge (no-SS3). In both groups, HRp-p increased with SS3, regardless of the speed condition (p=0.002) and HRvel increased in the fastest speed condition, regardless of SS3 (p<0.001). Data are displayed as means and standard error. *p<0.05. **p<0.001.
Figure 5.4.
Trunk control between-groups in 4 experimental conditions

Trunk roll peak-to-peak angular displacement (TRp-p; Figure 5.4-a) and velocity (TRvel; Figure 5.4-b) between-groups in the self-selected comfortable or fastest speed condition with serial subtraction by 3’s (SS3) or no additional cognitive challenge (no-SS3). In both groups, TRp-p significantly increased with S33 only at the self-selected comfortable (p=0.003) whereas TRvel significantly reduced with SS3 only at the fastest speed condition (p<0.001). Overall TRvel was lower in DM-group than noDM-group (p=0.046). Data are displayed as means and standard error. *p<0.05. **p<0.001.
Head-trunk correlation (H-Tcorr) between 2-4 meters of the walking path during the self-selected comfortable speed condition with no additional cognitive challenge (no-SS3: noDM-group Figure 5.5-a; DM-group Figure 5.5-b) or with serial subtraction by 3’s (SS3: noDM-group Figure 5.5-c; DM-group Figure 5.5-d). Higher overall H-Tcorr were observed in DM-group than noDM-group, regardless of SS3 or speed condition (p=0.009). Representative graphs during the fastest speed condition showed similar trends (data not shown).
CHAPTER 6: GENERAL DISCUSSION

Fear of falling (FoF) has been reported to be the most frequent fear among older adults (1) and potentially more debilitating than a fall itself (2). Traditional conceptualizations indicate that FoF can lead to a vicious cycle of reduced balance confidence, self-imposed activity restriction, deconditioning, postural instability, and social isolation which can expedite the pathway to disability (2,3). Consequently, FoF and balance confidence have been identified as key components within geriatric rehabilitation programs to improve overall health and prevent falls in older adults.

Diabetes mellitus (DM) is a chronic metabolic condition that is highly prevalent in older adults (age ≥65 years) (4). Several determinants of FoF and low balance confidence overlap with the consequences/complications of DM. Therefore, the cumulative effect of these DM-related consequences may contribute to higher FoF severity and lower balance confidence in older adults with DM when compared to those without DM. Additionally, falls-related psychological concerns can have differential effects on different populations due to the complex interaction between pathology, FoF and balance confidence (5–7). Therefore, if protocols for screening and intervention recommendations for patient education and targeted rehabilitation programs are to be developed for older adults with DM, it is first critical to understand the current state of knowledge, severity, determinants, assessments, and potential influence of falls-related psychological concerns in older adults with DM.

Three studies in this thesis were designed to advance our knowledge of falls-related psychological concerns of FoF and balance confidence in older adults with DM. Specifically, the purpose of this thesis was two-fold: (1) to examine the prevalence,
severity and determinants of FoF in older adults with DM, and (2) to evaluate the validity of the *short version of the Activities-specific Balance Confidence Scale* (ABC-6) and its association with balance and postural control in older adults with DM. The results of these studies provide converging evidence that older adults with DM have higher FoF severity and lower balance confidence when compared to those without DM (Studies I-III). Higher FoF severity and lower balance confidence in this population were significantly associated with worse physical function as well as clinical depressive symptoms (Studies I & II). Furthermore, low balance confidence in older adults with DM may contribute to the dependence on postural control strategies while walking that are usually only utilized in high-risk situations (Study III). Collectively, these studies highlight the need for the development of protocols for screening and intervention recommendations including patient education and targeted rehabilitation programs to address falls-related psychological concerns in older adults with DM. This chapter will provide a detailed discussion of the major findings presented in this thesis as well as clinical implications and direction for future studies.

6.1. Discussion of Major Findings

The FES-I and ABC-6 were advantageous over traditional FoF and balance confidence assessments in older adults with DM

FoF has been primarily assessed with a single dichotomous question enquiring about prevalence in older adults with DM (8–14). To our knowledge, Study I is the first study to examine FoF severity on the *Falls-Efficacy Scale International* (FES-I) between older adults with and without DM. Our results indicated that despite similar FoF
prevalence between-groups, the distribution of older adults with DM (i.e., 8.8% fewer in the low and 8.4% more in the high concern of falling FES-I categories; Figure 3.1) was significantly different than older adults without DM. Therefore, the use of overall FoF prevalence may be misleading and FES-I categorization is advantageous for clinicians to identify those with high concerns about falling.

Furthermore, the significantly higher proportion of older adults with DM who were classified with high concerns of falling on the FES-I is of clinical importance. High concerns of falling may lead to excessive activity restriction, physical deconditioning, loss of independence and reduced quality of life (15,16) whereas low concerns of falling often reflect appropriate cautious behaviour during challenging balance activities (e.g., walking on a slippery surface [FES-I item-11]). Although Study I documented the strongest determinant of higher FoF severity to be poor physical performance, it is currently unknown if the relationship between higher FoF severity and poor physical performance is attributed to physical deconditioning as a result of excessive activity restriction. Therefore, future research is warranted to explore the relationship between FoF severity, activity restriction and physical deconditioning in older adults with DM.

To our knowledge, balance confidence has only been assessed with the original Activities-specific Balance Confidence Scale (ABC-16) in older adults with DM (17,18). Study II was the first to document the discriminant validity of the shortened version (ABC-6), with its narrower continuum of activity difficulty, to be more sensitive to detect subtle differences in balance confidence between older adults with and without DM (without diagnosed DPN) when compared to the ABC-16 (Figure 4.2). These findings were consistent with Schepens et al. (19) who documented that the ABC-6 was able to
detect subtle differences in balance confidence between older adults who were fallers and non-fallers that were undetected by the ABC-16. In addition to its increased sensitivity, the ABC-6 is advantageous in busy clinical and research settings as it can be administered in less time than the ABC-16. Study II also revealed novel evidence that the increased sensitivity of the ABC-6 was primarily driven by item-6 (i.e., standing on a chair and reaching for something above your head) which was the only item on either ABC scale to independently discriminate balance confidence between older adults with DM (without diagnosed DPN) and those without DM. Therefore, this single item may be advantageous for rapid screening of balance confidence in older adults with DM even prior to diagnosed DPN. Although a cut-off score of <67% has been used to identify older adults who are at risk of falling with the ABC-16 (20), to date no studies have determined a cut-off score for the ABC-6. Therefore, future studies are warranted to determine a cut-off score for balance confidence on the ABC-6 in older adults with DM.

_The largest significant group-differences in FoF severity and balance confidence were activities that involved “reaching for something above your head”_

Of the limited evidence available, FoF prevalence has been reported to be significantly higher in older adults with DM than those without DM (13,14) and progressively higher with DM-related complications (noDM-group: 5%; DPN-group: 20%; DPN-Pain-group: 64%) (12). However, Studies I and II were the first to provide robust evidence of higher FoF severity in older adults with DM compared to those without DM (Figure 3.1) and progressively lower balance confidence in those with DM-related complications (DPN<DM<noDM; Figure 4.2). In both studies the largest significant group-differences in FoF severity and balance confidence were identified with
the common theme of reaching for something above your head (i.e., *reaching for something above your head or on the ground* (FES-I item-9: Study I); *stand on a chair and reach for something* (ABC-16 item-6: Study II). Interestingly, in Study II balance confidence to *stand on your tiptoes and reach for something above your head* [ABC-16 item-5], which is also included in the ABC-6 as one of the most challenging activities, was not found to be significantly different between older adults with and without DM without diagnosed DPN. However, it is possible participants may have rated their balance confidence differently when presented with two reaching tasks of increased postural threat on the ABC-16 (i.e., to stand on their tiptoes at ground level vs. the increased height of a chair; Study II) whereas in the FES-I only one reaching task was assessed (Study I). Overall Studies I and II provide converging novel evidence that reaching tasks in older adults with DM are of higher FoF severity and lower balance confidence when compared to those without DM.

