The Impact of Type 2 Diabetes Duration on Physical Functioning, Frailty Status, and Glycemia After 16 Weeks of Resistance Training

by

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Abstract

Background: Type 2 diabetes (T2DM) duration's impact on lifestyle intervention efficacy for frail older adults is unclear. **Objective:** To compare physical functioning, glycemia, and frailty between individuals with short-and long-duration T2DM after the Band-Frail program. **Methods:** This secondary analysis of the Band-Frail Study includes 130 adults (≥65 years) with T2DM and frailty who completed 16 weeks of elastic band resistance training. Participants were categorized as 1) short-duration T2DM (<10 years) and 2) long-duration T2DM (>10 years). Outcome measures included physical functioning (SPPB), glycemia (HbA1c), and frailty (Fried's scale). **Results:** Participants in both T2DM duration groups improved in SPPB score and frailty status post-intervention (p <0.05). The long-duration group improved HbA1c significantly more than the short-duration group (p =0.03). **Conclusion:** Our findings suggest that individuals, irrespective of T2DM duration, improve physical functioning and frailty status after the Band-Frail intervention, and that longer-duration T2DM is associated with greater improvements in HbA1c.

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List of Symbols, Nomenclature or Abbreviations

Abbreviation	Definition
T2DM	type two diabetes mellitus
ADL	activities of daily living
IADL	instrumental activities of daily living
CFS	Clinical Frailty Scale
BMI	body mass index
1RM	one repetition maximum
RPE	rating of perceived exertion
SPPB	Short Physical Performance Battery

Chapter 1: Introduction

As the global proportion of older adults ($\geq$ 65) is rapidly increasing, the prevalence of age-related conditions follows a similar trend. Older adults face an increased risk of chronic diseases and age-related syndromes, including frailty[1] and type 2 diabetes mellitus (T2DM). Frailty is a geriatric syndrome characterized by declines in physiologic reserve across multiple systems, resulting in heightened vulnerability[2,3]. T2DM is a progressive metabolic disorder characterized by chronic hyperglycemia due to pancreatic beta-cell dysfunction[4,5]. In older adults, T2DM and frailty are known to exacerbate each other, leading to accelerated declines in physical functioning and loss of independence, thereby increasing the financial strain on healthcare systems[6]. As over 220 million older adults worldwide are living with the dual burden of T2DM and frailty[7], understanding how to manage these coexisting conditions is imperative.

To counteract the consequences of an aging population, optimizing lifestyle interventions and facilitating widespread implementation could offer a viable solution. While lifestyle interventions are a cornerstone in T2DM management[8] and slowing frailty progression[9], they can be expensive and logistically challenging to implement. Resistance training has proven effective in managing these conditions and their complications in older adults by improving muscle strength and physical functioning[8,10,11]. Elastic band resistance training provides a more cost-effective and accessible alternative to traditional resistance training that provides similar benefits for T2DM and frailty independently[12–14]. Yet, few studies examine the coexistence of these conditions and the impact of lifestyle interventions in individuals with the coexistence of these conditions. An intervention that

targets T2DM and frailty, using inexpensive resistance equipment and leveraging existing resources could benefit a community setting and maximize the impact of limited resources.

An underappreciated risk factor in managing T2DM and its complications in older adults is diabetes duration. Longer disease durations can amplify the risks of micro and macrovascular complications[15], premature mortality[16], and functional limitations[17] and may influence the effectiveness of lifestyle interventions. To our knowledge, only one study has investigated the effects of diabetes duration on exercise intervention efficacy. The study consisted of 12 weeks of exercise, five times a week: two to three sets of fifteen to twenty repetitions of ten elastic band resistance exercises spread over two daily sessions[13]. Following the intervention, participants with both short- and long-durations of T2DM improved in measures of physical functioning, with the long-duration cohort exhibiting more pronounced improvements in certain areas[13].

As the prevalence of diabetes and frailty is expected to increase, and the number of intervention studies on older adults with T2DM and frailty is scarce, understanding factors that impact the efficacy of a community intervention in improving physical functioning in older adults is essential to prevent consequences of each condition, optimize intervention prescriptions, and lessen the burden on healthcare systems. Therefore, this study aimed to investigate how T2DM duration impacts the efficacy of a 16-week elastic band resistance training intervention to improve physical functioning in older adults with T2DM and frailty.

Chapter 2: Literature Review

2.1 Introduction to Aging and Frailty

Through the many definitions, aging is commonly referred to as a time-related functional decline experienced in the later stages of life[18], often associated with senescence, the progressive deterioration of bodily functions over time[19]. Aging is a deterioration at all levels of an organism, likely due to accumulated molecular and cellular damage throughout its lifetime[18,20]. Although no universal definition for aging exists, most studies agree that aging involves progressive impairment of the mental and physical functioning required for everyday life, resulting in increased vulnerability to stressors and increased risk of death and diseases[1]. Walking, balance, muscle strength, and flexibility are just a few of the functions impacted by senescence and aging.

Chronological age is defined as time since birth, usually expressed in years, and is frequently used to quantify a person's age[19]. However, studies suggest that aging can occur at different rates between individuals, indicating that chronological age may not accurately reflect biological deterioration, making it a poor indicator of health[19]. For instance, two individuals of the same chronological age could experience different rates of functional decline. *Biological age* is a biophysical measure that can determine the age-related risk of adverse outcomes based on the progressive deterioration of the physiological ability to meet environmental needs and functional status[19,21]. In the previous example, if one of the individuals were diagnosed with several diseases and comorbidities, they would be biologically older than their healthy counterpart of the same chronological age[19]. As such, biological aging can be used as a more accurate indicator of health and aging. Recent studies have found that individuals with a younger biological age

than chronological age tend to suffer fewer illnesses and live longer than those who are biologically older than chronologically[22]. Additionally, biological age provides predictive effects for mortality hazards as a one-year increase in biological age can have up to a 3% increase in the risk of death[22].

Aging is also associated with an increased risk of frailty[1]. Although there are many definitions of frailty, most studies suggest that frailty is a geriatric syndrome resulting from multilevel deterioration across physiological systems, increasing vulnerability to disability, disease, and death[2,3,23]. Frailty is often used to predict susceptibility to adverse outcomes and estimate the variability of risk, independent of chronological age, similar to biological age[21].

Several criteria are used to measure frailty, often based on physical capacity, fatigue/exhaustion, unintentional weight loss, muscle weakness, motor slowness, and low activity levels[24,25]. These criteria are incorporated into a number of the proposed measurements of frailty, some of the most common including Fried's Frailty Scale[26], Rockwood's Clinical Frailty Scale[27], and The Accumulation of Deficits Models (Frailty Index)[28].

2.1.1 Prevalence of Aging and Frailty

The aging population has rapidly increased since the start of the 21st century, and the fastest-growing segment of the global population remains those over 65[29]. With the population aging much faster than in the past, it is expected that the proportion of the global population above the age of 60 will nearly double from 12% in 2015 to 22% in 2050[30]. Additionally, the global population of those aged 65 years or older is expected to double from ~703 million in 2019 to 1.5 billion by 2050, with one in six people over 65[31].

Population aging has been fastest in Eastern and South-Eastern Asia, Latin America, and the Caribbean[31]. Still, Canada reflects these global trends, with an expected 22.8% of the population aged 65 years or older by 2030[31]. Although the prevalence of older adults is based on chronological age, aging varies considerably between individuals.

This variation among older adults of the same chronological age is related to the increasing prevalence of frailty. Depending on the frailty scale used, frailty affects 4.9-27.3% of the senior population[32]. In Canada, data from the Canadian Health Measures Study reported that the prevalence of frailty in adults 18-79 was 8.6% when using a frailty index and 6.6% when using Fried's Frailty scale[33]. A 2021 systematic review and meta-analysis examining the 50+ populations in 62 countries found that the prevalence of frailty was 24% using a frailty index and 12% when using Fried's Frailty scale[34]. Another systematic review and meta-analysis from 2022 found a 13% prevalence of frailty in people over the age of 50 when examining 28 studies[35]. When assessing age groups independently, it is observed that the prevalence of frailty increases with chronological age. One study found the prevalence of frailty to be 14% overall, but only affecting 6.5% of those aged 60-69 and 65% of those over the age of 90[36]. Similarly, in a Canadian study, frailty increased from 5.3% with the frailty index and 1.8% with Fried's Frailty scale for adults 18-34 to 7.8% on the frailty index and 20.2% using Fried's Frailty scale for the 65+ age group[33].

2.2 Consequences of Aging and Frailty

2.2.1 Multimorbidity and Increased Health Care Burden

Multimorbidity, the presence of multiple chronic diseases in an individual, significantly contributes to a decline in health within the aging population[37]. In recent

years, chronic health conditions have become a dominant healthcare burden, strongly related to the aging population. Older persons have an increased risk of experiencing multimorbidity due to their prolonged exposure and increased vulnerability to risk factors of chronic conditions[37]. It is estimated that 55-98% of the 60+ population experience multimorbidity[37]. This rise in chronic conditions and multimorbidity increases financial strain on healthcare systems[37]. In Canada, the average healthcare cost for one person is approximately $2,700 per year[38]. However, the average cost for an older adult is $12,000 annually[38]. It was estimated that the 65+ population accounts for approximately half of all healthcare costs in Canada and that the aging population will result in a $93 billion increase in healthcare costs from 2018 to 2028[38]. The presence of multiple chronic conditions (three or more) substantially increases health care costs compared to caring for individuals without chronic conditions[38]. As more than half of seniors experience multimorbidity[37], the aging population places even more financial strain on the healthcare systems globally[38].

Frailty also increases the financial burden on the medical system. Frailty is associated with unintentional weight loss (shrinkage), weakness, exhaustion/fatigue, low gait speed, and low physical activity, all of which can impact physical functioning[39]. As frailty increases the chances of falls, disability, dementia, hospitalization, and mortality, additional healthcare resources are required as one develops frailty. Frailty is significantly associated with an increased fall risk and risk of fractures in older adults[40]. Recurrent falls are 2.5-3 times more likely in frail women when compared to non-frail women[41]. In 2010, fall-related costs for frail older adults ranged from 0.85%-1.5% of all healthcare expenditures in the USA, EU15, Australia, and the UK[42]. The cost for a single fall and

related medical costs can range from $2,044 to $42,840 USD and has likely increased with the aging population[42]. Frailty can also increase dependency and require affected persons to reside in assisted living facilities, further burdening global healthcare systems[43]. Frailty has been found to increase the risk of experiencing adverse health outcomes when compared to non-frail individuals[44], and multiple studies have also demonstrated that there is a significant association between frailty and all-cause mortality[2,3,23].

2.2.2 Physical Functioning

Physical functioning is one's ability to perform activities of daily living (ADL) and instrumental activities of daily living (IADL) without limitation or requiring assistance[45]. Performing tasks such as self-care and shopping are essential for seniors to maintain their quality of life, independence, emotional well-being, and participation in social and recreational activities[45]. Declines in physical functioning have been found to increase morbidity and mortality risks and to be predictive of institutionalization, falls, and death[45].

Physical functioning is often measured through a series of physical tests involving strength (grip strength), speed (gait speed), and balance[46]. The Short Physical Performance Battery (SPPB), Late Life Functional Disability Instrument (LLFDI), and frailty phenotypes are similar in predicting risks of declining physical functioning over one and two year periods in older adults at risk for disability[47].

