Cardiovascular health risk indicators and their associations with meeting the Canadian 24-hour movement guidelines for older females: A cross-sectional secondary data analysis of WARM Hearts cohort study

by

Luming Chen

A Thesis submitted to the Faculty of Graduate Studies of

The University of Manitoba

In partial fulfilment of the requirements of the degree of

MASTER OF SCIENCE

Faculty of Kinesiology and Recreation Management

University of Manitoba

Winnipeg, Manitoba

Abstract

Background: Cardiovascular diseases (CVDs) have been a leading cause of morbidity and mortality among older women worldwide. Lifestyle factors, including physical activity, sedentary behaviour, and sleep patterns, have been identified as modifiable risk factors for CVD. The Canadian 24-hour movement guidelines (24HMG) provide comprehensive recommendations covering these behaviours, yet the association between guideline adherence and cardiovascular health in older females is not well understood.

Objective: This study investigates the association between meeting the Canadian 24HMG and cardiovascular health risk indicators among older females. By exploring this relationship, the study seeks to identify potential public health strategies to mitigate CVD risk in this population.

Methods: Utilizing a cross-sectional secondary data analysis approach, this study analyzed the WARM Hearts cohort, comprising older females aged 55 and above. Key variables included adherence to specific and different combinations of the Canadian 24HMG (physical activity, sedentary behaviour, and sleep) and cardiovascular health risk indicators (Framingham Risk Score, Body Mass Index, waist circumference, etc.). Statistical analyses assessed the associations between movement guideline adherence and cardiovascular health risks.

Results: The study found significant associations between adherence to the Canadian 24-hour movement guidelines and cardiovascular health indicators in older females. Only 2.1% of the sample met all three guidelines, while 44.8% of the sample met one component and 13.5% of the sample met two. Meeting at least one recommendation was linked to better cardiovascular health outcomes, including lower Framingham Risk Score (FRS), reduced waist circumference, lower Body Mass Index, and improved cholesterol levels. The group meeting all three guidelines showed better waist circumference and BMI than those meeting fewer guidelines. The findings

suggest increased adherence to the guidelines is associated with better cardiovascular health outcomes. Meeting physical activity was significantly associated with better cardiovascular health indicators when only one of the three components of the 24HMG was met. Additionally, meeting physical activity and sleep were significantly associated with better cardiovascular health outcomes when any two of the three components of the 24HMG were met.

Proposed Impact: The findings will inform public health interventions and policy-making by identifying the importance of promoting a holistic approach to daily movement behaviours in reducing cardiovascular health risks. By providing data to support the merits of evidence-based recommendations to promote the health of older female adults, this study contributes to the broader goal of enhancing cardiovascular health and well-being in aging populations.

Acknowledgements

Firstly, I would like to thank my advisor, Dr. Todd Duhamel, for his invaluable guidance, constant support, and mentorship throughout my research journey. Working at the Duhamel lab has been an enriching experience, and I am grateful for the camaraderie and collaborative spirit shared among my lab mates.

Thank you to the St. Boniface Hospital Foundation for funding the WARM Hearts research study and the Faculty of Kinesiology and Recreation Management for funding and their support in my academic career.

Finally, I would like to thank my family and friends in China and Canada. Your support and motivation have been the cornerstone of my achievements, and your belief in me has made all the difference.

Table of Contents

List of Tables

List of Figures

Chapter 1: Literature Review

1.1 Cardiovascular Health

Cardiovascular health applies to the health of the heart and blood vessels [1]. Cardiovascular disease (CVD) includes a variety of conditions that may be affected by heart and blood vessel conditions and is the second leading cause of death in Canada [2]. The most prevalent condition is coronary artery disease (CAD), also known as ischemic heart disease, caused by plaque accumulation on the arterial walls. This condition is called atherosclerosis. As plaques build up over time, they can narrow the channels in arteries, reducing or blocking the blood flow through a blood vessel [3]. Poor blood flow to the brain can result in stroke; to the arms or legs can result in peripheral artery disease; to the heart can cause angina or a myocardial infarction. In 2020, it was estimated over 450 million people were living with CVDs, leading to approximately 19.1 million deaths globally [4]. According to 2017-2018 data from the Public Agency of Canada, approximately one in twelve Canadian adults aged 20 and older have been diagnosed with heart disease, and the death rate increases with age; at age 40 and older, those with diagnosed heart conditions have a mortality rate that is 6.3 times higher than those without such conditions [2].

Although cardiovascular conditions can be passed down through generations, many risk factors are preventable or modifiable. Table 1 shows the risk factors that are linked with CVD. These factors are classified into behavioural factors and biological factors. Behavioural factors include smoking, physical inactivity, high sedentary behaviour, and alcohol intake. The biological factors include hypertension, high cholesterol, and diabetes. In addition to the behavioural and biological factors, it is also important to consider the social determinants of health, with a focus on socioeconomic indicators, including income level, education attainment,

occupation, and environmental factors [5]. Notably, Gerber et al. identified a correlation between income level and CVD risk, highlighting that for every $10,000 increase in a neighbourhood's median income, there is a 10% reduction in mortality risk following a myocardial infarction [6]. Moreover, Woodward et al. conducted an extensive study on the association between educational attainment and CVD risk in Australia and New Zealand. They found that individuals with only primary school education have a higher risk of CVD than those with secondary school education [7]. The study also highlights that there is an inverse relationship between higher education and unhealthy behaviours like smoking and poor nutrition [7].

Table 1. Cardiovascular disease risk factors

Behavioural factors	***Biological factors***	***Socioeconomic factors***
Smoking	Hypertension	Income level
Physical inactivity	High cholesterol	Education attainment
High sedentary behaviour	Diabetes	Occupation
Alcohol intake		Environmental factors

The Framingham Risk Score (FRS) is a commonly used tool for predicting an individual's 10-year risk of developing cardiovascular disease for middle-aged and older adults. It was developed using the data from the Framingham Heart Study, a long-term cardiovascular cohort study spanning several decades. The score is based on various factors linked to an increased risk of CVD, including age, gender, smoking status, blood pressure, diabetes, and cholesterol levels [8]. By calculating a person’s FRS, clinicians can classify patients into low-, intermediate-, or high-risk categories, which allows individualized management strategies and preventive interventions. Also, the quantifiable risk scores could help patients understand their risk in tangible terms [9]. Although FRS is a simple and valuable tool, there are some limitations. For example, it may not be as accurate in predicting risk in other ethnicities and age groups due to

the initial derivation from a predominantly Caucasian middle-aged population, as well as it does not account for the duration someone has had a risk factor and only provides a snapshot based on the current risk factor level, which may impact the actual risk trajectory of an individual [10, 11].