Consistent with the literature (21), Study II provided supporting evidence that half of older adults with DM were identified with possible vestibular dysfunction due to the inability to maintain balance while standing on a compliant surface with their eyes closed during the *modified Clinical Test of Sensory Integration and Balance* (mCTSIB, condition 4). Vestibular dysfunction can disrupt the ability to rapidly relay information about the head's position and orientation in space which is crucial to maintain gaze stabilization and overall balance (22). Consequently, vestibular dysfunction in older adults with DM may contribute to postural instability during rapid head movements while reaching as well as high FoF severity and low balance confidence. Therefore, older adults with DM may benefit from vestibular rehabilitation to enhance gaze stability and/or learn
compensatory strategies to enhance postural stability. Vestibular rehabilitation techniques to enhance gaze stability may include repeated periods of induced retinal slips to increase vestibular adaptation of the vestibulo-ocular reflex (VOR) at varied amplitudes and during horizontal (yaw) and vertical (pitch) head movements (23). Whereas compensatory strategies to enhance postural stability may include substitution with visual or somatosensory cues in the absence of diabetic retinopathy or DPN, respectively. However, future research is warranted to examine the relationship between vestibular dysfunction and falls-related psychological concerns during reaching tasks in older adults with DM.

Both physical and psychological measures were significantly associated with higher FoF severity and low balance confidence in older adults with DM

FoF has been primarily attributed to poor physical performance, particularly, mobility and balance impairments in older adults with DM (10–13). However, several other determinants for developing falls-related psychological concerns overlap with the consequences/complications of DM. Therefore, Study I was designed to identify which FoF determinants contribute to higher FoF severity in older adults with DM. The results of Study I supported our hypothesis that FoF determinants of higher FoF severity occurred in more than just the physical domain (i.e., poor physical performance, being female, fall history and clinical depressive symptoms: Please see discussion of Chapter 3). Likewise, Study II provided novel evidence that balance confidence was significantly correlated with both physical and psychological measures (i.e., physical activity level, balance, mobility and depressive symptoms: Please see discussion of Chapter 4) in older adults with DM.
Beyond the physical domain, Studies I and II provided novel evidence that higher FoF severity and lower balance confidence in older adults with DM were associated with increased depressive symptoms. Specifically, results from Study I indicated older adults with DM with clinical depressive symptoms (CES-D>16) were 1.48-times more likely to have moderate-to-high FoF than no-low FoF, and 78% with clinical depressive symptoms were classified with moderate-to-high FoF. Similarly, Study II indicated increased depressive symptoms (CES-D total score) were moderately correlated with lower balance confidence in older adults with DM with and without DPN. As well participants classified with clinical depressive symptoms (CES-D>16) were found to be 3 of the 4 participants with the lowest balance confidence in their group (Figure 4.1). Furthermore, a post hoc analysis of Study III revealed that one participant in the DM-group had clinical depressive symptoms (CES-D>16) and also had the lowest balance confidence overall. This link between falls-related psychological concerns and depression was also recently enforced by Moreira et al. (24) who reported older women with DM who had higher FoF severity (FES-I total score ≥23) had more depressive symptoms when compared to those with lower FoF severity (FES-I total score <23).

Collectively, these findings highlight the need for the development of screening protocols and intervention recommendations to address falls-related psychological concerns within and beyond the physical domain in older adults with DM. Furthermore, although the consequences of depression on falls-related psychological concerns are often described temporally (cause-and-effect), it is likely that these relationships are reciprocal, such that higher FoF severity and low balance confidence may also simultaneously increase depressive symptoms. Therefore, it is possible that the higher prevalence of
clinical depression (11%) in older adults with DM, when compared to the general population (5%), may be partially attributed to falls-related psychological concerns in older adults with DM.

**Low balance confidence may contribute to the dependence on postural control strategies normally only utilized in high-risk situations in older adults with DM**

The presence of FoF and/or low balance confidence can result in the misappraisal of risk, anticipatory anxiety, and ultimately, the dependence on postural control strategies that are normally only utilized in high-risk situations (25). Despite the high prevalence of FoF and low balance confidence in older adults with DM, limited studies have investigated its association with balance and postural control in older adults with DM. Study III was the first to provide evidence that higher head-trunk correlations (i.e., the correlation coefficient between head and trunk roll peak-to-peak angular displacements) in older adults with DM without DPN may reflect a potential need for head-trunk stiffening to simplify postural control and was partially explained by balance confidence.

The possible mechanism behind this generalized postural control strategy of head-trunk stiffening, regardless of the experimental condition, may be attributed to an over activation of the amygdala-driven fear response for longer than necessary or when not needed (25). The amygdalae are two-almond shaped groups of nuclei located in the temporal lobes of the brain responsible for the expression of anxiety and fear-related responses that receive information from the thalamus and sensory cortices (26). These anxiety and fear-related responses may include motor, physiological and/or endocrine alternations (26). In animal models, fear has been associated with motor freezing as well as autonomic responses of increased heart rate, blood pressure or respiration (27). In
humans, Murphy and Issacs (28) first published their observations of “post-fall syndrome” in that severe anxiety and fear can lead to changes in motor behaviour that affected their ability to stand and walk unsupported. Since then several researchers have documented the association between fear (or confidence) and changes in motor behaviour especially under conditions of postural threat (e.g., walking at increase heights, on a slippery surface or while performing secondary tasks) (29–32).

Study III was the first to link low balance confidence to the generalized postural control strategy of head-trunk stiffening in older adults with DM, even in the absence of DPN, while walking in a safe and predictable lab environment. Therefore, it is possible that persistent levels of low balance confidence may have led to the over activation of the amygdala-driven fear response, and consequently the execution of a strategy that is normally only utilized in high-risk situations. However, the execution of this generalized postural control strategy did not appear to be detrimental for overall task completion (i.e., all participants safely walked the 6-meter path, and had similar performance on the secondary task of serial subtraction by 3’s; Study III). Future work is warranted to extend the findings of this thesis to explore the influence of balance confidence on postural control during higher mobility challenges (i.e., stair negotiation; sit-to-stand) as well as in older adults with DPN.

6.2. Clinical Implications

The convergent results of this thesis indicate higher FoF severity and lower balance confidence in older adults with DM than those without DM (Studies I-III). High concerns about falling and low balance confidence are significant health concerns in
some people as they can lead to excessive activity restriction, deconditioning, postural instability, and social isolation which can expedite the pathway to disability (2,3). Accordingly, a key application of these thesis findings is the development of protocols for screening and intervention recommendations including patient education and targeted rehabilitation for falls-related psychological concerns for older adults with DM.

6.2.1. Protocols for Screening

It is known DM complications/consequences are not homogeneous across older adults with DM, therefore an individualized approach to protocols for screening of falls-related psychological concerns may be necessary. Study I suggests that screening for physical function, women, fall history and those with clinical depressive symptoms, and tailored interventions may help to reduce FoF severity in older adults with DM. Whereas Study II provided evidence that worse physical function (balance; mobility; physical activity level) and depressive symptoms were significantly correlated with lower balance confidence in older adults with DM. Therefore, based on the findings of this thesis, if an older adult with DM presents with declines in physical function, history of a fall or clinical depressive symptoms it is recommended that he/she be screened for falls-related psychological concerns.

There are several clinical assessments available to quantify falls-related psychological concerns. However, Studies I and II provided novel evidence that the FES-I and ABC-6 are advantageous over traditional FoF (single dichotomous FoF question) and balance confidence (ABC-16) assessments in older adults with DM. As well Study II provided evidence of the validity of the ABC-6 which may provide a means for early detection of balance and mobility-related declines in older adults with DM even in the
absence of DPN. Therefore, it is recommended that healthcare professionals utilize falls-related psychological concerns clinical assessments that measure FoF severity (FES-I) or balance confidence during challenging activities (ABC-6) for older adults with DM.