Aging and frailty are associated with several consequences that can impact physical functioning. A longitudinal study found that limitations in performing ADLs significantly increase with age globally[48]. This study also found an age effect across most

countries, with the prevalence of IADL limitations steadily increasing in those over the age of 70[48].

In older adults, many studies have found frailty to significantly increase the risk of disability and rapid decline of physical functioning[49]. A 2017 systematic review and meta-analysis found a nearly two-fold increase in risks of disability in ADL and IADL in frail and prefrail older adults compared to non-frail individuals[6]. A 2016 review also found that frailty is associated with a 1.6- to 2.0-fold risk of losing ADL function and a 1.5- to 2.6-fold risk of physical limitations[3]. In a population-based cohort study, frailty was associated with functional decline over a six-year period[50]. Notably, while only 9.7% of participants in the study were classified as frail at baseline, 26.6% of those who experienced declines in physical functioning over the six years were frail, compared to just 7.1% of the functional non-decliners[50]. In a prospective Japanese cohort study, the prevalence of frailty was nearly fivefold higher in those who developed disabilities (31.5%) within a two year period when compared to individuals who remained independent (5.9%)[51]. A secondary analysis of hospital data from Portugal also found that 72.7% of frail individuals experience declines in physical functioning six months post-discharge compared to only 27.3% of non-frail individuals[52].

Declines in physical functioning from frailty can also be observed through the increased fall risks. A systematic review and meta-analysis examining frailty as a predictor for future falls found a significant association for increased risk with an odds ratio of 1.84 and 95% CI= 1.10-1.41[53]. Another analysis corroborates this association, reporting a 1.2- to 2.8-fold risk for falls and fractures in frail individuals[3]. A cross-sectional study from 2018 in India found that a sample of older adults, 29.94% of whom

were frail, had a higher prevalence of falls (15.43%), multiple falls (7.73%), and injuries related to falls (6.68%) than the non-frail individuals[54].

2.3 Introduction to Type II Diabetes Mellitus

Diabetes mellitus is one of the most prevalent chronic diseases affecting Canadians[55]. Characterized by chronic hyperglycemia, diabetes mellitus occurs in two main forms: type 1 and type 2. Type 1 diabetes mellitus is an autoimmune disease that destroys the beta cells of the pancreas, which, in turn, impairs insulin production. Type 2 diabetes mellitus (T2DM) is caused by increased plasma glucose levels due to a combination of reduced glucose uptake by GLUT4 transporters and sustained hyperinsulinemia. When the pancreatic beta cells can no longer sustain this high level of insulin secretion, beta cells fail, and insulin secretion is reduced[4,55,56].

T2DM can be paradoxical as it involves both hyperinsulinemia and hyperglycemia. Patients are often characterized as having peripheral insulin resistance and impaired insulin secretion[5]. Given its progressive nature, T2DM may be preceded by at least 10 years of impaired glucose tolerance and beta cell dysfunction[5]. With the onset of peripheral insulin resistance, there is an overproduction of insulin from the pancreatic beta cells, placing the individual in a hyperinsulinemic state to compensate for ineffective insulin usage and to remain normoglycemic[5]. After a prolonged period of maintaining hyperinsulinemia, the beta cells become exhausted and can no longer sustain adequate insulin production, resulting in chronic hyperglycemia, leading to a T2DM diagnosis[5].

2.3.1 Prevalence of Type II Diabetes Mellitus

Diabetes mellitus is a growing epidemic that affects over 530 million people globally, with T2DM accounting for approximately 90% of all reported cases[57].

Projections indicate that the global prevalence of T2DM will surpass 600 million by 2030 and exceed 700 million by 2045, affecting 9.9% of both men and women on a global scale[57,58].

Canada is no exception to this rise in T2DM prevalence. It is estimated that the prevalence of diabetes in Canada will increase by nearly 50% from 2015 to 2025[59]. A 2019 study revealed that 7.5% of Canadians aged 20-79 years old had T2DM, while 6.1% had prediabetes[55,59]. According to Diabetes Canada's 2022 report, 5.7 million Canadians were living with diabetes, but 11.7 million were living with diabetes mellitus or prediabetes, which could contribute to the rising incidence of T2DM cases[60]. It is expected that the prevalence of diabetes will increase, on average, by 3.3% per year as the Canadian population increases[55]. New Brunswick has one of the highest proportions of T2DM, with 19% of the population affected[60].

As of 2017, 224 million or 49.7% of 18-99-year-old people living with T2DM were undiagnosed[58]. In the Canadian context, an estimated 37.3% of all diabetes cases are undiagnosed, as the HbA1c levels reported in the CHMS database suggest hyperglycemia, posing an elevated risk of rapid onset T2DM-related complications[59].

2.4 Consequences of Diabetes Mellitus

Type 2 diabetes mellitus is associated with several consequences, including micro and macrovascular complications, increased mortality risks, and decreased physical functioning that can impact an individual's quality of life, decrease life expectancy, and add strain to the broader healthcare system.

2.4.1 Macrovascular Complications

Macrovascular complications are the most severe consequences of T2DM. A 2018 study across 38 countries reports a crude prevalence of macrovascular complications of 12.7% in T2DM patients[61]. Alternatively, a ten-year (2007-2017) global analysis found 32.2% of T2DM patients experienced some form of cardiovascular disease (CVD). However, despite its prevalence, CVD was responsible for 9.9% of deaths and accounted for 50.3% of all T2DM-related deaths[62]. A 2022 systematic review conducted in low- and middle-income countries reported a prevalence of macrovascular complications ranging from 6-10% at the time of T2DM diagnosis[63]. Despite the comparatively lower prevalence of patients affected by macrovascular complications, preventing and managing these complications is vital, as cardiovascular disease is the leading cause of death in those with T2DM[64,65].

In patients with T2DM, insulin resistance and hyperglycemia can lead to atherosclerosis, resulting in arterial wall narrowing and stiffness, leading to macrovascular complications[65]. Cardiomyopathy, coronary heart disease, arrhythmias, cerebrovascular disease, and peripheral artery disease are some of the macrovascular complications that can arise from T2DM[65]. An association has been found between coronary heart disease and T2DM, with T2DM patients having significantly increased risks of atherosclerotic disease (10%), myocardial infarctions (53%), and heart failure (112%) when compared to their nondiabetic counterparts[62,65]. People with T2DM also have higher death rates from cardiovascular causes, with a 15.4% mortality rate for those without prior myocardial infarctions and a 42% mortality rate for those with a history of myocardial infarctions, compared to a 2.1% and 15.9% risk for those without T2DM, respectively[62]. Chronic

hyperglycemia experienced in T2DM can also alter cardiac function, leading to arrhythmias and sudden cardiac death[65]. Additionally, a heightened five-year mortality rate (18.9%) has been reported for T2DM patients diagnosed with macrovascular complications [66].

2.4.2 Microvascular Complications

There are a number of microvascular complications associated with T2DM [67]. Microvascular complications result from chronic hyperglycemia and genetic factors affecting the microvasculature[67]. Three serious microvascular complications of T2DM include diabetic nephropathy, which leads to end-stage renal disease; diabetic neuropathy, which can result in foot ulceration and amputation; and diabetic retinopathy, which is the leading cause of blindness in the developed world.

Diabetic nephropathy involves structural and functional changes in the kidneys, resulting in progressive deterioration of kidney function[68]. Diabetic nephropathy is linked to a heightened risk of morbidity and mortality and can progress to diabetic kidney disease, affecting 30-40% of the diabetic population[68–70]. Diabetic kidney disease manifests as hypertension, albuminuria, deposition of extracellular matrix, and glomerulosclerosis due to renal hypertrophy, glomerular hypertension, hyperfiltration, and altered composition[68]. There is also an established association between microalbuminuria and cardiovascular disease[67]. Microalbuminuria is an indicator of endothelial dysfunction that can result from high blood glucose levels and contribute to atherosclerosis, increasing macrovascular risks[71]. Hypertension, dysregulation of the renin-angiotensin system, and inflammation also share mechanisms of development that can contribute to microalbuminuria and increase risks of cardiovascular disease[71,72]. An

association also exists between diabetic nephropathy and diabetic retinopathy as they share pathophysiological mechanisms affecting the microvasculature[67,70].

Diabetic retinopathy is a common complication of diabetes involving vascular abnormalities in the retina[73]. In 2020, an estimated 22% of the diabetic population, or 103.12 million people, had diabetic retinopathy, which is expected to rise to approximately 160 million people affected by 2045[74]. Diabetic retinopathy often starts with dilation of blood vessels and altered blood flow, leading to increased retinal metabolism due to hyperglycemia[73]. The pathogenesis of retinal microvascular damage and metabolic pathways are heavily impacted by hyperglycemia, inflammation, and retinal neurodegeneration[73]. Retinal damage from diabetic retinopathy can lead to global vision loss and is the fifth leading cause of blindness and severe visual impairment[73,74].

Diabetic neuropathy is a progressive loss of nerve fibres due to damage from elevated blood glucose levels on axon degeneration and demyelination of the fibres[67]. Approximately 20% of diabetic patients experience diabetic neuropathy at the time of diagnosis, and over 50% of all T2DM patients are affected[67,69]. As diabetic neuropathy progresses, a number of positive and negative clinical signs arise, including pain, paresthesia, and loss of sensation[75]. A critical complication of diabetic neuropathy is diabetic foot syndrome, which is the leading cause of hospitalization due to T2DM complications[69]. Diabetic foot syndrome involves peripheral neuropathy resulting in decreased sensation and proprioception and intrinsic muscle atrophy in the lower limbs, resulting in high-pressure zones on the feet[76]. The process predisposes the skin to injury from repetitive trauma (i.e. walking) that can lead to ulceration and infection, which, if

left untreated, can result in amputation[76]. Up to 70% of non-traumatic amputations are attributed to diabetic lower limb amputations as a result of diabetic neuropathy[69].

2.4.3 Physical Functioning

T2DM is ranked the seventh leading disease in terms of human suffering[77] and the seventh leading cause of disability and years of life lost[78]. The consequences of T2DM on physical functioning are apparent in both men and women, especially those over the age of 60[79]. Studies have found a high prevalence of impaired functioning in individuals with T2DM and greater difficulty reported with daily tasks compared to those without diabetes[79]. The decline in physical functioning associated with T2DM is multifactorial, with factors such as disease duration, cognitive decline, micro and macrovascular complications, nutritional deficiencies, and chronic inflammation all potentially contributing to the process[79].

Adults with T2DM have an elevated risk of physical functioning impairment and physical disability than those without T2DM[80,81]. A 2010 review found that the presence of T2DM is associated with a 50-100% excess risk of disability in both sexes[82]. Subsequent studies in 2012 reported twice the risk[81], and in 2013 found a 50-80% increased risk of disability with T2DM and an increased risk of ADL- and IADL-related disability[83]. Women with T2DM have been reported to experience greater declines in physical functioning (38%/year) than nondiabetic women, as assessed through walking speed, chair stand, and balance parameters[83].