1.2 Physical Activity

Physical activity, as defined by the World Health Organization, encompasses "any bodily movement created by skeletal muscles that mandate energy expenditure." [11]. It includes actions resulting from everyday activities and is not limited to activities that relate to occupation, recreation, transportation, and sports. There is adequate evidence demonstrating that regular engagement in physical activity has been associated with significantly reducing the risk of premature mortality [13, 14]. Additionally, physical activity shows an overall benefit to bodily systems, including immunological, musculoskeletal, respiratory, and endocrine systems [13] [14]. Specifically for the cardiovascular system, physical activity increases fatty acid oxidation, cardiac output, and endothelial nitric oxide synthase[15]. Physical activity can be categorized into different exercise modes depending on the frequency, intensity, time, and type. A randomized clinical trial that Church and colleagues conducted showed a positive linear relationship between exercise doses and physical fitness [16]. There is not yet sufficient evidence to establish a minimal level of physical activity necessary to reap health benefits; however, some data suggest that even a small amount of physical activity may be associated with a reduced risk of CVD, particularly among those with very low levels of physical activity, which supports the concept of "even a little is good; more is better" [19, 20].

Historically, aerobic exercise has been the most recommended modality for CVD prevention. Aerobic exercise is defined as using aerobic metabolism to extract energy from muscles, often

performed at low to moderate intensity levels. The advantages of aerobic exercise for adults include boosting the metabolism of skeletal muscles and improving vascular function.Studies show that regularly engaging in aerobic activities improves heart health by increasing the heart's pumping capacity, which reduces the likelihood of arterial blockages by reducing low-density lipoprotein (LDL) levels and promoting elasticity in the arterial walls [21, 22]. Additionally, aerobic exercise can lead to better blood glucose regulation, which helps to fend off type 2 diabetes, as well as reduce adipose tissues by aiding weight management. On a cellular level, aerobic activities can increase mitochondrial density, thus improving cellular energy production and reducing oxidative stress [18]. Anaerobic exercise synthesizes energy sources without using oxygen as an energy source through glycolysis. Anaerobic energy sources are essential for high-intensity exercise. In some cases, high-intensity exercise has more beneficial effects on the cardiovascular system than low-intensity training, particularly in relation to endothelial nitric oxide (NO) production [19].

1.3 History of Physical Activity Guideline

Physical activity guidelines are a set of evidence-based recommendations developed by health organizations and the government to provide guidance on the amount, intensity, duration, and type of physical activity individuals should engage in to improve their health and well-being. The first major recognition of the importance of physical activity came in the 1960s and 1970s when researchers and health professionals began to study the relationship between physical activity and health outcomes. In the early 1960s, The Royal Canadian Air Force Exercise Plans were launched by William Robert Organ, who established the 5 Basic Exercises (5BX) for men and 10 Basic Exercises (XBX) for women. During his research, he learned through evaluating

oxygen consumption that long periods of exercise do not necessarily result in considerable fitness improvements; rather, the intensity of the exercise is more crucial [20]. This concept elicited a negative response from others in the field at the time. Still, it has proven its worth by highlighting the significance of regular exercise for healthy living and increasing awareness of its value [21]. In the late 1960s, former Canadian Association of Sport Science (CASS) president Max Howell led a nationwide fitness survey using the PWC 170 – predict the power output (Watts) at a projected heart rate of 170 beats per minute (bpm) cycle ergometer test on a representative sample of Canadian children aged 7-17-year-old, highlighting the importance of maintaining physical fitness among children and adolescents [22].

Later, in the 1970s, the American Heart Association published two handbooks for professional use, including *Exercise Testing and Training of Healthy Individuals* in 1972 and *Exercise Testing and Training of Individuals with Heart Disease or at high risk of its development* in 1975 [27, 28]. Those early training recommendations were based primarily on endurance exercise to enhance performance for adults, especially aerobic capacity; increases in aerobic capacity are most rapidly achieved by increasing the intensity of endurance exercise, and higher aerobic capacity is associated with reduced risk of heart disease, obesity, and certain cancers [24]. During the same time, exercise scientists initiated a systematic investigation into the quantity and quality of exercise required to achieve health benefits. In 1978, the American College of Sports Medicine (ACSM) initially endorsed this comprehensive method of exercise recommendations in its guidelines book for healthy adults. The position statement recommended the frequency of three to five days per week, an intensity of 50% to 85 % $VO_{2\,max}$ (60% to 90% maximum heart rate), and durations of 20 to 60 minutes [25]. Several large epidemiological studies were conducted in the 1980s to examine the health benefits of moderate-intensity

activities (MIPA) of daily living. For example, the Nurses' Health Study (NHS) was one of the largest and longest-running studies on women's health, whereas the Framingham Heart Study investigated various factors influencing cardiovascular health, and the Alameda County Study was a long-term investigation of various health behaviours and outcomes. Results from those studies show that regular engagement in moderate-intensity activities, including brisk walking, climbing stairs, and housework, was associated with improved cardiovascular health and reduced risk of chronic diseases [31, 32].

In the 1990s, the ACSM and the Centers for Disease Control and Prevention (CDC) released a detailed physical activity guideline in response to the increasing awareness of the health benefits of physical activity. They recommended that adults should aim to accumulate at least 30 minutes of moderate-intensity physical activity on most, ideally all, days of the week [25, 27]. Most elements in the guideline remained unchanged, but the recommended intensity range dropped from 50% to 40% VO2 max on the lower end. This shift in recognition of the importance of moderate-intensity physical activity altered the exercise prescription guidelines of the ACSM, and most importantly, it demonstrated that the majority of the active population's physical activity consisted of walking and other forms of MIPA [25]. The guideline was a notable milestone in promoting regular physical activity as part of a healthy lifestyle. Since the publication of the first guideline in 1975, physical activity recommendations have changed and been updated numerous times to reflect new research findings and developing data. Physical activity guidelines were produced by numerous organizations and government agencies, including the World Health Organization (WHO), the US Department of Health and Human Services (HHS), and other national health authorities [12, 34].

1.4 Canadian Physical Activity Guidelines

In 1998, the first-ever *Canada's physical activity guide to healthy active living* was launched [28]. The national guideline is designed to help Canadians improve their health through regular physical activity for adults 20-55 years of age [29]. The guide was created based on a number of compelling reasons, including substantial evidence of the health benefits of being physically active, sedentary living being a major public concern, and the increasing cost of physical inactivity [28, 29]. According to the guide, adults should aim to accumulate 60 minutes of daily physical activity or 30 minutes of moderate or vigorous physical activity for at least four days a week for health benefits. It also provides specific guidelines for various types of exercise, including endurance exercises performed 4-7 days/ week, flexibility exercises performed 4-7 days/ week, and strength exercises performed 2-4 days/week [30]. There is a need to produce more age-specific physical activity recommendations to target other specific sectors of the population, as different age groups have different physiological and health requirements. Therefore, *Canada's physical activity guide to healthy active living for older individuals* was released in 1999 [17] to address the specific needs of adults aged 55 and over. With the success of the first two guides for adults and adults older than 55 years of age, Health Canada and the Canadian Society of Exercise Physiology (CSEP) collaborated in 2002 to develop *Canada's physical activity guide for children aged 6 to 9 years* and *Canada's physical activity guide for adolescents aged 10 to 14 years* [18, 19]. It includes a call to action for parents, educators, physicians, and community leaders and introduces the idea of building up physical activity throughout the day for at least 5 to 10 minutes [31].