As indicated above, this thesis provides novel recommendations of when screening protocols should be implemented (Study I) and which assessment tools (Studies I-II) are appropriate for use in older adults with DM. However, development of protocols for screening and intervention recommendations requires further research to disentangle the complex relationship between pathology, FoF, balance confidence and physiological fall-risk. Drawing from the aging literature, Delbaere, Close, Brodaty and Lord (16) documented disparities between perceived and physiological risk of falling in older adults, and categorized participants in four categories: vigorous (low perceived and low physiological fall-risk), anxious (high perceived and low physiological fall-risk), stoic (low perceived and high physiological fall-risk), and aware (low perceived and low physiological fall-risk) (16). These categories may help identify which patients require physical and/or psychological interventions. For example, an older adult who is categorized as “anxious” may benefit from psychological interventions to build confidence. In contrast, an older adult who is categorized as “stoic” may have false confidence in their abilities and benefit from both psychological and physical interventions. Future research is warranted to determine the effectiveness of interventions within each category for older adults with DM.

6.2.2. Patient Education and Targeted Rehabilitation Programs

Allied healthcare professionals (physical and occupational therapists) are trained in detailed assessment and intervention of falls-related psychological concerns. Given the
Determinants of falls-related psychological concerns are multifactorial, an individualized approach to intervention is recommended for older adults with DM. Components for interventions may include a combination of patient education, physical conditioning, environmental modifications and/or cognitive behaviour therapy (CBT).

For example, drawing from the aging literature, Brouwer et al. (33) reported that both education and exercise programs were beneficial to improve balance confidence in older adults. The educational program involved participants to engage in discussions about their falls-related concerns (e.g., identifying risk factors, environmental hazards at home and in the community, footwear, etc.) whereas the activity program involved walking, stretching and low-resistance exercises. Additionally, assertiveness training and risk-taking behaviour may be beneficial to teach older adults with DM not to be afraid to ask for assistance in situations when they are fearful. Specifically, Walker and Howland (34) reported that older adults who talked about their fears had less activity restriction and remained active when compared to those who did not. Furthermore, CBT may be beneficial for older adults with DM to help break the vicious cycle of FoF, instill confidence, and provide gradual exposure to feared activities (e.g. reaching for something above your head). However, Finch et al (35) documented that the effectiveness of CBT as an intervention for FoF is dependent on an individualized approach with an in-depth understanding of the diverse experiences, motivations and perspectives of an individual’s fear. Overall, standardized physical and occupational therapy falls prevention programs address most of these factors and can be easily integrated into the management of falls-related psychological concerns in older adults with DM.
6.3. Conclusions

To summarize, very few studies have examined falls-related psychological concerns in older adults with DM. The investigations outlined in this thesis have provided insight into FoF, balance confidence and its association with balance and postural control in older adults with DM. Specifically, this thesis provided novel evidence of higher FoF severity and lower balance confidence in older adults with DM than those without DM. As well higher FoF severity and low balance confidence in this population were found to be significantly associated with worse physical function and clinical depressive symptoms, and low balance confidence partially explained group-differences in the execution of a generalized postural control strategy of head-trunk stiffening. Overall, findings from this thesis highlight the need for the development of protocols for screening and intervention recommendations, such as patient education and targeted rehabilitation programs, for older adults with DM.
6.4. References


9. van Sloten TT, Savelberg H, Duimel-Peeters IG, Meijer K, Henry RM, Stehouwer C DA, et al. Peripheral neuropathy, decreased muscle strength and obesity are


13. Bruce D, Hunter M, Peters K, Davis T, Davis W. Fear of falling is common in patients with type 2 diabetes and is associated with increased risk of falls. Age Ageing. 2015;687–90.


APPENDIX A: ETHICS APPROVALS

A.1. STUDY I
A.2. STUDY II
A.3. STUDY III
Comité d'éthique de la recherche
Edifice Cooper
3981, boulevard St-Laurent, Montréal
Montréal (Québec) H2W 1Y5

Le 9 juin 2011

Drs Maria-Victoria Zunzunegui
Département médecine sociale et préventive

a/s Drs Catherine Lord
Hôpital-Dieu du CHUM
Unité de Santé Internationale

courriel: catherine.lord@chum.qc.ca

Objet: 10.277 – Approbation FINALE CÉR

Differences de genre en mobilité: que pouvons nous apprendre sur comment améliorer la mobilité au cours du vieillissement.

Chère Doyenne,


À la lecture de tous les documents reçus, le tout est jugé satisfaisant. Je vous retourne sous pli une copie du formulaire portant l'estampille d'approbation du comité. Seul ce formulaire devra être utilisé pour signature par les sujets.

Le présent constitue l'approbation finale, valide pour un an à compter du 16 mars 2011, date de l'approbation initiale. Je vous rappelle que toute modification du protocole et/ou du formulaire de consentement en cours d'étude, doit être soumise pour approbation du comité d'éthique.

Cette approbation suppose que vous vous engagez:

1. à respecter la présente décision;
2. à respecter les moyens de suivi continu (cf Statuts et Règlements)
3. à conserver les dossiers de recherche pendant la période requise par les textes réglementaires, suivant le fin du projet, afin permettre leur éventuelle vérification par une instance déléguée par le comité;
4. à respecter les modalités arrêtées au regard du mécanisme d'identification des sujets de recherche dans l’établissement.

Le comité suit les règles de constitution et de fonctionnement de l’Énoncé de Politique des trois Conseils et des Bonnes pratiques cliniques de la CIH.

Pour toute question relative à cette correspondance, veuillez communiquer avec la soussignée à l’adresse courriel suivante : marie.josee.bernard.chum@ssss.gouv.qc.ca, ou avec sa collaboratrice, par téléphone ou courriel : lynda.ferlatte.chum@ssss.gouv.qc.ca – 514 890-8000 poste 14030.

Vous souhaitant la meilleure des chances dans la poursuite de vos travaux, je vous prie d’accepter, Cher Docteur, mes salutations distinguées.

[Signature]

Me Marie-Josée Bernardi, avocate
Vice-présidente
Comité d’éthique de la recherche du CHUM

MJB/lf

P. j. Formulaire de consentement français approuvé et estampillé

Cc : Par numérisation au Bureau des contrats
Centre de recherche
Hôtel-Dieu du CHUM – Pavillon Masson
ANNEX A.1.
ETHICS APPROVAL: STUDY I

QUEEN'S UNIVERSITY HEALTH SCIENCES AND AFFILIATED TEACHING HOSPITALS
ANNUAL RENEWAL

Queen's University, in accordance with the "Tri-Council Policy Statement, 1998" prepared by the Medical Research Council, Natural Sciences and Engineering Research Council of Canada and Social Sciences and Humanities Research Council of Canada requires that research projects involving human subjects be reviewed annually to determine their acceptability on ethical grounds.