Individuals with T2DM have been found to perform significantly worse on walking speed, chair stand, and balance tests when compared to their nondiabetic counterparts[84]. Self-reported diabetes is associated with a 60% increase in the likelihood

of poor performance in objective measures of lower-extremity performance, independent of age, gender, and chronic condition[82]. T2DM has been found to influence gait, leading individuals to take shorter, wider steps and significantly decrease walking speed compared to age-matched individuals without diabetes[85].

2.4.4 Financial Burden

The rise in T2DM can also have consequences on global health system expenditures. The average cost to treat a person with T2DM is estimated to be 2.3 times higher per year than for a nondiabetic individual[86]. In Germany, an analysis found that the healthcare costs associated with complications of T2DM rose ~5.6% from 2013 to 2015[87]. In 2017, $327 billion, or 1 in 4 healthcare dollars in the United States, was spent on patients with diabetes mellitus, a 26% increase over a five-year period[86]. In Canada, nearly $30 billion was spent in 2019 on treating diabetes mellitus, rising from $14 billion in 2008[88].

2.4.5 Mortality Risks

The mortality risk associated with T2DM varies by country, with approximately 7%, 12%, and 10% of deaths attributed to diabetes in low-, middle-, and high-income countries, respectively[89]. In a 2020 report, T2DM was ranked the ninth leading cause of mortality, responsible for over 1 million deaths a year globally[78]. In 2021, T2DM was ranked the seventh leading cause of death in Canada[90], with its complications reducing life expectancy by 5-15 years[91]. This increase in mortality is concerning as in 1990, T2DM was only ranked the eighteenth leading cause of death[78]. This escalation of mortality rates stresses the importance of managing T2DM and addressing its complications before they

progress to fatal outcomes. T2DM's impact on functional capacity and quality of life further emphasizes the potential for premature mortality[78].

2.5 Type II Diabetes and Frailty

It has been established that individuals with T2DM are prone to frailty[49]. A 2021 meta-analysis found that the prevalence of frailty and pre-frailty in community-dwelling older adults with T2DM was 20.1% and 49.1%, respectively[92], suggesting that adults with T2DM have a 1.6 times greater risk of developing frailty[34]. Sex and marital status were also identified as risk factors for developing frailty with T2DM[34].

2.5.1 Pathophysiology of T2DM and Frailty

The loss of skeletal muscle, weakness, and accelerated aging experienced with T2DM can lead to frailty[93]. Hyperglycemia and T2DM are associated with more rapid declines in muscle mass and quality, and reduced strength and decreased functional capacity when compared to nondiabetic and normoglycemic individuals due to reductions in proprioceptive acuity with neuropathy[93]. Older adults with T2DM are therefore at an increased risk for declines in physical functioning, fractures, and falls, which can contribute to the development of frailty[93]. The multimorbidity associated with aging and T2DM, especially complications related to T2DM, can also serve as an intermediary for frailty[93]. This association was observed in T2DM patients with renal impairment in Japan, who exhibited a higher risk of frailty than patients without impaired renal function[94].

2.6 Introduction to Type II Diabetes and Frailty Interventions

Exercise and lifestyle interventions are a cornerstone in preventing and managing T2DM. T2DM management typically includes pharmacological therapies, lifestyle changes to exercise and nutrition, and T2DM education.

2.6.1 Education as Type II Diabetes Intervention

Education on T2DM is recommended by both the American Diabetes Association and Diabetes Canada, typically encompassing a comprehensive disease overview, explanations of the importance of maintaining healthy body weight and engaging in regular exercise, the role of nutrition and blood sugar monitoring, and a broad range of surrounding topics[95].

Recent systematic reviews have shown that T2DM education and Diabetes Self-Management Education (DSME) are associated with improved glycemia, reduced risks of T2DM-related complications, and increased patient disease knowledge, self-efficacy, and quality of life[96,97]. A review of DSME in the United States found that T2DM education reduces healthcare expenditure by decreasing hospital admissions and lowering risks of T2DM-related complications[98]. The review echoed earlier analyses, highlighting that T2DM education improves HbA1c, reduces complications, and improves quality of life, self-efficacy, and lifestyle[98].

A 2021 meta-analysis found that peer support can play a large role in the effectiveness of T2DM education[99]. Peer support, in addition to T2DM education, enhanced significant improvements in glycemia when combined with short weekly education sessions in a small group[99]. Group-based T2DM education has also been found to have lasting effects on patients' glycemia. A 2012 meta-analysis found that with group-

based T2DM education, HbA1c was significantly improved in participants at all time points from six months to five years post-intervention[100].

2.6.2 Exercise as Type II Diabetes Intervention

Many studies have been conducted on the efficacy of exercise for individuals with T2DM and consistently recommend engaging in regular physical activity to reduce T2DM-related complications, manage glycemia, improve physical functioning, and decrease mortality[8]. However, exercise modality can influence the effects of an intervention on participants.

In a 22-week randomized controlled trial (RCT) in 2007, comparing aerobic, resistance, and combined training, the combined training group experienced the greatest reduction in HbA1c after intervention[101]. However, participants in the combined training group had a higher exercise volume than those in the solely aerobic or resistance training groups, potentially explaining the greater reduction observed in HbA1c[101]. A similar nine month study conducted by Church et al. in 2010, with equal total exercise volume across the aerobic, resistance, and combined training groups[102], supported these findings as the combined training group displayed a significant reduction in HbA1c compared to the control group[102].

A 2014 meta-analysis compared the impacts of resistance training, aerobic training, and combined aerobic and resistance training and their respective effects on glycemia. The results of this analysis corroborate the outcomes of the two RCTs, as the combined exercise group experienced the greatest reduction in glycemia[103]. However, aerobic training has been found to independently improve glycemia in adults with T2DM by approximately 0.5-0.7%[104], and resistance training has also been found to improve

HbA1c independently[11,105]. The variation in HbA1c change for aerobic and resistance training may be explained by the different physiological mechanisms that occur with each training modality. Aerobic exercise primarily decreases HbA1c by increasing insulin sensitivity[106] through an alteration in mitochondrial function and an increase in glucose transporter 4 (GLUT-4) translocation. Although resistance training involves increased GLUT-4 translocation, many of the beneficial effects of resistance training on HbA1c are thought to be related to muscle remodelling with a potential increase in muscle mass and reduction in fat mass[107,108]. However, change in body composition after resistance training may not be the greatest predictor of improvement in HbA1c from an exercise intervention, especially in older adults, considering the challenges associated with increasing muscle mass. Nevertheless, repeated bouts of exercise combined with appropriate intensity progression can result in more efficient use of the working muscles resulting in increased strength, GLUT-4 function, and insulin sensitivity[106], regardless of body composition changes. Combined aerobic and resistances training often results in a greater magnitude of glycemia change as it reaps the additive effects of the HbA1c lowering mechanisms associated with each training modality[106].

Physical activity and exercise also play an important preventative role in improving and maintaining strength and physical functioning[109]. A systematic review and meta-analysis in 2022 found that structured exercise programs, including aerobic training, resistance training, and combined aerobic and resistance training, can positively impact physical functioning for people living with T2DM[95]. Walking performance, chair stands, and walking speed can all improve after a structured exercise program of at least eight

weeks[110]. Resistance training alone was also found to increase muscle strength, leading to improved physical functioning[11,105].

2.6.2.1 Elastic Resistance Band Training and Type II Diabetes

Resistance training is an important part of T2DM management. Elastic band resistance training offers a low-cost, versatile, portable, and simple form of resistance training that can benefit those with T2DM[12]. Despite its potential benefits, high-quality studies examining the impacts of elastic band resistance training on glycemia and physical functioning in individuals with T2DM are limited.

A 2014 meta-analysis of seven RCTs found a nonsignificant 0.18% change in HbA1c after interventions using elastic band resistance training[111]. However, the studies used in this analysis had participants exercising at 40-60% of their one-repetition maximum (1RM), but did not describe how a 1RM was converted to a strength of resistance band or how resistance was adjusted throughout the intervention[111]. The small sample size of the RCTs, predominantly composed of women, also affects the generalizability of the results[111].

In 2015, Park et al. conducted a 12-week elastic band resistance training trial for women aged 46-65 with T2DM[13]. The study involved 10 exercises performed for three sets of 15-20 repetitions spread over two daily sessions, five times a week[13]. The resistance of the elastic bands was determined using a repetition maximum of 30 and was reassessed every four weeks to account for increases in strength[13]. Significant improvements in HbA1c and physical functioning, measured through bicep curls, abdominal crunches, and sit-to-stand repetitions, were found after the intervention[13].

A recent 16-week home-based study of progressive resistance training using resistance bands saw significant improvements in HbA1c in T2DM patients after the intervention[12]. This quasi-experimental trial involved participants aged 50 or older with T2DM performing three sets of eight repetitions of twelve exercises for 16 weeks[12]. Participants were instructed to focus on a fast concentric phase and slow eccentric phase of each movement using a high-intensity resistance (Borg Scale Rating of 16-18), which was increased throughout the program[12]. The study reported a 1.34% absolute reduction in HbA1c from 9.40 +/- 0.79 to 8.06 +/- 0.79 after the 16-week intervention, highlighting the benefits of progressive resistance training for older adults with T2DM[12].

A 2023 RCT using elastic band resistance exercise and modified Thai yoga saw a significant 2.51% improvement in glycemia after a 5-day/week 12-week intervention[112]. The existing literature collectively supports the benefits of elastic band resistance training for individuals with T2DM.

2.6.3 Exercise as a Frailty Intervention

Exercise plays an important role in preventing and managing frailty in older adults. Resistance training has been found to positively impact muscle strength, muscle power, functional outcomes, and improve frailty scores[10].

A 2021 systematic review showed that resistance training in the early stages of frailty can improve physical function, muscular strength, and body composition in frail and pre-frail older adults[9]. The review saw significant changes in strength, gait speed, and functional performance, describing resistance training as a highly effective preventative measure to delay the onset and progression. Additionally, combining resistance training with other forms of exercise can be beneficial for frailty. A 2013 systematic review found

that a multi-component exercise plan involving strength, endurance, and balance training improved fall rates, balance, strength, and gait in frail older adults[113]. These findings were reinforced by a 12-week quasi-experimental pilot study on pre-frail women that saw significantly improved frailty status, muscle strength, and functional tasks performance after a multi-component exercise intervention including aerobic, resistance, balance, and flexibility training[114].

The literature suggests that resistance training with weight machines and free weights can be beneficial for frail and pre-frail older adults to improve frailty scores and other health measures. However, using weights for resistance training can be inaccessible to some older adults due to financial constraints or discomfort in a public exercise setting[115] and alternative resistance training methods are needed.

2.6.3.1 Elastic Band Resistance Training and Frailty

Elastic-resistant bands offer an accessible alternative that can provide similar benefits to resistance training with weights, especially for frail older adults. For instance, a 2019 randomized controlled trial examined the effects of elastic band resistance training on the frailty scores of pre-frail older adults[14]. The trial involved eight weeks of supervised elastic band exercise in a group setting for 45-60 minutes three days a week[14]. Not only did the intervention group experience significant improvements in walking speed, grip strength, and physical activity, but there was also a change in frailty status. After four weeks of the intervention, 17 participants (51.5%) went from pre-frail to non-frail, and after 8 weeks, 27 participants (81.8%) returned to non-fail status[14].