Early in the twenty-first century, research on the association between physical activity and health developed fast, at least in part due to the introduction of physical activity

recommendations. The *Canadian Physical Activity Guidelines for Adults* 18–64 years of age and *Older Adults 65 years and Older* were produced in 2011 by the Canadian Society for Exercise Physiology in collaboration with other organizations. Adults were encouraged to engage in at least 150 minutes of moderate to vigorous level aerobic physical activity per week in bouts of at least 10 minutes. Muscle and bone-strengthening activities were also recommended at least twice per week [32].

1.5 Sedentary Behaviour

Sedentary behaviour and physical activity are crucial for health and are often interrelated; changes in one can affect the other. Sedentary behaviour refers to activities that require very little energy expenditure (≤1.5 metabolic equivalents) while sitting or reclining posture. It is different from being physically inactive, as even individuals who meet the physical activity guidelines may still engage in excessive sedentary behaviour, which can have negative health effects [33]. Two key components must be considered when assessing sedentary behaviour: the mode and pattern. The mode refers to the type or nature of the sedentary activity, such as watching TV, driving, or lying down. On the other hand, the pattern pertains to how sedentary time is accumulated throughout the day. This can either be in prolonged, uninterrupted periods or short bouts interspersed with activity.

In the early 2000s, Canadian scientists began to shift towards developing a clinical practice guideline for sedentary behaviour, separate from physical activity prescriptions [34]. These guidelines include the *Canadian Sedentary Behaviour Guidelines for Children and Youth* (15-17 years old) released in 2011 [34], and the *Canadian Sedentary Behaviour Guidelines for the Early Years* (0-4 years old), which were released in the following year [35]. Those guidelines included

more specific recommendations about recreational screen time (≤ 2 hours/day), sedentary transport (limit car or bus rides), and sitting for extended periods (break up long periods of sitting). These were among the first guidelines globally to provide specific recommendations on sedentary behaviour for children and infants [34]. However, specific sedentary behaviour guidelines for adults and older adults were not established immediately, as the focus remained predominantly on promoting sufficient physical activity. Additionally, there are challenges in the measurement of sedentary behaviour in large population-based studies, which were addressed by the advances in wearable technology over time. The WHO acknowledged the importance of reducing sedentary time in its global physical activity strategy, which emphasized the relevance for all age groups in 2016 [36], and set the strategic direction for future guideline development in 2018 [37].

According to epidemiological evidence, older adults are one of the most sedentary groups in society, spending around 8.5 hours per day and approximately 80% of their time in a seated posture. This increases their risk for CVD mortality, as prolonged sedentary behaviour is independently associated with a higher risk of cardiovascular disease [38]. There is also emerging evidence to suggest that breaking up sedentary time improves cardiovascular health with lower arterial stiffness parameters compared with individuals who spent continuous bouts of sedentary time [39].

1.6 Sleep

On average, humans spend about one-third of their lives sleeping. The typical sleep duration for adults aged 18 to 64 is 7.9 hours per day [47]. According to Carskadon and Dement, sleep can be defined as a recurring and reversible neuro-behavioural state in which an individual is

relatively disengaged from and unresponsive to their environment. During sleep, people often lie down, remain still, and keep their eyes closed [48].

The sleep cycle contains two states: Rapid eye movement (REM) sleep and non-rapid eye movement (NREM) sleep. There are five different stages of sleep that we go through multiple times each night. An adult sleep cycle typically lasts about 90 to 120 minutes and includes stages of light sleep (stages 1 and 2), deep sleep (stages 3 and 4), and REM [40]. Each of these stages has distinct brain wave activity and physiological characteristics:

- Stage 1 marks the transition from wakefulness to sleep. This stage typically lasts less than 10 minutes and is characterized by a slowing of the heartbeat, breathing, eye movements, and muscle relaxation.
- Stage 2 is a period of light sleep before entering deeper sleep, lasting roughly 20 minutes. It is characterized by further slowing of the heartbeat and breathing, and the brain begins to produce bursts of rapid, rhythmic brain wave activity known as sleep spindles.
- Stages 3 and 4 are the final stages of non-REM sleep. This is the most profound sleep period and lasts 20 to 40 minutes. Your heartbeat and breathing slow to their lowest levels, and your muscles are so relaxed that it may be hard to awaken you.
- REM sleep occurs 90 minutes after onset and is much deeper than any of the three stages of non-REM sleep. REM sleep is when most dreaming occurs; brain waves become more active while muscles become more relaxed or paralyzed.

The sleep-wake cycle is primarily influenced by changes in behaviour, physical activity, and light and dark exposure. These two components interact to determine when we go to sleep and when we wake up and the stability of waking neurocognitive functions (e.g., how well we feel when we are awake) [40].

Sleep is most often clinically measured through polysomnography (PSG), which encompasses electroencephalogram (EEG), electromyography (EMG), and electrooculography (EOG) [41]. PSG is the gold standard objective measurement for assessing sleep and diagnosing sleep disorders. The PSG monitors various bodily functions during sleep, including brain electrical activity, muscle activity, eye movement, respiratory effort, cardiac rhythm, and blood oxygen levels [42]. Therefore, a well-trained expert is needed to collect and analyze the data accurately, which requires considerable time and resources and may only be feasible in the sleep clinic and research settings. Conversely, an accelerometer is a small, wearable device that uses non-invasive monitoring of human movement cycles [43]. It has been commonly used in extensive population studies due to its convenience and cost-effectiveness. The accelerometer allows for sleep monitoring over extended periods in the participants' natural sleeping environment with less disruption, and it is simple to use [43].

The quality and length of sleep are increasingly acknowledged as crucial determinants of general health and wellness, encompassing cardiovascular health. Sleep disturbances, such as sleep apnea and insomnia, are known to contribute to the onset of conditions like hypertension, heart disease, and stroke [44].

1.7 Canadian Guidelines: Physical Activity to 24-hour Movement Focus

The Canadian 24-Hour Movement Guidelines (24HMG) for Children and Youth (ages 5 to 17 years) were released in 2016 through the collaborations of the Canadian Society of Exercise Physiology, the Public Health Agency of Canada (PHAC), and ParticipACTION [45]. These guidelines included recommendations for physical activity, sedentary behaviour, and sleep. For optimal health, they advocated a balanced strategy consisting of at least 60 minutes of moderate

to vigorous physical activity (MVPA) daily, no more than two hours of recreational screen time, and adequate sleep according to time [45]. Scientific articles and input from international experts made it evident that identifying a single "threshold" dose of physical exercise for children and adolescents was unsuitable [45]. Data from previous and current surveys showed that the target populations had seen major increases in obesity and type II diabetes mellitus due to a decline in physical activity and an increase in "screen time," which is time spent watching television and playing computer games [46]. Rather than a series of segregated recommendations, it would be preferable to integrate a set of guidelines that encompass the movement behaviour throughout the whole day, the concept of "The Whole Day Matter." [47]. Then, the Canadian Society of Exercise Physiology launched the 24-hour Movement Guideline for Early Years (aged 0-4 years) in 2017. The guidelines provided specific and age-appropriate recommendations for each age group in the early years. For example, infants (under one year) are recommended to be physically active several times a day, particularly through interactive floor-based play. They emphasized the need for physical activities to be fun, developmentally appropriate, and enjoyable instead of prescriptive tasks [35]. Following Canada's lead, several other countries, such as Australia [48], New Zealand [49], South Africa [50], and the World Health Organization (WHO) [51], have issued 24-hour movement guidelines for the early years and children and youth, embracing the idea that a variety of movement behaviour across the whole day is important when health enhancement is the goal [52].