A Research Ethics Board composed of:

- Dr. A.F. Clark, Emeritus Professor, Department of Biochemistry, Faculty of Health Sciences, Queen's University (Chair)
- Dr. H. Abdollahi, Professor, Department of Medicine, Queen's University
- Dr. R. Brison, Professor, Department of Emergency Medicine, Queen's University
- Dr. M. Evans, Community Member
- Dr. S. Horgan, Manager, Program Evaluation & Health Services Development, Geriatric Psychiatry Service, Providence Care, Mental Health Services Assistant Professor, Department of Psychiatry
- Ms. J. Hudatin, Community Member
- Ms. P. Newman, Pharmacist, Clinical Care Specialist and Clinical Lead, Quality and Safety, Pharmacy Services, Kingston General Hospital
- Dr. W. Racz, Emeritus Professor, Department of Pharmacology & Toxicology, Queen's University
- Ms. S. Rohland, Privacy Officer, ICES, Queen's Health Services Research Facility, Research Associate, Division of Cancer Care and Epidemiology, Queen's Cancer Research Institute
- Dr. B. Simchison, Assistant Professor, Department of Anaesthesiology and Perioperative Medicine, Queen's University
- Dr. A.N. Singh, WHO Professor in Psychosomatic Medicine and Psychopharmacology Professor of Psychiatry and Pharmacology Chair and Head, Division of Psychopharmacology, Queen's University Director & Chief of Psychiatry, Academic Unit, Quinte Health Care, Belleville General Hospital
- Dr. E. Tsai, Associate Professor, Department of Paediatrics and Office of Bioethics, Queen's University
- Dr. E. VanDenKerkhof, Professor, School of Nursing and Department of Anaesthesiology and Perioperative Medicine, Queen's University

has reviewed the request for renewal of Research Ethics Board approval for the project Gender differences in mobility: What we can learn to improve mobility in old age, as proposed by Dr. B. Alvarado Llano of the Department of Community Health and Epidemiology, at Queen's University. The approval is renewed for one year, effective April 06, 2012. If there are any further amendments or changes to the protocol affecting the participants in this study, it is the responsibility of the principal investigator to notify the Research Ethics Board. Any unexpected serious adverse event occurring locally must be reported within 2 working days or earlier if required by the study sponsor. All other adverse events must be reported within 15 days after becoming aware of the information.

Chair, Research Ethics Board

Renewal 1[X] Renewal 2 [ ] Extension [ ] Code# EPID-340-11 Romeo file# 8905862

Date: March 14, 2012

Chair, Research Ethics Board
QUEEN’S UNIVERSITY HEALTH SCIENCES & AFFILIATED TEACHING HOSPITALS
RESEARCH ETHICS BOARD (HSREB)

HSREB Renewal of Ethics Clearance

September 09, 2015

Dr. Nandini Deshpande
School of Rehabilitation Therapy
Louise D. Acton Building

ROMEO/TRAQ: #6095146
Department Code: REH-477-10
Study Title: Does Diabetes Mellitus-Induced Vestibular System Dysfunction Contribute to Higher Prevalence of Balance and Mobility Impairment in Diabetic Elderly? - A Pilot Study
Review Type: Delegated
Date Ethics Clearance Effective: September 7, 2015
Ethics Clearance Expiry Date: September 7, 2016

Dear Dr. Deshpande,

The Queen's University Health Sciences & Affiliated Teaching Hospitals Research Ethics Board (HSREB) has reviewed the application. This study, including all currently approved documentation, has been granted ethical clearance until the expiry date noted above.

Prior to the expiration of your ethics clearance, you will be reminded to submit your renewal report through ROMEO. Any lapses in ethical clearance will be documented below.

Lapse in Ethics Clearance:
August 11, 2015 – September 6, 2015

Yours sincerely,

[Signature]
Chair, Health Sciences Research Ethics Board

The HSREB operates in compliance with, and is constituted in accordance with, the requirements of the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2); the International Conference on Harmonization Good Clinical Practice Consolidated Guideline (ICH GCP); Part C, Division 5 of the Food and Drug Regulations; Part 4 of the Natural Health Products Regulations; Part 3 of the Medical Devices Regulations; Canadian General Standards Board, and the provisions of the Ontario Personal Health Information Protection Act (PHIPA 2004) and its applicable regulations. The HSREB is qualified through the CTOR Qualification Program and is registered with the U.S. Department of Health and Human Services (HHS) Office for Human Research Protection (OHRP). Federalwide Assurance Number: FWA#: 00004184, IRB#: 00001173
APPENDIX A.3.
ETHICS APPROVAL: STUDY III

QUEEN'S UNIVERSITY HEALTH SCIENCES & AFFILIATED TEACHING HOSPITALS RESEARCH ETHICS BOARD-DELEGATED REVIEW
July 12, 2012

Dr. Nandini Deshpande
School of Rehabilitation Therapy
Louise D. Acton Building
Queen’s University

Dear Dr. Deshpande

Study Title: REH-527-12 Understanding postural control of older persons with diabetes mellitus: effects of task, time constraints and cognitive loading
File # 6007096

I am writing to acknowledge receipt of your recent ethics submission. We have examined the protocol, budget, newspaper advertisement and information/consent form for your project (as stated above) and consider it to be ethically acceptable. This approval is valid for one year from the date of the Chair’s signature below. This approval will be reported to the Research Ethics Board. Please attend carefully to the following listing of ethics requirements: you must fulfill over the course of your study:

Reporting of Amendments: If there are any changes to your study (e.g. consent, protocol, study procedures, etc.), you must submit an amendment to the Research Ethics Board for approval. Please use event form: HSREC Multi-Use Amendment/Full Board Renewal Form associated with your post review file # 6007096 in your Researcher Portal (http://services.queenu.ca/researcher/)

Reporting of Serious Adverse Events: Any unexpected serious adverse event occurring locally must be reported within 2 working days or earlier if required by the study sponsor. All other serious adverse events must be reported within 15 days after becoming aware of the information. Serious Adverse Event forms are located with your post-review file 6007096 in your Researcher Portal (https://services.queenu.ca/researcher/)

Reporting of Complaints: Any complaints made by participants or persons acting on behalf of participants must be reported to the Research Ethics Board within 7 days of becoming aware of the complaint. Note: All documents supplied to participants must have the contact information for the Research Ethics Board.

Annual Renewal: Prior to the expiration of your approval (which is one year from the date of the Chair’s signature below), you will be reminded to submit your renewal form along with any new changes or amendments you wish to make to your study. If there have been no major changes to your protocol, your approval may be renewed for another year.

Yours sincerely,

[Signature]
Chair, Research Ethics Board
July 12, 2012

Investigators please note that if your trial is registered by the sponsor, you must take responsibility to ensure that the registration information is accurate and complete.
APPENDIX B:
PRIMARY STUDY DESIGNS AND SAMPLE SIZES

B.1. STUDIES I-III
APPENDIX B.1.
PRIMARY STUDY DESIGNS AND SAMPLE SIZES

Study I

Title: Gender differences in mobility: What can we do to improve mobility in old age?

Principle Investigator: Dr. Maria Victoria Zununegui, Université de Montréal

Funding: Canadian Institutes of Health Research

Study Design and Purpose: Study I conducted a cross-sectional secondary data analysis of baseline data (2012) from the International Mobility in Aging Study (IMIAS), an ongoing longitudinal population-based study of aging and mobility. The primary purpose of IMIAS is to better understand how to prevent or slow down the loss of mobility in older adults (aged 65-75). The primary objectives of IMIAS are to: (i) examine how lifetime experiences of isolation, violence, wealth and chronic disease can influence physical strength and mobility for older adults aged 65-74, and (ii) identify potential sex differences between men and women.

Sample Size: Study I used the Canadian IMIAS sample of 799 community-dwelling older adults (aged 65-74) from Kingston, Ontario (n=398) and Saint-Hyacinthe, Quebec (n=401). However, the larger IMIAS sample includes a total of 1995 older adults were recruited in five sites: Kingston (Ontario, Canada) and Saint-Hyacinthe (Quebec, Canada), Tirana (Albania), Natal (Brazil), and Manizales (Colombia). The sample size was calculated to achieve baseline mobility disability with a prevalence ratio of 1.8, alpha
of 0.05, power of 0.80. Furthermore, the sample was satisfied by sex with the aim to recruit 200 men and 200 women at each site.