Further benefits of elastic band resistance training include improving physical functioning, functional fitness, and activities of daily living (ADLs). A more recent

systematic review from 2021 assessed the effectiveness of elastic resistance band exercise for improving physical functioning in frail adults over the age of 65[116]. The study observed significant improvements in frailty after 24 weeks of elastic band resistance training and a significant reduction in depression at all time points[116]. Despite these improvements, no improvements were seen in the participants' leg or grip strength[116]. A Norwegian study involving participants over the age of 70 receiving home care showed significant improvements in physical functioning after eight months of elastic band, body weight, and water cane exercise[117]. This intervention involved exercising two times a week for 30-45 minutes, and lead to significantly improved chair stands, 8ft timed up and go, and stair climb[117]. A 2015 Taiwanese RCT using elastic resistance bands for wheelchair-bound older adults with cognitive impairments[118] similarly found that six months of resistance training three times a week for 40 minutes significantly improved ADL and functional fitness[118].

The benefits of elastic band resistance training extend to those with coexisting frailty and chronic conditions including T2DM. A prospective study from 2019 found that six months of elastic band resistance training and aerobic exercise can reduce the prevalence of frailty in T2DM patients[119]. Participants aged 70 or older with T2DM performed elastic band resistance training three days a week and walked for 30 minutes a day five days a week[119]. Following the intervention, frailty, according to Fried's criteria, decreased from 34.1% to 25%[119]. However, this study experienced a 20% dropout rate, and sessions not being supervised resulted in a 47.7% non-adherence rate to the resistance training component[119].

The evidence suggests that elastic band resistance training provides numerous benefits for frail and pre-frail older adults, improving frailty scores, functional capacity, and activities of daily living after as little as eight weeks.

2.7 Type II Diabetes Duration

Type 2 diabetes duration is the length of time an individual has lived with T2DM, usually expressed in years from the diagnostic year. Despite its importance, there is no universally accepted clinical definition for what constitutes a long- or short-duration of T2DM. Previous studies have used various classifications of <3 years, <5 years, <6 years, and > 10 years to create groups for comparison, but there are no clear cut-points in the current literature[120–122].

Recent findings surrounding T2DM remission suggest that achieving remission may be possible through lifestyle interventions within 10 years of a T2DM diagnosis[121]. These findings offer insight into what could be considered short- and long-duration T2DM in relation to the possibility of remission, as well as highlight the potential importance of considering T2DM duration in lifestyle interventions.

2.7.1 Consequences of T2DM Duration

As T2DM is a progressive disorder, early detection and intervention are essential for managing glycemia to minimize the development of complications. Increased T2DM duration has been linked with increased risks of complications[65,109], higher cancer risk, peaking approximately 4-8 years after T2DM diagnosis[123], multimorbidity[124], decreased physical functioning[17], and premature mortality[125].

2.7.1.1 Macrovascular Complications

Disease duration can be one of the most important risk factors when considering macrovascular events and complications.

A 2018 study found a 2% increased risk of macrovascular complications with every one-year increase in T2DM duration[61]. Similarly, 2014 findings suggest a 13% increased risk of macrovascular complications for every five-year increase in disease duration[15]. When comparing different T2DM durations and the development of both fatal and nonfatal cardiovascular diseases, the hazard ratio increases from 1.15 for individuals with 5-10 years T2DM duration to 2.22 for those with ≥15 years duration when compared to those with <5 years of disease duration[126].

In 1999, a study found that one of the most important risk factors for macrovascular risks in women was T2DM duration, with an 8% increase in risk with longer duration[127]. The relationship between disease duration and the development of peripheral artery disease in men was noted, with a 1.39-fold increase in risk for those with 1-5 years of T2DM up to a 4.53-fold increase in risk for those with >25 years duration[128]. Coronary heart disease is similarly impacted, with a 38% increase in risk for every decade after T2DM diagnosis[129]. Disease duration has also been identified as an independent risk factor for aortic stiffness and associated with macrovascular complications[130].

Many studies also note that increasing disease duration is significantly correlated with the risk of cardiovascular mortality[126,131–133]. For patients undergoing coronary angiography, cardiovascular mortality increases from a 1.76 hazards ratio for those with 1-5 years of T2DM to a 4.55 hazards ratio for individuals with 10 years of T2DM[133]. The risk of fatal coronary heart disease increases by 7% and 8% for every year of T2DM

duration for men and women, respectively[132], with an 86% increased risk for every decade of T2DM duration[129].

2.7.1.2 Microvascular Complications

T2DM duration plays an important role in the development of microvascular complications. Studies suggest that individuals diagnosed with T2DM at a younger age, who live to have a longer disease duration, are often at a higher risk for vascular diseases than individuals diagnosed at an older age with a shorter disease duration[125]. Long T2DM duration is more strongly related to microvascular risks than macrovascular risks in some studies[15], and is identified as one of the most important risk factors for microvascular complications in both men and women[127,134,135].

In 2014, it was found that the risk of microvascular complications experience a 28% increase for every five years of disease duration[15]. A Thai study also reported that individuals with longer-duration T2DM had a 12% increase in risk of developing microvascular complications for each five-year increase in duration[136]. Long-duration T2DM is a significant risk factor for retinopathy, neuropathy, and nephropathy[135]. Increased T2DM duration has been associated with a more rapid decline in estimated glomerular filtration rate compared to those with a short duration, resulting in increased albuminuria[137]. There is also a significant correlation between the prevalence of microalbuminuria and T2DM duration, with an approximate 13.5% prevalence in those with <2 years of T2DM and up to a 27% prevalence in those with >9 years of disease duration[130]. Additionally, increased T2DM duration is an important risk factor for retinopathy[138] as the risk of diabetic retinopathy can increase by 8% for each one-year increase in disease duration[139].

Alternatively, a 2017 study found a negative association between T2DM duration and microvascular complications[140]. In this study, microvascular complications developed in the first three years after diagnosis, and individuals with a shorter disease duration were at greater risk for retinopathy and nephropathy[140]. However this study only included individuals with T2DM durations of 2-10 years, with an average of 6.41 years, making the 'long-duration' group more recently diagnosed than those in most other studies identified[140].

2.7.1.3 Physical Functioning

The duration of T2DM can also impact physical functioning and disability. Individuals with longer durations of T2DM tend to exhibit lower scores on physical functioning tests[141]. In a 6-minute walking distance test, years since T2DM diagnosis was significantly associated with physical functioning[17], and T2DM duration could predict walking distance in participants >59 years, with a longer duration resulting in a shorter distance[17]. Poor glycemia is also associated with subclinical functional limitations and poor physical performance in those with longer durations of T2DM[142].

Disease duration is a known risk factor for muscle impairment[143], which can lead to greater difficulty performing activities of daily living (ADLs) and reduce independence. Longer duration T2DM (>6 years) was associated with poorer muscle quality in both the upper and lower limbs and with limitations of physical functioning[144]. A 2011 study in Taiwan found that increased time since T2DM diagnosis was associated with reported middle to low physical functioning capabilities[145].

Increased T2DM duration is similarly associated with a greater risk of disability in both ADLs and IADLs, even when controlling for age and sex[146]. There is also an

increase in self-reported physical limitations as T2DM duration increases[146]. In the United States, it is reported that the odds of having a physical disability increase with disease duration, likely impacting quality of life[147]. The prevalence of disability also increases with disease duration, with a more pronounced effect in middle-aged adults and a less pronounced impact in older adults (>75 years)[148]. However, in some studies, no relationship between T2DM duration and the risk of functional disability was found[149].

2.7.1.4 Mortality Risks

The impact of T2DM duration extends to mortality risks, with various studies examining the association between longer disease duration and elevated risks of premature death.

The risk of premature mortality increases with T2DM duration. Individuals who have had T2DM for more than five years experience a 23% increased risk, and those with more than 10 years of T2DM duration experience a 36% higher risk[16]. There is also a 15% increase in the risk of all-cause death for each 5-year increase in disease duration[15]. A 2023 study found a 76% increased mortality risk in those with 1-4 years T2DM duration and a 116% increased mortality risk in those with ≥30 years duration[150].

A study in Mexico reported that death from renal disease, infection, and cardiovascular causes all increased with T2DM duration[151]. The combined death rates from these causes were 5 times higher in those with less than 5 years of T2DM duration and up to 12 times higher in those with 10 or more years of disease duration when compared to nondiabetics[151]. Whereas a study in Verona found that death rates from both natural and diabetes-related diseases increase with an increased duration of T2DM [131], and a UK study saw an association between increased disease duration and higher risks of all-

cause mortality[126]. Interestingly, a study also suggests that the increase in mortality risks associated with longer T2DM duration is independent of other risk factors, including cardiovascular risk factors[152].

2.8 Knowledge Gap

The existing literature reveals a significant gap in our understanding of the impact of T2DM duration on physical functioning, frailty status, and glycemia after a lifestyle intervention, particularly in the context of resistance training programs for frail older adults. High-quality studies directly comparing the response of short- and long-duration T2DM cohorts to exercise interventions are scarce. Most existing studies either include T2DM duration as a baseline characteristic or to examine surgical outcomes, medication usage, or the role of long-duration T2DM as a risk factor for various complications.

To our knowledge, only one study has been conducted to compare the impact of diabetes duration exercise intervention efficacy. This 2016 study, conducted by Park et al. (2016), used elastic band resistance training on a cohort of 26 women with T2DM, categorized into short (3 +/- 2 years) or long (10 +/- 3 years) duration T2DM groups. Following a 12-week intervention, favourable outcomes were observed in both groups for glycemia, body composition, and physical function[13]. While the long-duration T2DM group demonstrated greater improvement in some areas, including grip strength, no significant effect of T2DM duration was noted[13]. However, this study had a small sample size, only included female participants, did not include older adults (>65 years), did not consider frailty status, and involved a high-volume exercise regime of twice a day, five days a week for 12 weeks.

As the global population is aging and co-occurring age-related conditions like T2DM and frailty are known to exacerbate each other, it is important to understand how different factors influence the efficacy of interventions. Further research is required to determine whether there is a meaningful difference in the response rate to exercise interventions based on the duration of T2DM, especially considering frail older adults.

2.9 Objective

The aim of this secondary analysis is to compare the changes in physical functioning, glycemia, and frailty between individuals with short- and long-duration T2DM who participated in 16 weeks of elastic band resistance training.

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Chapter 3: Article

The Impact of Type 2 Diabetes Duration on Physical Functioning, Frailty Status, and Glycemia After 16 Weeks of Resistance Training: Results from the Band-Frail Study

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Chapter 3: Article

3.1 Abstract

Background: Type 2 diabetes (T2DM) duration's impact on lifestyle intervention efficacy for frail older adults is unclear.

Objective: To compare physical functioning, glycemia, and frailty between individuals with short-and long-duration T2DM after the Band-Frail program.

Methods: This secondary analysis of the Band-Frail Study includes 130 adults (≥65 years) with T2DM and frailty who completed 16 weeks of elastic band resistance training. Participants were categorized as 1) short-duration T2DM (<10 years) and 2) long-duration T2DM (≥10 years). Outcome measures included physical functioning (SPPB), glycemia (HbA1c), and frailty (Fried's scale).

Results: Participants in both T2DM duration groups improved in SPPB score and frailty status post-intervention (p <0.05). The long-duration group improved HbA1c significantly more than the short-duration group (p =0.03).