In October 2020, Canada released the world's first 24-hour movement guideline for adults (aged 18-64 years) and older adults (aged 65 years and older), considering a balanced approach to physical activity, sedentary behaviour, and sleep [52]. The new guidelines offer a holistic approach compared to the *2011 Canadian Physical Activity Guidelines*, which primarily focus on

achieving a target amount of moderate to vigorous physical activity per week without taking into account the interplay between different types of movement and rest within the entire day [32]. Incorporating sleep recommendations into the 24HMG is a significant step toward highlighting for adults and older adults the critical roles that sleep duration and quality play in overall health. Additionally, the 24HMG offers specific advice on minimizing sedentary time, encouraging regular breaks from sitting and reducing recreational screen time. Unlike the traditional physical activity guidelines, which emphasized moderate and vigorous physical activities, the new 24-hour movement guidelines acknowledged the benefits of incorporating light physical activity throughout the day and encouraged a variety of intensities. Moreover, the *24-hour Movement Guideline for Older Adults* includes activities to enhance balance and functional training, which is crucial for fall prevention. McLaughlin et al. conducted a systematic review to examine the effect of balance, functional strength training, and 3-dimensional physical activities (e.g., Tai Chi, dance, or exergames) on health outcomes [53]. Their findings showed significant benefits: engaging in balance and functional training led to a 13% reduction in the risk of falling, while those practicing Tai Chai saw a 20% reduction in the risk of falling compared to the control group [54].

1.8 Canadian 24-hour Movement Guidelines and Health Outcomes

The Canadian 24HMG takes an integrative approach to physical activity, sedentary behaviour, and sleep, aiming to optimize health outcomes across various demographics. Research in this field can be broadly categorized into two groups: studies examining guideline adherence and those analyzing movement behaviour over a 24-hour period.

The studies presented in Table 2 primarily review the adherence to the guidelines (meeting or meeting). The review highlights a significant gap in studies that focus on adults, especially older adults, with a limited investigation into the relationship between adherence to guidelines and the risk of CVD. While numerous studies explore the benefits of these guidelines in children and adolescents, such as improvements in mental health and physical fitness, there is very limited research on the adult population [62-65]. The few studies involving adults were published after 2021, when more research began on this population [54, 65, 66], these studies tended to use objective measures such as accelerometers for data collection. This recent interest in adult populations can be partly attributed to the guidelines for adults and older adults being established only in 2020, sparking new avenues of research in this demographic. Furthermore, the reliability of previous studies is often questioned due to the prevalent use of self-reported data for measuring physical activity and sleep patterns [67, 69]. This approach has inherent limitations, such as recall bias and inaccuracies in self-assessment.

The studies show that meeting all or multiple components of the movement guidelines is more beneficial for health than meeting just one [54, 62-65]. Those studies indicate that being physically active, reducing sedentary, and accumulating adequate sleep have a synergistic effect on health. Moreover, individuals who adhere to both physical activity and sleep guidelines have markedly better health outcomes than those who meet only one guideline. However, it is important to note that adherence patterns and associated health outcomes vary between children and adults. Therefore, age-specific guidelines and recommendations are necessary, as children have different physical activity and sleep needs than adults.

Table 2. Studies assessing the association between 24-hour movement and health outcomes

Authors	Population	Physical activity Measurement	Sedentary Behaviour Measurement	Sleep Measurement	Main Outcome
Broad Health Focused studies					
Porter et al. (2023)	Adults (aged 18-29 years) n=17,874	MVPA **≥150 minutes/week** Questionnaire (International Physical Activity Questionnaire)	**≤ 8 hours sedentary time/ ≤ 3 hours recreational screen time;** Questionnaire (International Sedentary Assessment Tool)	***18-64 years old*** **7-9 hours/day** Questionnaire: "What time they typically went to sleep and woke up during weekdays and on the weekend over the past seven days?"	Adults with chronic health conditions and disabilities (CCD) were 18% less likely to meet all three movement guidelines concurrently than their peers without CCD. However, this also means that there is a significant potential for improvement. Those with a CCD had significantly lower odds of meeting the sleep (12% lower), physical activity (6%), and sedentary behaviour (13% lower) guidelines. With targeted interventions and support, these numbers can be improved, offering hope for better health outcomes. There are beneficial associations between 24-movement guideline adherence and indicators of mental health, which appear to be consistent among adults with and without CCD.
Baillot et al. (2022)	Adults (aged 18-79 years) n=10,515	**MVPA ≥150 minutes/week** Hip-worn Actical Accelerometers ***18-19 years old*** MVPA (≥ 1500 cpm) ***20-79 years old*** MVPA (≥ 1535 cpm)	**Sedentary time ≤ 9 hours** Hip-worn Actical Accelerometers Sedentary time(<100 cpm) **≤ 3 hours recreational screen** time Questionnaire: "In a typical week in the past three months, how much time did you usually spend" (1) on a computer, including using the Internet, playing computer games, emailing, or chatting online? (2) playing video games, such as on Xbox, Nintendo, and PlayStation; (3) watching television, DVDs, or videos?"	***18-64 years old*** **7-9 hours/day** ***65 years and older*** **7-8 hours/day** Questionnaire: "How many hours do you usually spend sleeping in a 24-hour period, excluding time spent resting?"	A considerably smaller percentage of adults classified as overweight (6.1%) or as having class I (4.3%) and class II or III (3.9%) obesity met all three 24-hour Movement Guidelines when compared to individuals with normal weight (9.5%). Regardless of BMI class, meeting all three or two recommendations of the 24-hour Movement Guidelines was generally linked to a lower waist circumference, improved aerobic physical fitness, and better self-perceived general health.