**Study II**

**Title:** Does diabetes-induced vestibular system dysfunction contribute to higher prevalence of mobility and balance impairment in diabetic elderly – a pilot study

**Principle Investigator:** Dr. Nandini Deshpande, Queen’s University

**Funding:** Canadian Institutes of Health Research

**Study Design and Purpose:** Study II conducted a cross-sectional analysis secondary data analyses to examine the validity of the *short version of the Activities-specific Balance Confidence Scale* (ABC-6) as a measure of balance confidence in older adults with DM with and without diagnosed DPN. Whereas the primary purpose of the larger study was to: (i) understand whether diabetes-induced deficits in vestibular system function can explain higher prevalence of impaired balance and functional mobility reported in older adults with diabetes, and (ii) to examine whether the status of vestibular system function is correlated with glycemic control in older adults with diabetes.

**Sample Size:** The sample size for the larger study was determined based on findings from Darlington et al. (1) and Nicholson et al. (2) who detected significant differences between older adults with and without diabetes in balance and vestibulo-ocular reflex parameters (velocity), respectively. However, information about the exact values of the means and standard deviations for calculating potential sample size were unavailable. Consequently, comparable sample size (n=20) with a 20% attrition rate was sought for
each group in the larger study for a total of 72 participants. In this study 10 participants were identified with diagnosed diabetic peripheral neuropathy.

Study II was designed to include three study-groups: older adults without diabetes (noDM-group), older adults with diabetes (DM-group) and older adults with diabetes and diagnosed peripheral neuropathy (DPN-group). A sample size calculation was conducted with the program $G^*Power$ (3) was used to determine a sufficient sample size with an alpha of 0.05, power of 0.80. Based on these assumptions and previous studies in individuals who experienced a stroke (ABC-6 and TUG, $r=-0.52$, $p<0.05$) (4) and community-dwelling older adults (ABC-16 and Functional Gait Assessment, $r=0.53$, $p<0.001$) (5) the desired sample size per group was calculated as 9 in both of these calculations. Therefore, 10 older adults were concluded as sufficient in each group for this secondary data analysis (N=30). Participants were age- and sex-matched to the 10 participants identified with diabetic peripheral neuropathy.

Study III

Title: Does diabetes-induced vestibular system dysfunction contribute to higher prevalence of mobility and balance impairment in diabetic elderly – a pilot study

Principle Investigator: Dr. Nandini Deshpande, Queen’s University

Funding: Senate Advisory Research Committee

Study Design and Purpose: Study III conducted a cross-sectional analysis of kinematic walking data (Optrotak motion capture), balance confidence, sensorimotor and cognitive assessments. The primary purpose of the larger study was to: (i) identify the effects of diabetes on balance during three mobility tasks: walking, sit to stand and stair
negotiation, and (ii) understand the impact of additional cognitive loading and time constraint on the stability of performance of these tasks.

**Sample Size:** Gait analyses of older adults with diabetes have been documented to be as few as 20 participants per group to demonstrate significant differences (6). However, no studies could be cited that have investigated axial segmental postural control during challenging conditions, which may increase the effect size and power to detect differences, in older adults with DM. Therefore, drawing from the aging literature, a sample size calculation of axial segmental control was conducted with the program G*Power (3) to determine a sufficient sample size with an alpha of 0.05 and power of 0.80. Based on these assumptions and trunk control between young and older adults (trunk roll average, Cohen’s d = 1.70) (7) the desired sample size per group was calculated as 10 per group. Consequently, a sample size (n=10) with a 20% attrition rate was sought for each group for a total of 24 participants for this pilot study.
References


APPENDIX C:
FOF AND BALANCE CONFIDENCE QUESTIONNAIRES

C.1. Falls-Efficacy Scale International
(FES-I: Yarley et al., 2005)

C.2. Activities-specific Balance Confidence Scales
(ABC-16: Powell & Myer, 1995; ABC-6 (Peretz et al. 2006)
Now we would like to ask some questions about how concerned you are about the possibility of falling. Please reply thinking about how you usually do the activity. If you currently don’t do the activity (e.g. if someone shops for you), please answer to show whether you think you would be concerned about falling IF you did the activity. For each of the following activities, please tick the box which is closest to your own opinion to show how concerned you are that you might fall if you did this activity.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Not at all concerned</th>
<th>Somewhat concerned</th>
<th>Fairly concerned</th>
<th>Very concerned</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Cleaning the house (e.g. sweep, vacuum or dust)</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>2 Getting dressed or undressed</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>3 Preparing simple meals</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>4 Taking a bath or shower</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>5 Going to the shop</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>6 Getting in or out of a chair</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>7 Going up or down stairs</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>8 Walking around in the neighborhood</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>9 Reaching for something above your head or on the ground</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>10 Going to answer the telephone before it stops ringing</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>11 Walking on a slippery surface (e.g. wet or icy)</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>12 Visiting a friend or relative</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>13 Walking in a place with crowds</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>14 Walking on an uneven surface (e.g. rocky ground, poorly maintained pavement)</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>15 Walking up or down a slope</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>16 Going out to a social event (e.g. religious service, family gathering or club meeting)</td>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
</tbody>
</table>
APPENDIX C.2.

Activities-Specific Balance Confidence Scale

**ABC-16:** All 16 items (Powell & Myer, 1995)

**ABC-6:** 6-items (items 5, 6, 13-16; Peretz et al. 2006)

For each of the following, please indicate your level of confidence in doing the activity without losing your balance or becoming unsteady by choosing one of the percentage points on the scale from 0% to 100%. If you do not currently do the activity in question, try and imagine how confident you would be if you had to do the activity. If you normally use a walking aid to do the activity or hold onto someone, rate your confidence as if you were using these supports. If you have any questions about answering any of these items, please ask the administrator.

<table>
<thead>
<tr>
<th>Percentage Points</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>No confidence</td>
</tr>
<tr>
<td>10</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td></td>
</tr>
<tr>
<td>70</td>
<td></td>
</tr>
<tr>
<td>80</td>
<td></td>
</tr>
<tr>
<td>90</td>
<td></td>
</tr>
<tr>
<td>100%</td>
<td>Completely confident</td>
</tr>
</tbody>
</table>

“How confident are you that you will not lose your balance or become unsteady when you…”

1. … walk around the house? _____%
2. … walk up or down stairs? _____%
3. … bend over and pick up a slipper from the front of a closet floor? _____%
4. … reach for a small can off a shelf at eye level? _____%
5. … stand on your tip toes and reach for something above your head? _____%
6. … stand on a chair and reach for something? _____%
7. … sweep the floor? _____%
8. … walk outside the house to a car parked in the driveway? _____%
9. … get into or out of a car? _____%
10. … walk across a parking lot to the mall? _____%
11. … walk up or down a ramp? _____%
12. … walk in a crowded mall where people rapidly walk past you? _____%
13. … are bumped into by people as you walk through the mall? _____%
14. … step onto or off of an escalator while you are holding onto a railing? ____%
15. … step onto or off an escalator while holding onto parcels such that you cannot hold onto the railing? ______
16. … walk outside on icy sidewalks? _____%
APPENDIX D:
CLINICAL ASSESSMENTS IN THE PHYSICAL DOMAIN

D.1. Short Physical Performance Battery
(SPPB: Guralik et al., 1994)

D.2. Human Activity Profile
(HAP: Fix and Dauugton, 1988)

D.3. Modified Timed-up and Go
(mTUG: Deshpande, Novak and Patla, 2006)

D.4. Modified Clinical Test of Sensory Integration and Balance
(mCTSIB: Shumway-Cook & Horak, 1986)

D.5. Frailty and Injuries: Cooperative Studies of Intervention Techniques
(FICSIT-4: Rossiter-Fornoff et al., 1995)
APPENDIX D.1.
Short Physical Performance Battery
(SPPB: Guralik et al., 1994)

The SPPB includes 3 components: a hierarchical test of standing balance, a 4-meter walk, and 5-repeated chair stands. SPPB total scores range from 0-12 points.

Higher scores indicate better physical performance, and <8 is an established cut-off for poor physical performance.