Conclusion: Our findings suggest that individuals, irrespective of T2DM duration, improve physical functioning and frailty status after the Band-Frail intervention, and that longer-duration T2DM is associated with greater improvements in HbA1c.

3.2 Introduction

As the global proportion of older adults (≥ 65) is rapidly increasing, the prevalence of age-related conditions follows a similar trend. Older adults face an increased risk of chronic diseases and age-related syndromes, including frailty[1] and type 2 diabetes mellitus (T2DM). Frailty is a geriatric syndrome characterized by declines in physiologic reserve across multiple systems, resulting in heightened vulnerability[2,3]. T2DM is a progressive metabolic disorder characterized by chronic hyperglycemia due to pancreatic beta-cell dysfunction[4,5]. In older adults, T2DM and frailty are known to exacerbate each other, leading to accelerated declines in physical functioning and loss of independence, thereby increasing the financial strain on healthcare systems[6]. As over 220 million older adults worldwide are living with the dual burden of T2DM and frailty[7], understanding how to manage these coexisting conditions is imperative.

To counteract the consequences of an aging population, optimizing lifestyle interventions and facilitating widespread implementation could offer a viable solution. While lifestyle interventions are a cornerstone in T2DM management[8] and slowing frailty progression[9], they can be expensive and logistically challenging to implement. Resistance training has proven effective in managing these conditions and their complications in older adults by improving muscle strength and physical functioning[8,10,11]. Elastic band resistance training provides a more cost-effective and accessible alternative to traditional resistance training that provides similar benefits for T2DM and frailty independently[12–14]. Yet, few studies examine the coexistence of these conditions and the impact of lifestyle interventions in individuals with the coexistence of these conditions. An intervention that targets T2DM and frailty, using inexpensive resistance equipment and leveraging existing

resources could benefit a community setting and maximize the impact of limited resources.

An underappreciated risk factor in managing T2DM and its complications in older adults is diabetes duration. Longer disease durations can amplify the risks of micro and macrovascular complications[15], premature mortality[16], and functional limitations[17] and may influence the effectiveness of lifestyle interventions. To our knowledge, only one study has investigated the effects of diabetes duration on exercise intervention efficacy. The study consisted of 12 weeks of exercise, five times a week: two to three sets of fifteen to twenty repetitions of ten elastic band resistance exercises spread over two daily sessions[13]. Following the intervention, participants with both short- and long-durations of T2DM improved in measures of physical functioning, with the long-duration cohort exhibiting more pronounced improvements in certain areas[13].

As the prevalence of diabetes and frailty is expected to increase, and the number of intervention studies on older adults with T2DM and frailty is scarce, understanding factors that impact the efficacy of a community intervention in improving physical functioning in older adults is essential to prevent consequences of each condition, optimize intervention prescriptions, and lessen the burden on healthcare systems. Therefore, this study aims to investigate how T2DM duration impacts the efficacy of a 16-week elastic band resistance training intervention to improve physical functioning in older adults with T2DM and frailty.

3.3 Methodology

3.3.1 Study Design

This study is a secondary analysis of the Band-Frail study. The Band-Frail study was a 16-week case series design intervention for older adults living with frailty and T2DM. The community program ran in 14 locations across the province of New Brunswick, implementing an elastic band resistance training and diabetes education intervention. This analysis will examine if diabetes duration impacts the effects of the Band-Frail program on physical functioning in older adults living with T2DM and frailty. All participants provided written informed consent prior to participating and data collection. This project was reviewed and approved by the University of New Brunswick Research Ethics Board (REB 2020-029).

3.3.2 Sample Size

A power sample calculation was performed using G-power software (version 3.1.9.4, Germany) to determine the sample size. Using an independent sample t-test we are expecting a difference of 0.65 points on the total SPPB score with an alpha of 0.05 and a power of 0.8. Based on this calculation, a sample size of 39 participants in each T2DM duration group was required for an overall sample size of 78. However, in order to be conservative and because some studies report a 30-50% dropout rate within 6 months of intervention,[18] we anticipated a dropout rate of 40-45%. Therefore, to account for this dropout rate, we recruited a total of 110 participants.

3.3.3 Participants

Participants were recruited between April 2021 and August 2022 through promotional flyers, digital advertising, social media, newspaper and radio advertisements,

presentations to senior groups, articles in senior journals and handbooks, newsletter articles, and programmatic displays.

Participants were considered eligible for this analysis if they were: 1) aged over 65 years, 2) classified as pre-frail or frail on Fried's frailty scale, 3) self-reported a diagnosis of T2DM. Freid's frailty scale is a five-item frailty scale including: I) Unintentional weight loss of 10lbs OR 5% of their body weight in the past year, II) Exhaustion based on the Center for Epidemiologic Studies Depression Scale, III) Lowest 20th percentile in physical activity level based on the Minnesota Leisure Time Activity Questionnaire, IV) Slowest 20th percentile in walking speed based on sex and height, and V) Weakest 20th percentile for grip strength based on sex and BMI. Participants were given a score of one for each criterion they met. The criteria scores were then summed to create a final score. Participants who scored three or higher were considered frail, individuals who scored one or two were considered pre-frail, and those who scored zero were considered robust.

A total of 167 participants completed the Band-Frail study; participants excluded from this analysis were 1) robust on Fried's frailty scale (n=20) and 2) missing T2D duration and/or primary outcome measures (n=17), resulting in a total sample size of 130 individuals. Participants who reported a T2DM duration ± 2 years of the 10-year duration cut point (n=18) were excluded from the between group comparison, resulting in a sample size of 112 individuals (Figure 1).

3.3.4 The Band-Frail Intervention

In the Band-Frail study, participants attended a baseline testing session, 16 weeks of exercise and education intervention, and a post-testing session. The post-testing

sessions occurred at least 48 hours after the final exercise session but no more than one week after the final session. Throughout the intervention, participants attended two elastic band resistance training sessions a week and one diabetes education session a week.

Exercise Component

The Band-Frail exercise program followed a program developed by Diabetes Canada in 2019. Participants underwent 16 weeks of supervised, progressive full-body resistance training using elastic resistance bands. The program began with a progressive start; participants performed eight exercises at each session in week one, ten exercises in week two, and twelve exercises for the remaining fourteen weeks (Appendix 1). The exercises included chair sit-to-stands, seated chest press, seated upper back reverse fly, seated single arm row, seated single arm shoulder press, seated single arm lateral raise, seated single arm bicep curl, seated single arm triceps extension, seated single leg quadriceps extension, standing hamstring curl, standing leg extension, and seated abdominal crunches.

There was a progression of exercise volume and intensity throughout the study. In week one, participants started with one set of eight repetitions of each exercise and then progressed to three sets of ten repetitions by week fourteen. The rest between each set was 60 seconds, and the rest between exercises was self-determined by participants. The level of resistance band each participant exercises with was determined using the 6-20 Borg rating of perceived exertion (RPE) scale. In weeks one and two, participants were expected to have a light RPE (11 or under), in weeks 3-13 a moderate RPE (12-13), and in weeks 14-16 a somewhat hard RPE (14) (Appendix 1-2). The supervisor could also

change the participant's elastic band resistance if they deemed it to be hindering the participant's form.

Diabetes Education Component

The diabetes education information presented to participants was developed in collaboration with a certified diabetes educator and a registered dietitian, using information from Diabetes Canada. A certified diabetes educator delivered the education sessions to participants once a week before an exercise session. The diabetes education content covered topics relating to T2DM management with tips on how to help manage T2DM-related complications.

3.3.5 Exposure Variable- Diabetes Duration

Participants' T2DM duration was self-reported during baseline testing and recorded as time in years since clinical diagnosis. The participants were categorized as follows: short-duration T2DM: T2DM duration <10 years and long-duration T2DM: T2DM duration ≥10 years. Although there are no universally accepted cut-points for diabetes duration, recent research suggests that with exercise interventions, a shorter T2DM duration coupled with other lifestyle interventions could induce T2DM remission[19], which allows this study to be compared with results from pre-existing literature. As self-reported disease duration can be impacted by recall bias, and a previous study has found that on average, self-reported T2DM duration is one year and eight months earlier than physician report, individuals with a T2DM duration ± 2 years of a 10-year disease duration were excluded from the between group analysis. T2DM duration was also explored as a continuous variable and through additional cut-points of 3 years, 5

years, 15 years, and 20 years to gain a broader understanding of the impact of disease duration.

3.3.6 Primary Outcome Measure- Physical Functioning

Physical functioning was measured using the Short Physical Performance Battery (SPPB)[20] before and after the 16-week intervention. The SPPB is a standardized test including balance, gait, and chair stand components scored out of 12 points.

The first part of the test involved three 10-second balance tests. The participants were asked, in order, to hold a side-by-side stance, a semi-tandem stance, and a tandem stance. If the participant failed to maintain balance for 10 seconds in one of the positions, the balance portion of the test was terminated. One point was scored for completing the side-by-side stance, two points were scored for completing the semi-tandem stance, three points were scored if the participants held the tandem stance for 3 to 9.99 seconds, and four points were scored if they completed the tandem stance. Participants were given a score of 0 if they could not complete the first 10-second side-by-side stance.

Gait speed was measured using a three-meter walk test. A walking aid was permitted during this portion of the test if required. Participants were asked to walk at their normal walking speed for three meters. If the participants took more than 6.53s to walk the three-meter distance, one point was scored; if their speed was between 4.66s to 6.52s, two points were scored; a walking speed between 3.62s and 4.65s was given three points; and if the participant had a walking speed of less than 3.62s four points were scored. If the participant could not complete the walking test, a score of zero was given.

The chair stand test involved timing how long it took for participants to perform five chair sit-to-stance without using their arms. Points were recorded based on how fast

the chair sit-to-stands were completed. If the participant was faster than 11.20s, they received four points; if the participant took between 11.20s and 13.69s, they received three points; if the participant completed the test between 13.70s and 16.69s, two points were given; and one point was recorded if the participant took between 16.70s and 59.99s to complete the test. If the participant took longer than 60s or could not complete the test, a score of zero was recorded.

3.3.7 Exploratory Outcome Measure- Frailty (Fried's Frailty Scale)

Frailty was measures using Fried's frailty scale. The scale includes five frailty criteria including: unintentional weight loss, exhaustion, low physical activity, slowness, and weak grip strength. Weight loss was self-reported by participants. Exhaustion was measures using the Center for Epidemiological Studies Depression Scale questions. Low physical activity level was assessed using the Minnesota leisure physical activity questionnaire. Slowness was measured via a 15-foot walking test, and weak grip strength was measured in the dominant hand with a hand dynamometer.

Participants were scored in each of the five criteria and then given a cumulative score to represent their frailty status. Participants who scored three or higher were considered frail, individuals who scored one or two were considered pre-frail, and those who scored zero were considered robust, as discussed in the inclusion criteria.

3.3.8 Exploratory Outcome Measure- Glycemia (HbA1c)

Glycemia, measured by glycated hemoglobin (HbA1c), was recorded for a subset of participants (n = 74) prior to and upon completion of the Band-Frail program at the Fredericton, New Brunswick location. A finger prick was conducted using a Safe-T Pro Plus single-use lancet to collect a 1 microliter sample of whole blood. The sample was

then loaded into a DCA Vantage Analyzer (V 4.4.0.0, Germany) where the rapid assessment of HbA1c was conducted.