Rollo et al. (2022)	Adults (aged 18-79 years) n=8297	**MVPA ≥150 minutes/week** Hip-worn Actical Accelerometers	**Sedentary time ≤ 8 hours** Hip-worn Actical Accelerometers: **Screen time** Questionnaire: 1) "In a typical week in the past three months, how much time did you usually spend on a computer, tablet or iPad, including watching videos, playing computer games, emailing or using the Internet?" 2) "In a typical week in the past three months, how much time did you usually spend playing other types of video games on a game console or hand-held electronic device?" 3) "In a typical week in the past three months, how much time did you usually spend watching television, DVDs or videos?"	***18-64 years old*** **7-9 hours/day** ***65 years and older*** **7-8 hours/day** Questionnaire: "*How many hours do you usually spend sleeping in a 24-hour period, excluding time spent resting?*"	"19% of the sample met none of the recommendations, 43.9% met one recommendation, 29.8% met two, and 7.1% met all three." "Compared with meeting no recommendations, meeting one, two and all three of the recommendations were significantly associated with better health for one, six and seven health indicators, respectively."
Clarke et al. (2021)	Adults (aged 20 years and older) n=3471	**MVPA (≥ 2020 cpm)** Hip-worn Actigraph Accelerometers	**≤ 8 hours sedentary time/ ≤ 3 hours recreational screen time;** Hip-worn Actigraph Accelerometers; Sedentary time(<100 cpm) Questionnaire: "Over the past 30 days, on average, how many hours per day did you sit and watch TV or videos?".	Questionnaire: "How much sleep do you actually get at night on weekdays or workdays?"	"63.8% met the sleep duration recommendation; 41.5% met MVPA recommendation; 35.3% met the SED recommendation; 12.3% met all three recommendations." "Meeting any 2 guideline recommendations were mostly associated with statistically significant reductions in mortality risk that ranged from 49%–62%. Meeting all 3 guideline recommendations was associated with a significant reduction in mortality risk when the screen time component alone was required for SED guideline adherence, but not when the sedentary time component alone (or both the sedentary time and screen time

					components were required for SED guideline adherence."
Dumuid et al. (2018)	Children (aged 9-11 years) n=5855	**LPA and MVPA** Hip-worn Actigraph GT3X + accelerometer	**Sedentary time** Hip-worn Actigraph GT3X + accelerometer	**Nocturnal sleep duration** Hip-worn Actigraph GT3X + accelerometer	The relationship between children's health-related quality of life and their movement behaviors is moderated by their country's human development index. "In the very high human development index strata alone, health related quality of life was significantly related to the movement behavior composition, with moderate-to-vigorous physical activity (relative to remaining behaviors) being positively associated with health-related quality of life."
Walsh et al. (2018)	Children (aged 9-10 years) n=4524	**MVPA:** **≥ 60 min/day** Questionnaire	**Screen time:** **≤ 2 hours/day** Questionnaire	**Nocturnal sleep duration** **9-11 hours/night** Questionnaire	"Overall, 51% of participants met the sleep recommendation, 36.6% met screen time, and 17.5% met the physical activity recommendation. 70.6% of participants met at least 1, whereas 4.8% of participants met all 3 recommendations." "There was a statistically significant positive association between global cognition and meeting sleep and screen recommendations or meeting the screen-only recommendation compared to not meeting any recommendations."
Carson et al. (2017)	Children and youth (aged 6-17 years) n=5217	**MVPA (≥1500 cpm)** Waist-worn Actical accelerometers	Questionnaire: <u>*6-11 years old*</u> "On average, how many hours a day does your child..." 1) "...watch TV or videos or playing video games?" and 2) "... spend on a computer?" <u>*12-17 years old*</u> "In a typical week in the past three months, how much time did you usually spend..." 1) "...watching television, videos,	Questionnaire: "How many hours do you (your child) usually spend sleeping in a 24-hour period, excluding time spent resting?"	"11% of the sample met none of the recommendations, 71.9 % met either one or two recommendations, 17% of the sample met all three recommendations." "Meeting two or fewer recommendations compared with meeting all three recommendations (reference group) was significantly associated with worse health for five out of ten health indicators, including BMI z-scores, waist circumference, behavioural strengths and difficulties scores, aerobic fitness, and insulin."

			or DVDs?" 2) "...on a computer?" and 3) "...playing video games?"		"Meeting at least one recommendation compared with meeting no recommendations (reference group) was significantly associated with better health for seven out of the ten health indicators, including BMI z-scores, waist circumference, systolic blood pressure, behavioural strengths and difficulties scores, aerobic fitness, triglycerides, and insulin."
Janssen et al. (2017)	Children and youth (aged 10-17 years) n=22,115	**MVPA:** ≥60 min/day Questionnaire: About how many hours a week do you usually take part in physical activity that makes you out of breath or warmer than usual in your class time at school?" and "Outside of school hours: How many hours a week do you usually exercise in your free time so much that you get out of breath or sweat?" On a typical day, the main part of your journey to school is made by...." and "How long does it usually take you to travel to school from your home?"	**Sedentary time:** ≤2.0 h/day Questionnaire: "How many hours a day, in your free time, do you usually spend watching TV, videos (including YouTube or similar ser- vices), DVDs, and other entertainment on a screen?"; "How many hours a day, in your free time, do you usually spend playing games on a computer, games console, tablet (like iPad), smartphone or other electronic device (not including moving or fitness games)?"; and "How many hours a day, in your free time, do you usually spend using electronic devices such as computers, tablets (like iPad) or smartphones for other purposes (e.g., homework, email- ing, tweeting, Facebook, chatting, surfing the internet)?" Re- sponse options ranged from "none at all" to "about 7 or more hours a day".	***6-13 years old*** 9.0–11.0 h/night ***14-17 years old*** 8.0–10.0 h/night Questionnaire: **"**The times that they typically turned out the lights to go to sleep and woke up in the morning."	Only 3% of the sample met all three of the key recommendations contained in the guidelines, and 25% met two of the recommendations, 51% met one of the recommendations, and 21% met none of the three recommendations. More children and youth met recommendations for sleep duration (66%) than for moderate-to-vigorous physical activity (35%) and screen time (8%).
Sampasa-Kanyinga et al. (2017)	Children (aged 9-11 years) n=6106	**MVPA:** **≥ 60 min/day** Waist-worn Actigraph	**Sedentary time** Waist-worn Actigraph GT3X + accelerometer	**Nocturnal sleep duration** **9-11 hours/night**	Children meeting the screen time recommendation, the screen time and sleep recommendation, and all three

		GT3X + accelerometer **(≥** 574 counts per 15 s)	**Screen time: ≤ 2 hours/day** Questionnaire: 'How many hours they typically watched TV, and how many hours they played video games and/or used the computer for something that was not schoolwork per weekday, and per weekend day"	Waist-worn Actigraph GT3X + accelerometer	recommendations had significantly better health-related quality of life than children not meeting any of these guidelines.
Cardiovascular health risk indicators specific focused studies					
Vanderloo et al.(2021)	Children (aged 3-4 years) n=767	**MVPA: ≥60 min/day** **180 minutes of physical activity/week** Questionnaire	**≤1 hour of screen viewing/day** Questionnaire	***0-4 years age*** **10 to 13 hours of sleep/night** Questionnaire	"26.4% met none of the guideline's recommendations, 41.3%, 33.1%, and 10.6% of the sample met 1, 2, or all 3 recommendations, respectively." "The number of recommendations met was not associated with the total CMR score or individual CMR factors (P > .05), with the exceptions of high-density lipoprotein (P = .01)."
Katzmarzyk and Staiano (2017)	Children and adolescents (aged 5-18 years) n=357	**MVPA: ≥ 60 min/day on at least 5 days/week** Questionnaire: During the past 7 days, how many days were you physically active for a total of at least 1 hour (60 min) per day?	**Screen time: ≤ 2 hours/day** Questionnaire: "During the past 30 days, on average how many hours per day did you sit and watch TV or videos?"	***5-13 years old*** **9-11 hours/day** ***14-18 years old*** **8-10 hours/day** Questionnaire: (Pittsburgh Sleep Quality Index) "During the past month, on average, how many hours of actual sleep did you get each night?	"A total of 26.9% of the sample met none of the guidelines, whereas 36.4%, 28.3%, and 8.4% of the sample met 1, 2, or all 3 guidelines, respectively." "There were significant associations between the number of guidelines met and body mass index, visceral and subcutaneous adipose tissue, triglycerides, and glucose. There were no associations with blood pressure or high-density lipoprotein cholesterol."