**BALANCE**

*Instructions:* Demonstrate each position and ask participant try to stand 10 seconds. You may use your arms, bend your knees, or move your body to maintain your balance, but try not to move your feet. Try to hold this position until I tell you to stop.

A. Side-by-side-stand
- Held for 10 sec  ☐ 1 point
- Not held for 10 sec  ☐ 0 points
- Not attempted  ☐ 0 points
- Number of seconds held if less than 10 sec: _____. _____sec

B. Semi-Tandem Stand
- Held for 10 sec  ☐ 1 point
- Not held for 10 sec  ☐ 0 points
- Not attempted  ☐ 0 points
- Number of seconds held if less than 10 sec: _____. _____sec

C. Tandem Stand
- Held for 10 sec  ☐ 2 points
- Held for 3 to 9.99 sec  ☐ 1 point
- Held for < than 3 sec  ☐ 0 points
- Not attempted  ☐ 0 points
- Number of seconds held if less than 10 sec: _____. _____sec

**Total Balance Tests score _____________ (sum points)**
**GAIT SPEED TEST**

Instructions: Now I am going to observe how you normally walk. If you use a cane or other walking aid and you feel you need it to walk a short distance, then you may use it. Please walk along to the other end of the course at your usual speed, just as if you were walking down the street to go to the store. I’ll be timing you with a stopwatch.

If time is more than 8.70 sec: ❑ 1 point
If time is 6.21 to 8.70 sec: ❑ 2 points
If time is 4.82 to 6.20 sec: ❑ 3 points
If time is less than 4.82 sec: ❑ 4 points

Total Gait Speed score ____________ (points)

**REPEATED CHAIR STANDS**

Instructions: Please stand up straight as QUICKLY as you can five times, without stopping in between. After standing up each time, sit down and then stand up again. Keep your arms folded across your chest. I’ll be timing you with a stopwatch.

Safety Precautions: Stop if participant becomes tired or short of breath during repeated chair stands; uses his/her arms; After 1 minute, if participant has not completed rises; or at your discretion, if concerned for participant’s safety.

Scoring:
Participant unable to complete 5 chair stands or >60 sec: ❑ 0 points
If chair stand time is 16.70 sec or more: ❑ 1 points
If chair stand time is 13.70 to 16.69 sec: ❑ 2 points
If chair stand time is 11.20 to 13.69 sec: ❑ 3 points
If chair stand time is 11.19 sec or less: ❑ 4 points

Total Repeated Chair Stands score ____________ (points)

Total SPPB Score _____ / 12 (sum of all points)
## Human Activity Profile (HAP: Fix and Dauugton, 1988)

### Instructions:
- **Check Column 1 ("Still Doing This Activity") if:** You completed the activity unassisted the last time you had the need or opportunity to do so.
- **Check Column 2 ("Have Stopped Doing This Activity") if:** You have engaged in the activity in the past, but you probably would not perform the activity today even if the opportunity should arise.
- **Check Column 3 ("Never Did This Activity") if:** You have never engaged in activity.

<table>
<thead>
<tr>
<th>Still Doing This Activity</th>
<th>Stopped Doing This Activity</th>
<th>Never Did This Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Getting in and out of chairs or bed (no assistance)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Listening to the radio</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Reading books, magazines or newspapers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Writing (letters, notes)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Working at a desk or table</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Standing (for more than one minute)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Standing (for more than five minutes)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Dressing or undressing (without assistance)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Getting clothes from drawers or closets</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Getting in or out of a car (without assistance)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Dining at a restaurant</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Playing cards/table games</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. Taking a bath (no assistance needed)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. Putting on shoes, stockings or socks (no assistance needed)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. Attending a movie, play, church event or sports activity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16. Walking 30 yards (27 meters)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17. Walking 30 yards (non-stop)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18. Dressing/undressing (no rest or break needed)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19. Using public transportation or driving a car (100 miles or less)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20. Using public transportation or driving a car (99 miles or more)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>21. Cooking your own meals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>22. Washing or drying dishes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>23. Putting groceries on shelves</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24. Ironing or folding clothes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25. Dusting/polishing furniture or polishing cars</td>
<td></td>
<td></td>
</tr>
<tr>
<td>26. Showering</td>
<td></td>
<td></td>
</tr>
<tr>
<td>27. Climbing six steps</td>
<td></td>
<td></td>
</tr>
<tr>
<td>28. Climbing six steps (non-stop)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29. Climbing nine steps</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30. Climbing 12 steps</td>
<td></td>
<td></td>
</tr>
<tr>
<td>31. Walking ½ block on level ground</td>
<td></td>
<td></td>
</tr>
<tr>
<td>32. Walking ½ block on level ground (non-stop)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>33. Making a bed (not changing sheets)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>34. Cleaning windows</td>
<td></td>
<td></td>
</tr>
<tr>
<td>35. Kneeling, squatting to do light work</td>
<td></td>
<td></td>
</tr>
<tr>
<td>36. Carrying a light load of groceries</td>
<td></td>
<td></td>
</tr>
<tr>
<td>37. Climbing nine steps (non-stop)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>38. Climbing 12 steps (non-stop)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>39. Walking ½ block uphill</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40. Walking ½ block uphill (non-stop)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>41. Shopping (by yourself)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>42. Washing clothes (by yourself)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>43. Walking one block on level ground</td>
<td></td>
<td></td>
</tr>
<tr>
<td>44. Walking two blocks on level ground</td>
<td></td>
<td></td>
</tr>
<tr>
<td>45. Walking one block on level ground (non-stop)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>46. Walking two blocks on level ground (non-stop)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>47. Scrubbing (floors, walls or cars)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>48. Making beds (changing sheets)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>49. Sweeping</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50. Sweeping (five minutes non-stop)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>51.</td>
<td>Carrying a large suitcase or bowling (one line)</td>
<td></td>
</tr>
<tr>
<td>52.</td>
<td>Vacuuming carpets</td>
<td></td>
</tr>
<tr>
<td>53.</td>
<td>Vacuuming carpets (five minutes non-stop)</td>
<td></td>
</tr>
<tr>
<td>54.</td>
<td>Painting (interior/exterior)</td>
<td></td>
</tr>
<tr>
<td>55.</td>
<td>Walking six blocks on level ground</td>
<td></td>
</tr>
<tr>
<td>56.</td>
<td>Walking six blocks on level ground (non-stop)</td>
<td></td>
</tr>
<tr>
<td>57.</td>
<td>Carrying out the garbage</td>
<td></td>
</tr>
<tr>
<td>58.</td>
<td>Carrying a heavy load of groceries</td>
<td></td>
</tr>
<tr>
<td>59.</td>
<td>Climbing 24 steps</td>
<td></td>
</tr>
<tr>
<td>60.</td>
<td>Climbing 36 steps</td>
<td></td>
</tr>
<tr>
<td>61.</td>
<td>Climbing 24 steps (non-stop)</td>
<td></td>
</tr>
<tr>
<td>62.</td>
<td>Climbing 36 steps (non-stop)</td>
<td></td>
</tr>
<tr>
<td>63.</td>
<td>Walking one mile</td>
<td></td>
</tr>
<tr>
<td>64.</td>
<td>Walking one mile (non-stop)</td>
<td></td>
</tr>
<tr>
<td>65.</td>
<td>Running 110 yards (100 meters) or playing softball/baseball</td>
<td></td>
</tr>
<tr>
<td>66.</td>
<td>Dancing (social)</td>
<td></td>
</tr>
<tr>
<td>67.</td>
<td>Doing calisthenics or aerobic dancing (5 minutes non-stop)</td>
<td></td>
</tr>
<tr>
<td>68.</td>
<td>Mowing the lawn (power mower, but not a riding mower)</td>
<td></td>
</tr>
<tr>
<td>69.</td>
<td>Walking two miles</td>
<td></td>
</tr>
<tr>
<td>70.</td>
<td>Walking two miles (non-stop)</td>
<td></td>
</tr>
<tr>
<td>71.</td>
<td>Climbing 50 steps</td>
<td></td>
</tr>
<tr>
<td>72.</td>
<td>Shoveling, digging or spading</td>
<td></td>
</tr>
<tr>
<td>73.</td>
<td>Shoveling, digging or spading (five minutes non-stop)</td>
<td></td>
</tr>
<tr>
<td>74.</td>
<td>Climbing 50 steps (non-stop)</td>
<td></td>
</tr>
<tr>
<td>75.</td>
<td>Walking three miles or golfing 18 holes without a riding cart</td>
<td></td>
</tr>
<tr>
<td>76.</td>
<td>Walking three miles (non-stop)</td>
<td></td>
</tr>
<tr>
<td>77.</td>
<td>Swimming 25 yards</td>
<td></td>
</tr>
<tr>
<td>78.</td>
<td>Swimming 25 yards (non-stop)</td>
<td></td>
</tr>
<tr>
<td>79.</td>
<td>Bicycling one mile</td>
<td></td>
</tr>
<tr>
<td>80.</td>
<td>Bicycling two miles</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>81.</td>
<td>Bicycling one mile (non-stop)</td>
<td></td>
</tr>
<tr>
<td>82.</td>
<td>Bicycling two miles (non-stop)</td>
<td></td>
</tr>
<tr>
<td>83.</td>
<td>Running or jogging ¼ mile</td>
<td></td>
</tr>
<tr>
<td>84.</td>
<td>Running or jogging ½ mile</td>
<td></td>
</tr>
<tr>
<td>85.</td>
<td>Playing tennis or racquetball</td>
<td></td>
</tr>
<tr>
<td>86.</td>
<td>Playing basketball (game play)</td>
<td></td>
</tr>
<tr>
<td>87.</td>
<td>Running or jogging ¼ mile (non-stop)</td>
<td></td>
</tr>
<tr>
<td>88.</td>
<td>Running or jogging ½ mile (non-stop)</td>
<td></td>
</tr>
<tr>
<td>89.</td>
<td>Running or jogging one mile</td>
<td></td>
</tr>
<tr>
<td>90.</td>
<td>Running or jogging two miles</td>
<td></td>
</tr>
<tr>
<td>91.</td>
<td>Running or jogging three miles</td>
<td></td>
</tr>
<tr>
<td>92.</td>
<td>Running or jogging one mile in 12 minutes or less</td>
<td></td>
</tr>
<tr>
<td>93.</td>
<td>Running or jogging two miles in 20 minutes or less</td>
<td></td>
</tr>
<tr>
<td>94.</td>
<td>Running or jogging three miles in 30 minutes or less</td>
<td></td>
</tr>
</tbody>
</table>