3.3.9 Statistical Analysis

The normality of the data was assessed using the Kolmogorov-Smirnov test and confirmed with a visual inspection of the data. General characteristics for the sample are presented as mean ± standard deviation (SD) for continuous variables and n (%) for categorical variables unless otherwise stated. Paired sample t-tests were performed to assess changes from baseline, while independent t-tests were performed to test for differences in these changes between the short- and long-duraiton T2DM groups. Linear regression models were performed for all outcome measures to adjust for confounding variables. A significance level was accepted at $p < 0.05$, and all analyses were performed using IBM SPSS statistics version 22.0.

3.4 Results

3.4.1 Descriptive Characteristics

Of the 130 participants included in this analysis, 49 were with short-duration T2DM, 63 with long-duration T2DM, and 18 were ± 2 years of a 10-year duration and only included for the regression analysis using the continuous variable. An overview of the baseline descriptive characteristics is outlined in Table 1. Briefly, the average diabetes duration of the short-duration cohort was 4.2 ± 2.4 years and 21.1 ± 7.6 years ($p < 0.01$) for the long-duration cohort. There were no significant differences in Fried frailty score, grip strength, SPPB total score or any SPPB components (all $p > 0.05$) between the duration groups. Glycemia differed significantly between the groups at baseline ($p = 0.03$) with an average of 7.1 ± 1.0 in the short-duration cohort and 7.8 ± 1.4 in the long-duration group. The long-duration T2DM cohort was older ($p = 0.04$), took a greater number of T2DM medications ($p < 0.01$), and had a greater number of individuals taking insulin ($p < 0.01$) than the short-duration cohort.

3.4.2 Changes in Physical Functioning

Table 2 describes the impact of the Band-Frail program on physical functioning in frail older adults with long and short durations of T2DM. Significant changes were observed in total SPPB score ($p <0.01$), SPPB chair stand score ($p < 0.01$), and SPPB gait speed score ($p < 0.05$) for both the long- and short-duration T2DM groups. The long-duration cohort also experienced a significant change in the SPPB balance score ($p = 0.02$) and grip strength ($p = 0.04$). No changes in physical functioning were significantly different between the duration cohorts (all $p > 0.05$) and there was no association between T2DM duration and percent change in total SPPB score when controlling for age and sex

(Tables 3-4). Further analysis exploring T2DM duration continuously and using alternative cut-points showed similar results.

3.4.4 Changes in Frailty

A significant change in frailty status was also observed in both the short- and long-duration T2DM cohorts ($p < 0.01$) based on Fried's frailty scale. A total of 20 participants (11 from the short-duration cohort and 9 from the long-duration) scored as robust after the intervention, and the number of participants with a frail score decreased from 24 to 10 after the intervention. The weight loss and physical activity components of Fried's frailty scale improved in both duration groups ($p < 0.05$). The short- and long-duration groups also improved in exhaustion ($p = 0.03$) and slowness ($p = 0.02$), respectively, post-intervention. No between duration group differences were observed in overall frailty score or component changes (all $p > 0.05$). Linear regression analysis revealed no effect of T2DM duration on the percent change of total frailty score when controlling for differences in sex and age (Tables 3-4). Further analysis exploring T2DM duration continuously and using alternative cut-points showed similar results.

3.4.3 Changes in Glycemia (HbA1c)

A significant change in glycemia was observed in the long-duration cohort with an average decrease of 0.5 ± 1.0 ($p < 0.01$) in HbA1c after the Band-Frail intervention, with 18 (48.6%) participants decreasing their HbA1c by the MCID of 0.3% or more. The short-duration cohort had 9 (34.6%) participants reaching the -0.3% threshold, however there was not a significant change ($p > 0.05$). A significant difference in glycemia change was observed between those with long-duration T2DM and those with short-duration T2DM ($p < 0.01$). Linear regression analysis revealed an effect of continuous T2DM

duration on percent change in HbA1c when controlling for age and sex ($p < 0.05$). This effect of T2DM duration remained significant when comparing the short- and long-duration groups ($p < 0.05$). Number of T2DM medications used was not significantly different between the duration cohorts in this subsample. Changes in glycemia remain similar when examining a 5-year split of T2DM duration but become nonsignificant when incorporating larger year categories due to the unequal distribution of participants among T2DM duration groups.

3.5 Discussion

The main objective of this secondary analysis was to investigate T2DM duration-based differences in physical functioning, frailty status, and glycemia after a 16-week resistance training and diabetes education intervention for older adults living with T2DM and frailty. The principal findings of this study suggest that individuals with short- and long-duration T2DM improved physical functioning and frailty status to the same extent following the Band-Frail program. Furthermore, our sub-analysis of glycemia indicates that individuals with longer-duration T2DM may see a greater change in glycemia post-intervention compared to short-duration T2DM. These results are important as they offer insight into the role of diabetes duration in intervention efficacy for older adults living with both T2DM and frailty.

This analysis of the Band-Frail intervention revealed significant improvements in physical functioning after 16 weeks of elastic band resistance training and diabetes education, regardless of T2DM duration. Approximately 80% of participants —72% of the short-duration cohort and 85% of the long-duration cohort— exhibited a meaningful clinically important change in their total SPPB score, improving by one or more points [21]. Although our analysis did not detect differences between T2DM duration cohorts in SPPB components, total score, or grip strength, our results align with previous research on the impact of resistance training for T2DM. For instance, the MID-Frail study conducted by Rodrigues-Manas et al. (2019) reported a comparable increase (0.86 points) in total SPPB score among older adults with coexisting T2DM and frailty who underwent diabetes education and traditional resistance training using weight machines[22]. Similarly, Park et al. (2016) observed no T2DM duration effects on physical functioning outcomes in

response to an elastic band resistance training program for women with T2DM[13]. Interestingly, aligning with the present study results, Park et al. (2016) reported a significant increase in grip strength in the long-duration participants, which was not reflected in the short-duration participants, despite a lack of between-group differences[13]. As the long-duration cohorts in both studies had non-significant tendencies for lower grip strength at baseline, this could have provided an opportunity for greater improvement post-intervention compared to the short-duration cohorts. However, as Park et al. (2019) did not report frailty status and had a younger long-duration group (59 years vs. 74 years) with a shorter average disease duration (10 years vs. 21 years), the Band-Frail study suggests that the potential for grip strength to increase after elastic band resistance training persists as T2DM and frailty progress. This improvement in grip strength is important due to grip strength's role as a predictor of overall muscle strength and physical functioning[23]. Alternatively, the change in grip strength could be related to glycemia as the duration groups differed in HbA1c pre- and post-intervention; weaker grip strength has been associated with higher HbA1c[24] and greater changes in HbA1c have been associated with increased in muscle strength[25]. Likewise, the SPPB balance score improved only in our long-duration cohort post-intervention. A recent meta-analysis supports these findings as participants with > 10 years T2DM duration performed better in certain balance tests after exercise interventions than those with < 10 years disease duration[26]. The difference in baseline scores between duration cohorts in the present study may explain the varied outcomes, as the short-duration cohort began with a perfect median SPPB balance score of four points, limiting the room for improvement. Despite these observed differences,

participants with both long and short durations of T2DM significantly improved physical functioning following the Band-Frail program.

Following four months of elastic band resistance training and diabetes education, we demonstrate that individuals with short- and long-durations of T2DM similarly improve their frailty status. Studies examining frailty independently of T2DM have found that resistance training can significantly improve frailty status in older adults [9,10,27]. For instance, Chen et al. (2020) found that after eight weeks of supervised elastic band resistance training, nearly 82% of pre-frail older adults returned to non-frail/robust status[14]. As SPPB score can be predictive of frailty[28], especially when considering a frailty scale using physical criteria, it is possible that a greater increase in total SPPB score could be synonymous with a decrease in the number of frailty criteria met. This interaction between physical functioning and frailty status is reflected in the findings of Garcia Diaz et al. (2019), who investigated the impact of a 6-month elastic band resistance training and aerobic exercise intervention in older adults with T2DM and frailty[29]. They observed improvements in Fried's frailty criteria for 47.7% of participants and an increase in SPPB score for 47.6%[29]. However, this intervention was not supervised, resulting in a nearly 50% nonadherence rate to the resistance training component, and T2DM duration was not reported[29]. In the current analysis, this overlap of frailty status and physical functioning may explain the lack of duration-based impacts on change in frailty status, as both groups significantly improved in physical functioning measures and frailty status after the Band-Frail program. These results may suggest that despite the role of T2DM duration in increasing risks of complications and rapid declines in physical functioning, individuals of long- and short-duration T2DM can obtain the same benefits in physical functioning

and frailty status from a supervised, community-based elastic band resistance training and diabetes education intervention.

Our sub-analysis of glycemia revealed a significant reduction in HbA1c among participants with long-duration T2DM and an association between T2DM duration and HbA1c change following the Band-Frail intervention. The findings of Tan et al. (2012), who examined the impact of six months of combined aerobic and resistance training in older adults with longstanding T2DM (16.7± 6.7 years) and saw an average 0.55% decrease in HbA1c[30], support the 0.54% average decrease in HbA1c observed in the long-duration T2DM participants after the Band-Frail intervention. The similar reduction in HbA1c between studies may also indicate that for older adults with longer durations of T2DM and frailty, 16 weeks of elastic band resistance training can elicit comparable changes in glycemia to six months of combined aerobic and resistance training. Conversely, previous research has primarily reported significant reductions in HbA1c among individuals with < 10 years disease duration only[19], or no impact of T2DM duration on changes in HbA1c after a lifestyle intervention[13,31]. However, many studies examining changes in HbA1c in individuals with shorter disease duration do not directly compare with groups of varying disease durations, do not consider frailty status, and are primarily focused on inducing T2DM remission, rendering direct result comparison unrealistic for our analysis. Our results also diverge from those of Park et al. (2016), who observed greater changes in glycemia than our data in both their long- and short-duration T2DM participants but found no between-duration group differences. The magnitude of difference in HbA1c change may be attributed to exercise exposure, as participants in the Park et al. (2016) study performed whole-body elastic band resistance training twice a

day, five days a week, for 12 weeks – substantially more than participants in the Band-Frail program. The difference in T2DM duration group-based differences could be related to the greater variation in disease duration in our analysis, with an almost 17-year difference between the average disease durations of the cohorts compared to the approximately 7-year difference between Park et al. (2016) duration groups. This difference could suggest that a longer diabetes duration may be required to detect between-group differences in HbA1c change. The current findings support the notion that resistance training alone can positively impact HbA1c[11–13,32], and that the Band-Frail elastic band resistance training program presents an effective alternative to traditional weight training[12,14,29,33] for older adults with longer durations of T2DM.

3.5.1 Strengths and Limitations

The current analysis has some limitations that should be acknowledged. First, the Band-Frail program did not include a non-experimental control group, which minimizes the conclusions drawn from this study. Second, the primary exposure variable of this analysis is a self-reported duration of T2DM which could be impacted by recall bias. However, to control for that approximate 2 year bias recall in self-reported T2DM duration, participants with a 10 ± 2 years duration were excluded from the analysis[34]. Third, this analysis did not include or account for nutritional information. Finally, using the SPPB as our primary test of physical functioning may not have been representative of all changes observed from the whole-body Band-Frail intervention due to the SPPB's focus on lower limb functionality. Nonetheless, this analysis is strengthened by incorporating a sample size appropriately powered to detect differences in physical functioning and controlling for baseline differences in the analysis. Additionally, the

Band-Frail intervention was progressive in intensity, and involved small, supervised group exercise sessions, allowing for well controlled exposure to the exercise intervention.