Chapter 2: Statement of the Problem and Methods

2.1 Statement of the Problem

Cardiovascular disease is one of the leading causes of illness and death among women, especially those in middle-aged and older age groups [60]. This emphasizes the need for effective strategies to reduce the risk factors associated with CVD. Recent evidence suggests that adhering to a comprehensive lifestyle regimen that includes physical activity, reduced sedentary behaviour, and improved sleep patterns can significantly impact cardiovascular health [61]. However, there is a noticeable gap in research, especially regarding middle-aged and older women. This group is particularly susceptible to cardiovascular risks due to physical changes associated with aging and menopause, yet they are often underrepresented in health-related research [62]. Researching how their adherence to the 24-hour movement guideline could generate knowledge to inform better public health messaging, novel strategies and interventions tailored to support middle-aged and older women better to improve their cardiovascular health. Additionally, this is an important step that could contribute to a deeper understanding of how lifestyle behaviours interact with aging-related physiological changes, possibly leading to more effective and personalized health recommendations for this demographic.

2.2 Thesis Objective and Hypotheses

The main objective of this thesis is to examine the associations of cardiovascular health risk indicators with meeting none, one, two or three components of the Canadian 24HMG (i.e., physical activity, sedentary behaviour, and sleep recommendations) among community-dwelling middle-aged and older females. The secondary objective is to identify which specific component

or combination of Canadian 24HMG is most strongly associated with cardiovascular health outcomes in this population.

I hypothesize that:

1. There is an association between the number of 24HMG components and CVD risk, where meeting more components of the 24HMG is associated with lower CVD risk.
2. Meeting the physical activity guidelines is strongly associated with lower CVD risk than sedentary behaviour guidelines and sleep guidelines when only one component is met.
3. Meeting the physical activity and sedentary behaviour guidelines is strongly associated with lower CVD risk than other combinations of two components (Physical activity and sleep, sedentary behaviour and sleep).

2.3 Methods

2.3.1 Research Design

Observational, cross-sectional research data from the Women's Advanced Risk-Assessment in Manitoba (WARM) Hearts cohort (ClinicalTrials.gov ***NCT03938155***) will be used in this thesis to conduct a secondary analysis of existing data. The WARM Hearts project aims to explore a series of novel non-invasive cardiovascular disease risk assessments and biomarkers to determine if the collected measurements can predict adverse cardiovascular outcomes within five years of screening in the populations of 55-year-old and older females. Rose et al. published a protocol paper describing the WARM Hearts cohort in November 2021 [63]. The study received ethical approval from the University of Manitoba Health Research Ethics Board (H2019:063) and the St. Boniface Research Review Committee (RRC/2019/1833). This thesis will follow the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines

(see Appendix 1 for the STROBE checklist). The following section will briefly describe the methodological approaches specific to my thesis research.

2.3.2 Setting/Participants

The WARM Hearts study collected data using two in-person testing appointments: one at the Active Living Center at the University of Manitoba and then one at Asper Clinical Research Institute at the St. Boniface Hospital. The two testing appointments were separated by a minimum of 8 days apart in between visits. The first appointment took approximately two hours, whereas the second appointment took an hour and a half. The assessments performed during the appointments are listed in Table 3.

Table 3. WARM Hearts Assessments

Appointment 1	***Take-home Assessment***	***Appointment 2***
Medical history	Cardiovascular risk factors questionnaire	Resting blood pressure
Height and weight measurements	Reproductive health questionnaire	Non-invasive measures of arterial stiffness
Body composition measurements	Physical Activity Levels Questionnaire (IPAQ)	Blood pressure in response to 3 minutes of exercise
Functional fitness testing	Quality of life questionnaire	Patient Health Questionnaire (PHQ-9)
Completion of a 6-minute waking test with heart rate assessment	Self-compassion Scale	
	Sleep quality questionnaire (PSQI)	
	Diet questionnaire (SCREEN II)	
	Self-esteem Scale	
	Stool sample collection to characterize the gut microbiome	
	7-day accelerometer on the wrist to assess activity, sleep, and body position	
	Activity monitor logbook	

The WARM Hearts study recruited female participants through convenience sampling. The inclusion criteria for the WARM Hearts study were a female aged 55 years and older and residents of Manitoba who have valid Manitoba Personal Health Information Number (PHIN). The exclusion criteria include medical advice against physical exercise; previous hospitalization or treatment for one of the following conditions: ischemic heart disease, acute myocardial disease, stroke/transient ischemic attack, peripheral artery disease, congenital heart defects, arrhythmia; previous participation in the Assessment of large and Small Artery Elasticity for the Early Detection of Cardiovascular Disease study (clinicaltrails.gov ID ***NCT02863211***). The recruitment of the cohort used media advertising, radio interviews on local stations and presentations on cardiovascular health at community events. Recruitment for the WARM Hearts began on October 10, 2019, and continued until a COVID-19-related data collection pause on March 23, 2020. During this period, 480 individuals were recruited to participate in the WARM Hearts trial; of those individuals, 240 completed data collection. Data collection recommenced on September 16, 2020, and continued until another COVID-19-related data collection pause on November 10, 2020. Recruitment restarted again on October 2, 2021, and continued until December 20, 2021. At this point, a cumulative total of 522 individuals were recruited to participate, and 330 participants completed data collection. The COVID-19 Omicron variant then caused the research to pause again until the research was able to reopen on February 1, 2022. Recruitment and collection were continuing. The data collection was completed on December 22, 2022, with 1018 participants enrolled and 993 eligible participants after removing individuals who were not cleared for exercise or failed screening. For this thesis research, 961 females from the WARM Hearts cohort will be used for analysis after excluding participants with missing data: 16 participants missed one or more Accelerometer files; 10 participants missed blood

results; 5 participants had less than 4 valid Accel wear days; 1 participant missed Day 2 appointment files.