**HAP-Activity Adjusted Score (HAP-AAS):**

[Highest Activity Still Doing] – [Total Number of Activities Stopped Doing]
APPENDIX D.3.
Modified Timed-up and Go
(mTUG: Deshpande, Novak and Patla, 2006)

Procedure:
1. Setup the large foam mat, place a blue chair on the end of the mat
2. Place blurring goggles on participant
3. Ask participant to rise from the chair (without using arms), walk a distance of 3-meters to the yellow dashed taped line, turn, walk back and sit back down in chair
4. Participant completes a practice trial and then trial 1

Safety Precautions:
- Demonstrate a “safe turn” by taking multiple small steps rather than swinging the leg to turn
- Research assistants walk on the hard surface to guard in case of fall

Recording Results:
1. With a stopwatch record the time to complete the test (start timer at “go” signal and stop when participants back is flat against the chair)
2. Record both the practice time and trial 1

Note: This picture demonstrates the experimental setup of the mTUG in the Motor Performance Lab, Queen’s University.
APPENDIX D.4.
Modified Clinical Test of Sensory Integration and Balance
(mCTSIB: Shumway-Cook & Horak, 1986)

Procedure:
1. Participants stands with arms by their side and feet together
2. The participant stands as still as possible for period of 30 seconds. Ensure that no other distractions in the lab (e.g., noise, talking) during the test
3. Conditions 1-4 are completed twice (1-4, 1-4)
   - **Condition 1:** Eyes open, firm surface
   - **Condition 2:** Eyes closed, firm surface
   - **Condition 3:** Eyes open, unstable surface (foam)
   - **Condition 4:** Eyes closed, unstable surface (foam)

Safety Precautions:
- Research assistant stands guard beside participant (not shown in photo)
- Time is stopped during a trial and recorded if:
  o the participant opens eyes during an "eyes closed" trial condition, or
  o the participant moves feet (takes a step) or requires manual assistance

Recording Results:
- Total Time standing in each condition was recorded with a stopwatch, and summed for mCTSIB total time (seconds).

Note: This picture demonstrates the experimental setup of mCTSIB condition 4 in the Motor Performance Lab, Queen's University.
APPENDIX D.5.
Frailty and Injuries: Cooperative Studies of Intervention Techniques
(FICSIT-4: Rossiter-Fornoff et al., 1995)

INSTRUCTIONS:
Demonstrate each position to the subject, then ask them to perform and time.

F-1. FEET CLOSELY TOGETHER, UNSUPPORTED, eyes open (ROMBERG POSITION)
INSTRUCTIONS: Stand still with your feet together as demonstrated for 10 seconds.
☐ 4 able to stand 10 seconds safely
☐ 3 able to stand 10 seconds with supervision
☐ 2 able to stand 3 seconds
☐ 1 unable to stand 3 seconds but stays steady
☐ 0 needs help to keep from falling
If subject is able to do this, proceed to the next position, if not, stop.

F-2. FEET CLOSELY TOGETHER, UNSUPPORTED, eyes closed (ROMBERG POSITION)
INSTRUCTIONS: Please close your eyes and stand still with your feet together as demonstrated for 10 seconds.
☐ 4 able to stand 10 seconds safely
☐ 3 able to stand 10 seconds with supervision
☐ 2 able to stand 3 seconds
☐ 1 unable to keep eyes closed 3 seconds but stays steady
☐ 0 needs help to keep from falling
If subject is able to do this, proceed to the next position, if not, stop.

F-3. SEMI-TANDEM: eyes open HEEL OF 1 FOOT PLACED TO THE SIDE OF THE 1ST TOE OF THE OPPOSITE FOOT (SUBJECT CHOOSES WHICH FOOT GOES FORWARD)
INSTRUCTIONS: Please stand still with your feet together as demonstrated for 10 seconds.
☐ 4 able to stand 10 seconds safely
☐ 3 able to stand 10 seconds with supervision
☐ 2 able to stand 3 seconds
☐ 1 unable to stand 3 seconds but stays steady
☐ 0 needs help to keep from falling
If subject is able to do this, proceed to the next position, if not, stop.
F-4. **SEMI-TANDEM**: *eyes closed* HEEL OF 1 FOOT PLACED TO THE SIDE OF THE 1\textsuperscript{ST} TOE OF THE OPPOSITE FOOT (SUBJECT CHOOSES WHICH FOOT GOES FORWARD)

**INSTRUCTIONS**: Please close your eyes and stand still with your feet together as demonstrated for 10 seconds.

- 4 able to stand 10 seconds safely
- 3 able to stand 10 seconds with supervision
- 2 able to stand 3 seconds
- 1 unable to keep eyes closed 3 seconds but stays steady
- 0 needs help to keep from falling

If subject is able to do this, proceed to the next position, if not, stop.