3.6 Conclusion

This analysis demonstrates that individuals living with T2DM and frailty, irrespective of T2DM duration, can improve physical functioning and frailty status through a 16-week elastic band resistance training and diabetes education intervention. The results also suggest that longer durations of T2DM are associated with greater improvements in glycemia when compared to shorter durations of T2DM after adjusting for relevant confounders. The findings presented offer further insight into managing comorbid T2DM and frailty in older adults and understanding the potential role of T2DM duration in an intervention. Future studies should continue to investigate the impact of T2DM duration on exercise interventions for older adults through randomized controlled trials to confirm these findings.

3.7 References

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Table 1- Descriptive Characteristics

	Total Sample	Short-Duration T2DM <10 Years	Long-Duration T2DM > 10 Years	*p*
n (%)	130	49 (43.8)	63 (56.2)	
Age	72.9 ± 5.4	71.7 ± 5.4	73.8 ± 5.2	**0.037**
Male n (%)	56 (43.1)	18 (36.7)	31 (49.2)	0.188
Ethnicity				
White n (%)	127 (97.7)	47 (95.9)	62 (98.4)	0.311
Smoking Status				
Current Smoker n (%)	3 (2.3)	1 (2.0)	2 (3.2)	0.715
Household Income				
Below $50000	57 (43.8)	25 (51.0)	24 (38.1)	
$50000-$100000	45 (34.6)	17 (34.7)	24 (38.1)	0.876
More than $100000	12 (9.2)	4 (8.2)	7 (11.1)	
Did Not Answer	16 (12.3)	3 (6.1)	8 (12.7)	
T2DM				
Diabetes Duration (years)	13.2 ± 9.6	4.2 ± 2.4	21.1 ± 7.6	**<0.001**
Age at Diagnosis (years)	59.8 ± 10.3	67.5 ± 6.2	52.8 ± 8.9	**<0.001**
HbA1c (%)	7.6 ± 1.3	7.1 ± 1.0	7.8 ± 1.4	**0.032**
Fried's Frailty Criteria				
Weight loss n (%)	12 (9.2)	5 (10.2)	5 (7.9)	0.680
Exhaustion n (%)	47 (36.2)	18 (36.7)	20 (31.7)	0.584
Physical Activity n (%)	65 (50)	24 (49.0)	32 (50.8)	0.851
Slowness n (%)	25 (19.2)	6 (12.2)	15 (23.8)	0.110
Weakness n (%)	88 (67.7)	29 (59.2)	46 (73.0)	0.130
Pre-Frail n (%)	101 (77.7)	40 (81.6)	48 (76.2)	0.259
Frail n (%)	29 (33.3)	9 (18.4)	15 (23.8)	0.861
Fried Frailty Score (0-5)	1.8 ± 1.0	1.7 ± 1.0	1.9 ± 1.0	0.301
Physical Functioning				
Grip Strength (kg)	22.8 ± 8.4	24.5 ± 9.1	21.8 ± 8.0	0.096
Physical Functioning (0-100)	58.6 ± 23.9	61.2 ± 21.8	57.1 ± 26.4	0.374
SPPB Balance Score (0-4)	3.3 ± 0.9	3.5 ± 0.9	3.1 ± 1.0	0.056
SPPB Gait Speed Score (0-4)	3.3 ± 0.8	3.4 ± 0.7	3.2 ± 0.9	0.204
SPPB Chair Stand Score (0-4)	2.0 ± 1.1	2.0 ± 1.1	2.0 ± 1.1	0.842
SPPB Total Score (0-12)	8.6 ± 2.2	8.9 ± 1.9	8.4 ± 2.3	0.158
Medications				
Diabetes (n)	1.7 ± 1.0	1.4 ± 0.8	1.9 ± 1.0	**0.005**
Insulin n (%)	27 (20.8)	4 (8.2)	20 (31.7)	**0.001**
Cholesterol (n)	0.7 ± 0.5	0.7 ± 0.5	0.8 ± 0.5	0.123
Blood Pressure (n)	1.8 ± 1.3	1.6 ± 1.3	1.9 ± 1.3	0.224

Continuous variables presented as mean ± standard deviation, categorical variables presented as n (%). P-values calculated using paired-sample t-tests.

Table 2- Within and Between Group Changes After Band-Frail Intervention

	Short-Duration T2DM < 10 Years			Long-Duration T2DM > 10 years		
	Baseline	**Post**	***p***	**Baseline**	**Post**	***p***
Glycemia n (%)	**26 (40)**			**37 (60)**		
HbA1c (%)	7.1 ± 1.0	7.1 ± 1.1	0.404	7.8 ± 1.4	7.3 ± 1.2	0.002*
Fried's Frailty Criteria n (%)	**49 (43.8)**			**63 (56.2)**		
Weight loss n (%)	5 (10.2)	0	0.024	5 (7.9)	0	0.024
Exhaustion n (%)	18 (36.7)	10 (20.4)	0.031	20 (31.7)	15 (23.8)	0.255
Physical Activity n (%)	24 (49.0)	15 (30.6)	0.002	32 (50.8)	18 (28.6)	<0.001
Slowness n (%)	6 (12.2)	4 (8.2)	0.322	15 (23.8)	8 (12.7)	0.018
Weakness n (%)	29 (59.2)	28 (57.1)	0.785	46 (73.0)	43 (68.3)	0.410
Robust n (%)	0 (0)	11 (22.4)		0 (0)	9 (14.3)	
Pre-Frail n (%)	40 (81.6)	35 (71.4)		48 (76.2)	47 (74.6)	
Frail n (%)	9 (18.4)	3 (6.1)		15 (23.8)	7 (11.1)	
Fried Frailty Score (0-5)	1.7 ± 1.0	1.2 ± 0.9	<0.001	1.9 ± 1.0	1.3 ± 0.9	<0.001
Physical Functioning n (%)	**49 (43.8)**			**63 (56.2)**		
Grip Strength (kg)	24.5 ± 9.1	24.4 ± 9.3	0.836	21.8 ± 8.0	22.9 ± 8.0	0.040
Physical Functioning (0-100)	61.2 ± 21.8	67.0 ± 21.6	0.026	57.1 ± 26.4	62.5 ± 24.2	0.002
SPPB n (%)	**42 (41.2)**			**60 (56.2)**		
SPPB Balance Score (0-4)	3.4 ± 0.9	3.5 ± 0.7	0.361	3.1 ± 1.0	3.4 ± 0.8	0.017
SPPB Gait Speed Score (0-4)	3.3 ± 0.7	3.7 ± 0.6	0.009	3.3 ± 0.8	3.5 ± 0.7	0.027
SPPB Chair Stand Score (0-4)	1.7 ± 0.9	2.0 ± 1.1	<0.001	2.0 ± 1.0	2.9 ± 1.2	<0.001
SPPB Total Score (0-12)	8.5 ± 1.7	10.1 ± 1.7	<0.001	8.3 ± 2.2	9.8 ± 2.1	<0.001

Continuous variables presented as mean ± standard deviation, categorical variables presented as n (%). Within group p-values calculated using paired-sample t-tests. * significant difference in magnitude of change between T2DM duration groups using independent sample t-tests.

Table 3- Linear Regression Models for Continuous T2DM Duration and Percent Change of Outcomes

	Sample size	Coefficient	95% CI	*p*
Δ% HbA1c (%)	n= 74	-0.256	[-0.498, -0.013]	**0.039**
Δ% Fried Frailty Score (0-5)	n=130	0.041	[-0.974, 1.057]	0.936
Δ% SPPB Total Score (0-12)	n=119	0.096	[-0.329, 0.520]	0.657

Models includes participants with all T2DM durations. All models adjusted for potential confounders (age and sex) identified through DAG analysis.

Table 4- Linear Regression Models for Categorical T2DM Duration and Percent Change of Outcomes

	Sample size	Coefficient	95% CI	*p*
Δ% HbA1c (%)	n= 63	-5.949	[-10.873, -1.026]	**0.019**
Δ% Fried Frailty Score (0-5)	n=112	-1.190	[-23.303, 20.922]	0.915
Δ% SPPB Total Score (0-12)	n=102	-0.722	[-9.430, 7.986]	0.870

All models adjusted for potential confounders (age and sex) identified through DAG analysis.

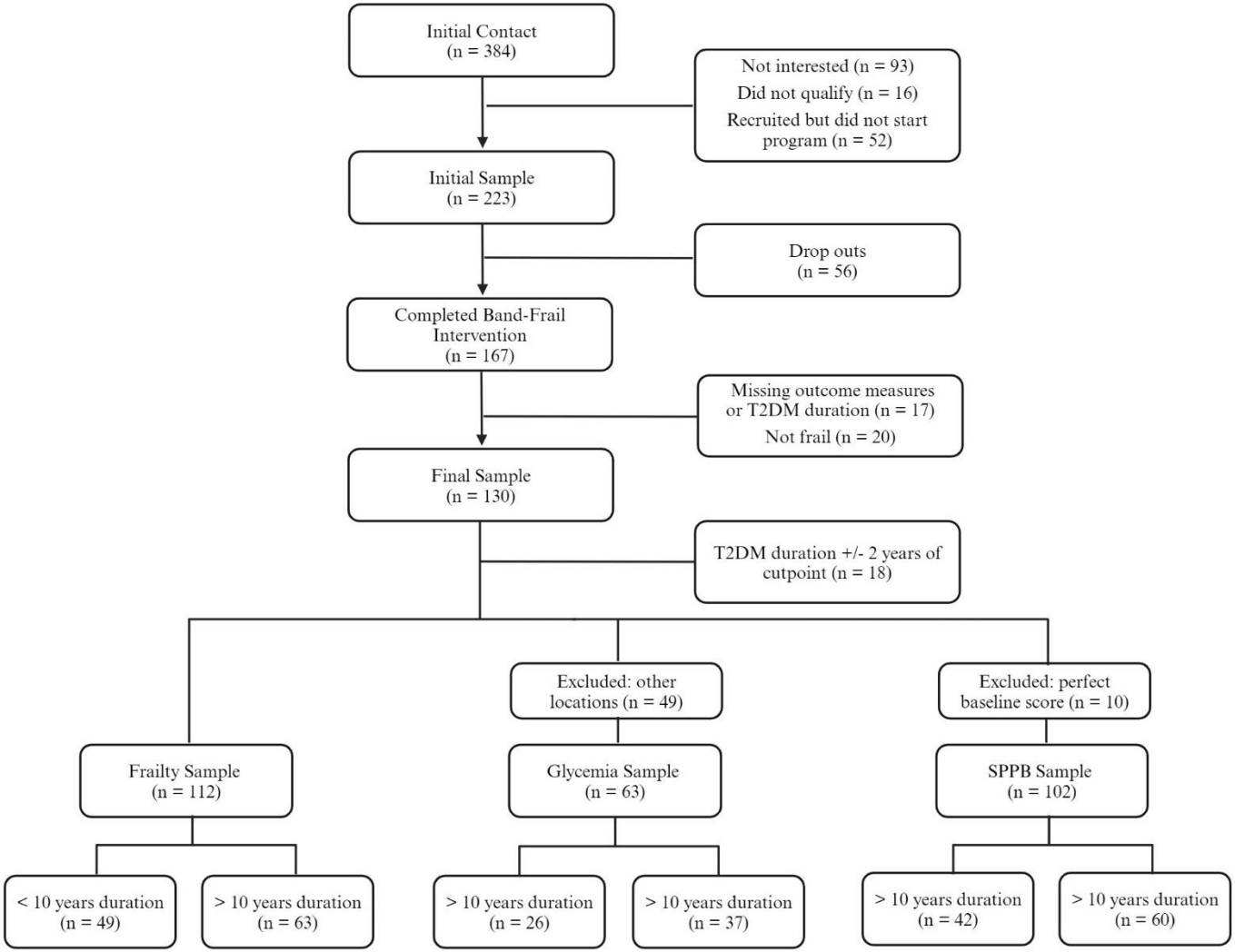


Figure 1: Participant Flow Chart

Appendix:

Appendix 1: Exercise Component Progression

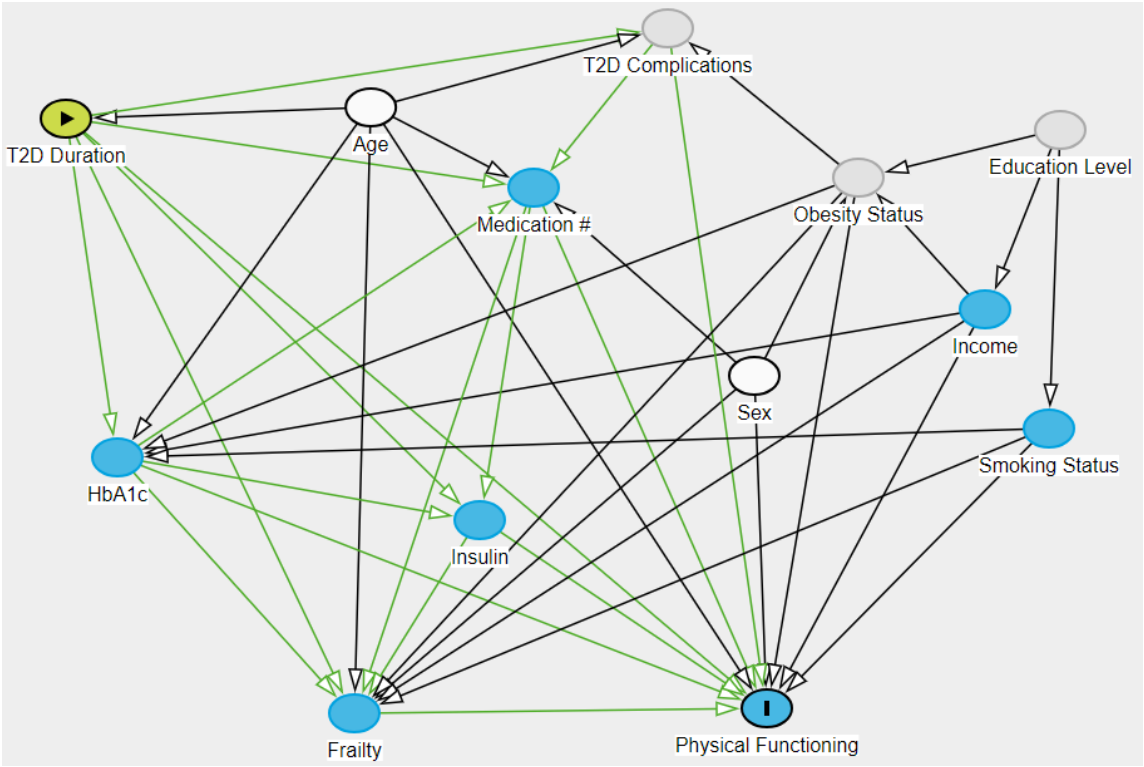
Week	Number of Exercises	Sets	Repetitions	RPE – Borg Scale
1	8	1	8	Light (≤11)
2	10	1	10	Light (≤ 11)
3	12	1	12	Moderate (12-13)
4	12	2	8	Moderate (12-13)
5-7	12	2	10	Moderate (12-13)
8-10	12	2	12	Moderate (12-13)
11-13	12	3	8	Moderate (12-13)
14-16	12	3	10	Somewhat Vigorous (≥14)

Appendix 2: Elastic Resistance Band Scale

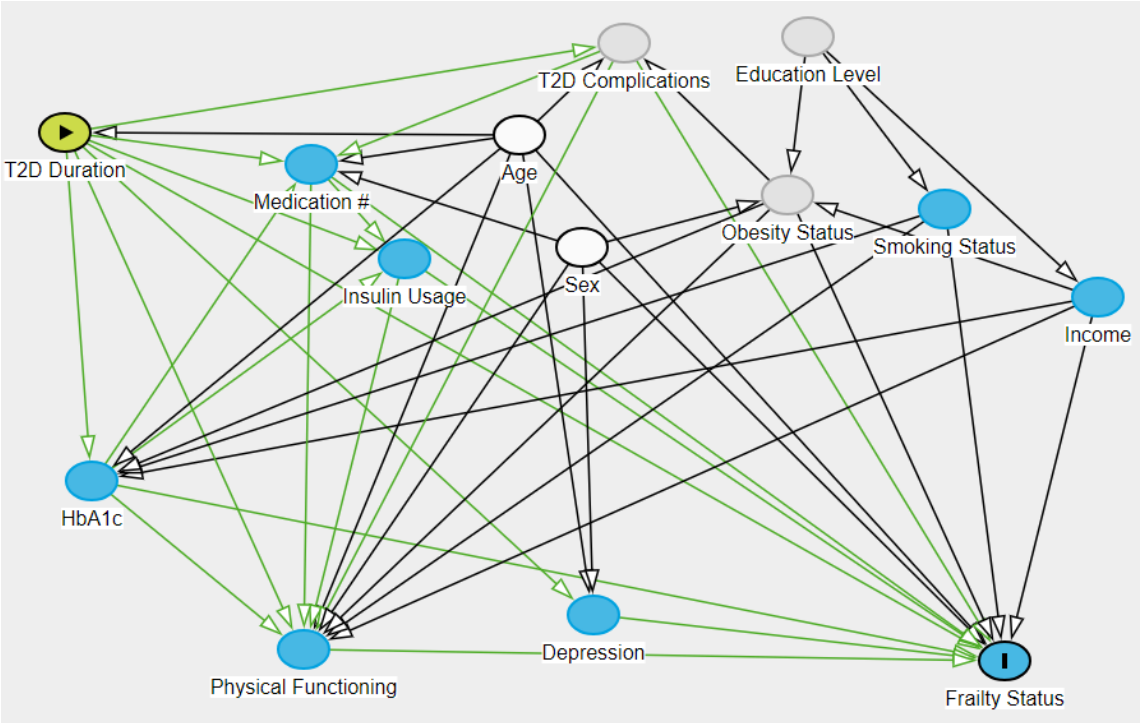
Elastic Resistance Band Colour	Extension Load (lbs)	Intensity
Peach	6	Light
Orange	9	Light to Moderate
Green	12	Moderate
Blue	15	Moderate to Vigorous
Purple	18	Vigorous

Supplemental Information:

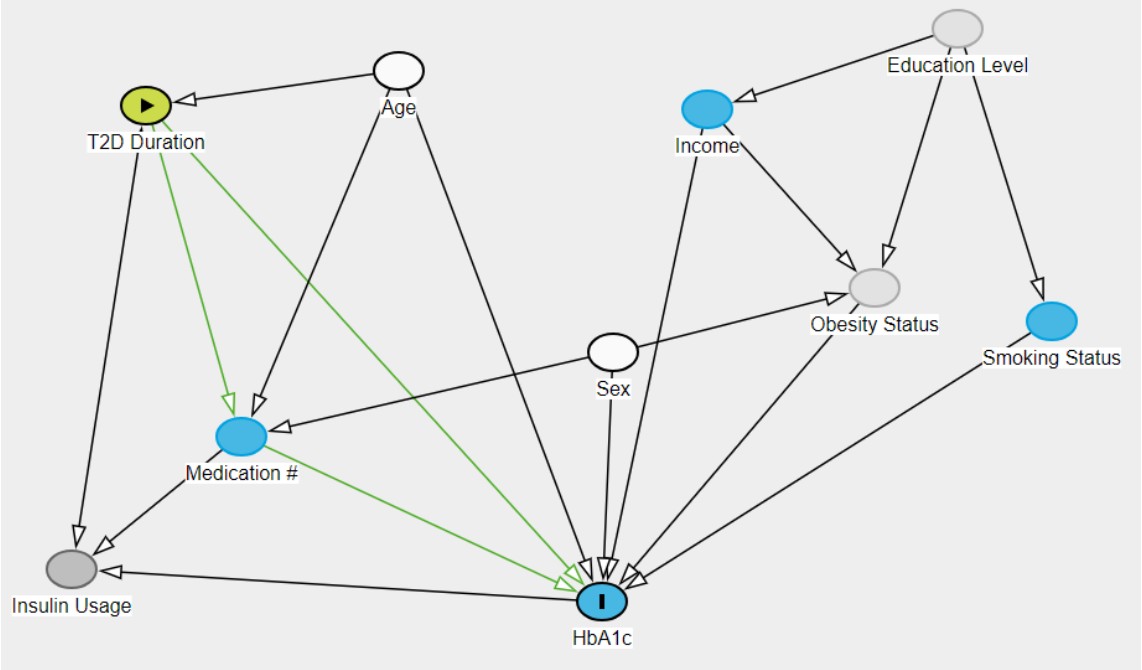
DAG – Physical Functioning Outcome



DAG – Frailty Outcome



DAG – Glycemia Outcome



Curriculum Vitae

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Publications:

Thomson, A.M., Rioux, B.V., Hrubeniuk, T.J., Bouchard, D.R., Sénéchal, M. (2023). *Does Type 2 Diabetes Duration Influence the Effectiveness of an Aerobic Exercise Intervention: Results from the INTENSITY Study*. PLOS ONE. *Under Revision.*

Conference Presentations:

Thomson A.M., Rioux B.V., Hrubeniuk T.J., Bouchard D.R., Sénéchal M. (2023). *Influence of type 2 diabetes mellitus duration on the effectiveness of a lifestyle intervention: results from the INTENSITY study*. Atlantic Provinces Exercise Scientists and Socioculturists: APES+ 2023. Moncton, NB, Ca.

Thomson A.M., Paudel Y., Rioux B.V., Peskett L., Hrubeniuk T.J., Sénéchal M. (2023). *The impact of aerobic exercise on irisin levels in individuals with different T2DM durations*. Research NB Health Research Week: From Paper to Practice. Saint John, NB, Ca.

Thomson A.M., Cull I.C., Bouchard D.R., Sénéchal M. (2024). *The impact of type 2 diabetes duration on physical functioning, frailty status, and glycemia after 16 weeks of resistance training: results from the band-frail study*. Canadian Active Aging Research Meeting. Wolfville, NS, Ca.