2.3.3 Measurements

Canadian 24-hour Movement Guidelines for Adults aged 18-64 years and Older Adults aged 65 and Older

The 24HMG provides general recommendations on each of the three behaviours, including:

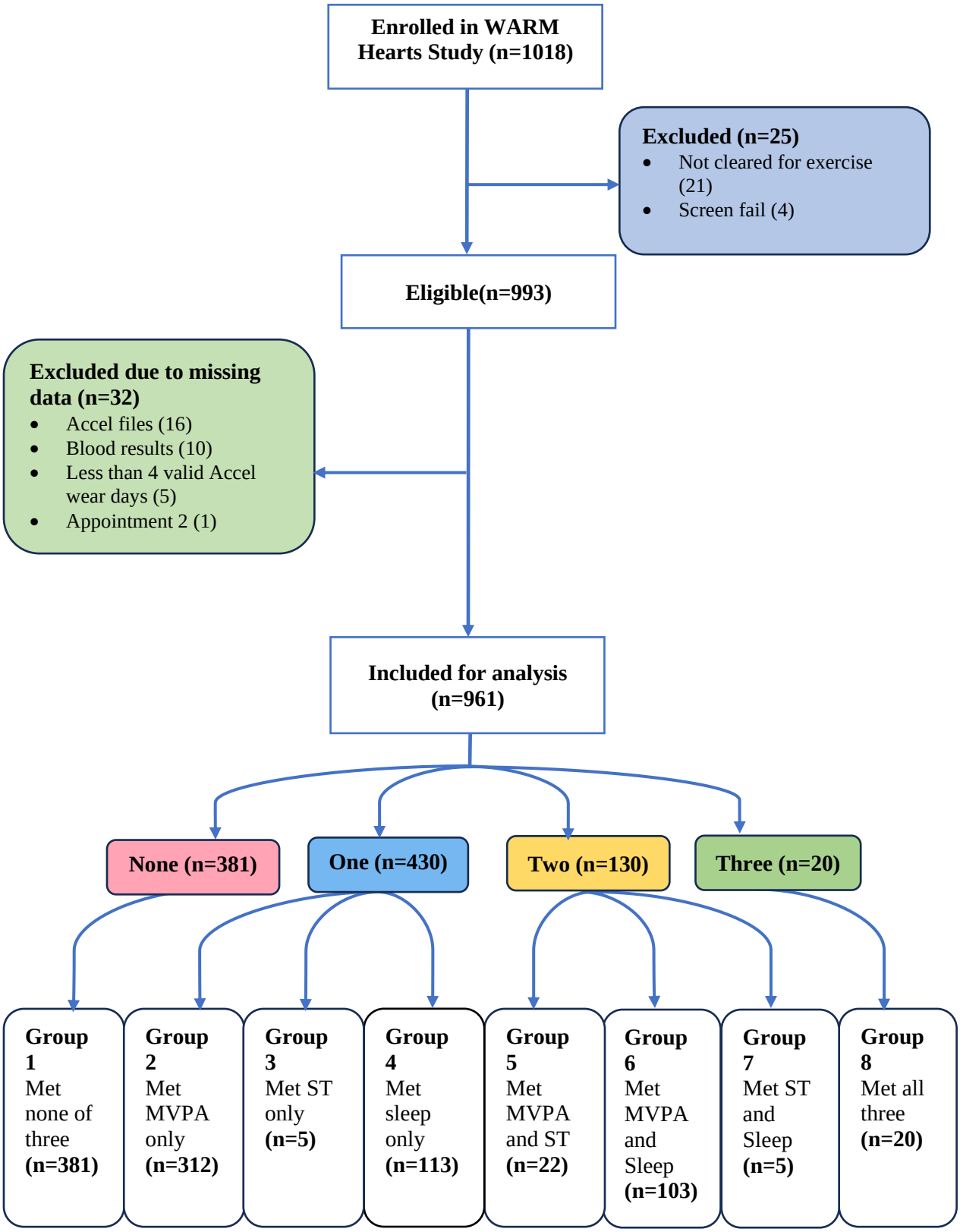
1) an accumulation of at least 150 minutes per week of moderate to vigorous aerobic physical activities;
2) sedentary time of 8 hours or less per day;
3) getting 7 to 9 hours of good quality sleep for individuals aged 18 to 64 and 7 to 8 hours for individuals aged 65 and older.

Participants will be categorized into eight groups for having met or not met each component behaviour based on time. The time spent on physical activity, sedentary behaviour, and sleep, as measured by ActiGraph GT3X + accelerometer worn on each participant's non-dominant wrist for 24 hours per day and seven consecutive days. Additional information about the accelerometer method and analyses will be provided later in this thesis. Other components of the 24HMG, such as muscle-strengthening and light physical activity, balance-challenging activity for adults aged 65 years and older, recreational screen time, and breaking up long periods of sitting, are not required when examining adherence to the overall criteria [64]. Table 4 shows the group combinations of movement behaviour, categorizing participants into one of four general groups and eight specific groups for meeting the components of the Canadian 24HMG. A study flowchart is shown in Figure 1. Individuals were considered to meet the overall guideline if they met all three criteria during a week [52].

Table 4. Categories of the general and specific groups

General groups	Specific groups	Meeting Guidelines
None	**1** (None)	Met none of the guidelines
One of three	**2** (Physical activity only)	Had a accumulate at least 150 minutes of MVPA based on accelerometry.
	3 (Sedentary time only)	Had 8 hours or less sedentary time per day based on accelerometery.
	4 (Sleep only)	For adults aged 55 to 64, had 7 to 9 hours of good quality sleep based on accelerometry. For adults aged 65 and older 7 to 8 hours of good quality sleep based on accelerometry.
Two of three	**5** (Physical activity and Sedentary time)	Had accumulated at least 150 minutes of MVPA and 8 hours or less sedentary time per day based on accelerometry
	6 (Physical activity and Sleep)	For adults aged 55 to 64, had accumulated at least 150 minutes of MVPA and 7 to 9 hours of good quality sleep based on accelerometry For adults aged 65 and older, had accumulated at least 150 and 7 to 8 hours of good quality sleep based on accelerometry
	7 (Sedentary time and Sleep)	For adults aged 55 to 64, had 8 hours or less sedentary time per day and 7 to 9 hours of good quality sleep based on accelerometry For adults aged 18 to 64, had 8 hours or less sedentary time per day and 7 to 8 hours of good quality sleep based on accelerometry
All three	**8** (Physical activity, Sedentary time and Sleep)	For adults aged 55 to 64, had a accumulated at least 150 minutes of MVPA, 8 hours or less sedentary time per day, and 7 to 9 hours of good quality sleep based on accelerometry For adults aged 65 and older, had a accumulated at least 150 minutes of MVPA, 8 hours or less sedentary time per day, and 7 to 8 hours of good quality sleep based on accelerometry

Figure 1. Study Flowchart



Activity Monitor Logbook

While wearing the accelerometer, participants were instructed to complete an Activity Monitor Logbook, which provides additional benefits and enhances the overall understanding of an individual's activity and sleep patterns. It will be used to cross-verify the data from the accelerometer to validate the accuracy of the recorded activities [65]. The logbook briefly explained why participants were to wear the accelerometer and instructions on how to wear it. Participants were instructed to record if they took off the accelerometer (for example, when they showered or planned to go swimming) and the time when the accelerometer was taken off and placed back to the nearest minute. The time when the monitor was removed due to activity is non-wear time, which will be manually excluded from the analyses. Participants were instructed to record the time when they got on the bed ("Bedtime"), the time when they estimated that they fell asleep ("Time you fell sleep"), the time when they woke up from sleep ("Wake time") as well as the time when they physically get out of bed ("Time you got out of bed"). The participants also recorded the nap time, if there was any during the day of the estimated nap started time and end time. Participants were instructed to log their activity on the night of their first appointment and continue until they finished the full seven-day wear time. The recorded time will be used to modify sleep data analysis.