F-5. **FULL TANDEM**: *eyes open* HEEL OF 1 FOOT DIRECTLY IN FRONT OF THE OTHER FOOT (SUBJECT CHOOSES WHICH FOOT GOES FORWARD)

**INSTRUCTIONS**: Please stand still with your feet together as demonstrated for 10 seconds.

- 4 able to stand 10 seconds safely
- 3 able to stand 10 seconds with supervision
- 2 able to stand 3 seconds
- 1 unable to stand 3 seconds but stays steady
- 0 needs help to keep from falling

If subject is able to do this, proceed to the next position, if not, stop.

F-6. **FULL TANDEM**: *eyes closed* HEEL OF 1 FOOT DIRECTLY IN FRONT OF THE OTHER FOOT (SUBJECT CHOOSES WHICH FOOT GOES FORWARD)

**INSTRUCTIONS**: Please stand still with your feet together as demonstrated for 10 seconds.

- 4 able to stand 10 seconds safely
- 3 able to stand 10 seconds with supervision
- 2 able to stand 3 seconds
- 1 unable to stand 3 seconds but stays steady
- 0 needs help to keep from falling

If subject is able to do this, proceed to the next position, if not, stop.

F-7. **STANDING ON ONE LEG**: *eyes open*

**INSTRUCTIONS**: Stand on one leg as long as you can without holding.

- 4 able to lift leg independently and hold >10 seconds
- 3 able to lift leg independently and hold 5-10 seconds
- 2 able to lift leg independently and hold = or >3 seconds
- 1 tries to lift leg unable to hold 3 seconds but remains standing independently
- 0 unable to try or needs assist to prevent fall

\[\text{Total FICSIT-4 Static Balance score} = \text{_____} / 28\]
APPENDIX E:
CLINICAL ASSESSMENTS IN THE PSYCHOLOGICAL DOMAIN

E.1. Centre for Epidemiological Studies Depression Scale
   (CES-D: Radloff, 1977)

E.2. Montreal Cognitive Assessment
   (MoCA: Nasreddine et al., 1977)

E.3. Trail Making Test – Part B
   (TMT-B: Tombaugh, 2004)
APPENDIX E.1.
Centre for Epidemiological Studies Depression Scale
(CES-D: Radloff, 1977)

Below is a list of the ways you might have felt or behaved. Please tell me how often you have felt this way during the past week.

<table>
<thead>
<tr>
<th>In the past week…</th>
<th>Rarely or none of the time (&lt; 1 day)</th>
<th>Some or a little of the time (1-2 days)</th>
<th>Occasionally or moderate amount of time (3-4 days)</th>
<th>Most or all of the time (5-7 days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I was bothered by things that usually don’t bother me.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. I did not feel like eating; my appetite was poor.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. I felt that I could not shake off the blues even with help from my family or friends.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. I felt I was just as good as other people.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. I had trouble keeping my mind on what I was doing.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. I felt depressed.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. I felt that everything I did was an effort.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. I felt hopeful about the future.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. I thought my life had been a failure.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. I felt fearful.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. My sleep was restless.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. I was happy.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. I talked less than usual.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. People were unfriendly.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16. I enjoyed life.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17. I had crying spells.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18. I felt sad.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19. I felt that people dislike me.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20. I could not get “going.”</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX E.2.
Montreal Cognitive Assessment
(MoCA: Nasreddine et al., 1977)

Montreal Cognitive Assessment (MoCA)
Version 7.1 Original Version

**VISUOSPATIAL / EXECUTIVE**
- Copy cube
- Draw clock (9:40 minutes)

**NAMING**
- Contour: Rhinoceros
- Numbers: 13
- Hands: 10

**MEMORY**
- Read list of words, subject must repeat them. Do 2 trials, even if 1st trial is successful. Do a recall after 5 minutes.
- 1st trial: A, B, C, D, E
- 2nd trial: A, B, C, D, E

**ATTENTION**
- Read list of digits (1 digit/sec.). Subject has to repeat them in the forward order.
- Subject has to repeat them in the backward order.
- 1st trial: 21854
- 2nd trial: 742

**LANGUAGE**
- Read list of letters. The subject must tap with his hand at each letter. No points if ≥ 2 errors.
- Serial 7 subtraction starting at 100:
  - 93
  - 86
  - 79
  - 72
  - 65
- 4 or 5 correct subtractions: 3 pts. 2 or 3 correct: 2 pts. 1 correct: 1 pt. 0 correct: 0 pt

**ABSTRACTION**
- Similarity between e.g. banana - orange = fruit
- Train - bicycle
- Watch - ruler

**DELAYED RECALL**
- Has to recall words with no cue
- Category cue
- Multiple choice cue
- Points for uncorrected recall only

**ORIENTATION**
- Date
- Month
- Year
- Day
- Place
- City

© Z. Nasreddine MD
www.mocastest.org
Normal: ≥ 26 / 30
Add 1 point if ≤ 12 years old

167
APPENDIX E.3.
Trail Making Test – Part B
(TMT-B: Tombaugh, 2004)

**Instructions:**
On this page are some numbers and letters. Begin at 1 and draw a line from 1 to A, A to 2, 2 to B, and so forth until you reach the end. Remember first you have a number, then a letter, then a number, and so on.

Draw the lines as fast as you can.

**Practice Trial:**

Total Time: ________
Trial 1: TMT-B

Begin

End

Total Time: ______
APPENDIX F:
SAMPLE ADVERTISEMENTS

This appendix includes a sample of the advertisements and the recruitment poster utilized to recruit older adults with type 2 diabetes for Study II and build the Deshpande Participant Pool for Study III.

Recruitment locations:
Kingston Senior Centre (56 Francis St);
Diabetes Education Center, Hotel Dieu Hospital;
Dr. Robyn Houlden, Endocrinology and Metabolism Clinic;
Dr. Angeles Garcia, Memory Disorders Clinic;
Kingston Family Health Team;
School of Rehabilitation Therapy, Queen’s University.
APPENDIX F: STUDIES II & III

Sample Advertisements

**Vista Seniors Magazine**
Vista 1/8 page ad (2.125 x 3.375 inches) = $70 + HST

*Are you 65+ years of age and have had Type 2 Diabetes for at least 5 years?*

A research team at Queen's University invites you to participate in a study to understand effects of Type 2 Diabetes on balance, mobility, and sensory functions

The study takes only 3.5 hours; refreshments provided and $40 to cover parking, gas, and meal cost

For information contact Patricia at (613) 483 3184 or queensdiabetes@yahoo.ca

*This study has been reviewed for ethical compliance by the Queen’s University Health Sciences and Affiliated Teaching Hospitals Research Ethics Board*

**Kingston This Week Newspaper**

KTW Newspaper ad = $150 + HST

*Are you 65+ years of age and have had Type 2 Diabetes for at least 5 years?*

A research team at Queen's University invites you to participate in a research study to understand the effects of Type 2 Diabetes on balance, mobility and sensory function

The study takes only 3.5 hours; refreshments provided and $40 to cover transportation

For more information contact Patricia by (p) 613-483-3184
or (e) queensdiabetes@yahoo.ca

*This study has been reviewed for ethical compliance by the Queen’s University Health Sciences and Affiliated Teaching Hospitals Research Ethics Board*
Are you 65+ years of age and have **Type 2 Diabetes** for at least 5 years?

A research team at Queen’s University invites you to participate in a study to understand effects of Type 2 Diabetes on balance, mobility and sensory functions

The study will take only 3.5 hours of your time

**Refreshments will be provided and $40 to cover parking, gas and meal cost**

**For more information please contact us today**

(613) 483 3184 or queensdiabetes@yahoo.ca

---

This study has been reviewed for ethical compliance by the Queen's University Health Sciences and Affiliated Teaching Hospitals Research Ethics Board

---

I believe that people with Diabetes must always keep themselves educated, thus helping themselves, and others, in the fight against Diabetes, to avoid complications. That is why I’m delighted to take part in this study.

---

[Man in his late 70's and has been diagnosed with Type 2 Diabetes for 20 years. He is an active member in the community and volunteers with the Canadian Diabetes Association.]