Actigraphy for physical activity, sedentary behaviour, and sleep assessment

In population-based research, objective assessments of physical activity, sedentary behavior, and sleep have mainly been measured using actigraphy to quantify movement patterns [66] instead of relying on the participant's ability to recall the behaviours (i.e., self-reported measurements). Participants in the WARM Hearts trial were instructed to wear an ActiGraph

GT3X+ accelerometer on their non-dominant wrist for 24 hours per day and seven consecutive days as part of their take-home assessment. Then, the accelerometer was returned to the research team at their second appointment about 8 to 14 days later. The accelerometer has a dynamic range of ±6*g* and was sampled at a rate of 90Hz. The accelerometer was programmed to collect data starting at 6:00 am on the first day of their appointment and ending at 6:00 am on the eighth day. Raw accelerometer data were downloaded in .gt3x and .csv formats and reintegrated into 1-second epochs using the ActiLife software (Version 6.13.4).

Data processing

The raw data was processed using the R package GGIR (Version 3.0.5). This open-source package is designed for processing multi-day raw acceleration data for physical activity and sleep research [67]. The raw triaxial accelerometer signals are auto-calibrated and converted into gravity-corrected vector magnitude (VM) units known as the Euclidean norm minus one (ENMO) [68]. The R package GGIR is a suitable and validated software application to process wrist-worn accelerometer data for daily estimates of 24-hour movement behaviours [67]. The GGIR outputs provide average estimates of daily physical activity, physical inactivity (which the GGIR method uses as a surrogate measure for sedentary behaviour; more information about this definition is articulated in the next paragraph), and sleep. The package includes five functionalities in logical processing order: g.part1, g.part2, g.part3, g.part4, and g.part5 [68]. Initially, we plan to include each participant's accelerometer data with valid wear time recorded as 24 hours per day for a total of 7 days (i.e., GGIR output variable complete_24hcycle =1.0) and post-calibration error of <10 mg will be included in the final dataset [69]. However, the sample size is too limited when using 24 hours per day for seven days, so we implemented the alternate

definition of valid wear time used by Eke et al., which is at least 16 hours per day for four days [70]. The non-wear time is identified as a period of low acceleration with minimal variability (accelerations is <50mg and standard deviation of the accelerations <13mg), lasting for at least 60 consecutive minutes [68]. This process was done in g.part1. The g.part1 function auto-calibration of raw data according to local gravity, acceleration metric calculation, and detecting non-wear time. This function is the most time-consuming part of all the data processing for a 7-day data file [68]. The specific GGIR Input code is shown in Appendix 2, and Appendix 3 provides a detailed standardized operating procedure that will be implemented for the 24HMG analysis that will be performed.

Physical activity and sedentary behaviour analysis

The activity monitor recorded the participant's movement acceleration in three axes (x, y, z). It objectively recorded activity intensity, frequency, and duration during wear time. Signal processing in GGIR calculates the average magnitude of dynamic acceleration (ENMO = $\sum \sqrt{x^2 + y^2 + z^2}$-g) [71]. The acceleration data was converted to 5-second epochs for analysis and quantified overall physical activity expressed as acceleration in milligravity units (1 mg = 0.00981 ms^{-2}). Activity variables were classified into four categories based on the intensity level: inactive, light, moderate, and vigorous, using specific intensity thresholds. GGIR defines sedentary time as physical inactivity time, which includes time spent sitting or reclining with low energy expenditure and standing without moving during waking time [68]. Due to the technical limitation of the wrist-worn accelerometer in capturing the posture of the activities, all low-level motions register as inactivity, such as sitting still and standing still. While the GGIR approach is not perfectly aligned with the expert definition of sedentary behaviour, it reasonably estimates

sedentary behaviour and physical activity patterns [71]. According to Sanders et al., inactive (≤ 1.5 METs) less than and equal to 57 mg; light-intensity (1.5-2.9 METs) physical activity is defined as the total time between 58 mg and 104 mg; moderate intensity (3 – 5.99 METs) is defined as the total time above 104 mg [72]. All activity above 104 mg was defined as MVPA. Briefly, this approach was used because no specific cut-off point for vigorous intensity (≥ 6 METs) was provided by Sander et al. [72]. However, we could have used the Bammann et al. vigorous cut-off point as a total time above 254 mg to classify the physical activity intensity and add transparency to our activity data analysis [73]. This is a suitable cut-off point for vigorous activity to use for the WARM Heart cohort since Sanders et al. used the GENEActive (GA) non-dominant wrist accelerometers in older adults aged 60-86 years, which is one of the published studies that aligns most with the WARM Heart cohort, which recruited women over 55 years of age and older. Similarly, Bammann et al. used the ActiGraph non-dominant wrist accelerometers, which are the same as the WARM Heart cohort, and their study population has an average age of 62.9 years [73]. The selected cut-off points are comparable to those utilized by literature recruiting younger adults [75, 76]. Time spent in physical activity is displayed for each minute that fits the required cut-off range. The average daily time spent in intensity-specific categories was determined for all valid wear days. The latest physical activity guidelines from the WHO have eliminated the recommendation for at least a 10-minute bout duration. Instead, the new public health guidelines highlight the importance and health benefits of engaging in short bouts of physical activity to reduce mortality and CVD risk. This emphasizes the importance of integrating physical activity into daily routines, even in short time periods, for overall health and well-being [76]. According to Ahmadi et al., participating in activities that last less than 1-minute bout shows a lower effect for the 5-year mortality risk at 4.28% compared to

bouts of 1 minute to less than 3 minutes at 2.83% [77]. Therefore, the total MVPA time is the average time engaged in activities above 104 mg in a 1-minute bouted length during the waking day. This process was done in g.part2 functions, then g.part5, providing a descriptive person summary of time spent in MVPA based on the specific cut-off values [68]. The result (dur_day_MVPA_bts_1_min_pla) was compared to the guideline on PA of an average weighted 21.43 minutes per day. Table 5 shows studies using different bout accelerometer-measured physical activity.

Studies have shown that the risk of all causes of mortality increased more rapidly above 7 to 9.5 hours per day for device-measured sedentary behaviour while using lower thresholds for self-reported sedentary behaviour [79-81]. Devices such as accelerometers provide more precise and objective measurements of sedentary behaviour, capturing short bursts of activity and providing a more accurate total sedentary time. However, most studies on sedentary behaviour have generally used the self-reported method [81-83], and it is impractical to provide a range of thresholds for 24HMG [81]. Therefore, the total inactive time is the average time engaged in activities below 57 mg in a 1-minute bout during the waking day, compared to the modified guideline (ST $\leq$ 9.5 hours/day) instead of the suggested guideline (ST $\leq$ 8 hours/day). This approach is more suitable for the accelerometer-measured movement of the cohort and using a 1-minute bout to be consistent with other analyses. This was performed in g.part2 functions, and then g.part5 produced the person summary of the time spent inactive (dur_day_IN_bts_1_min_pla), compared to the ST guideline of 570 minutes.

Table 5. Studies using different bout accelerometers measured physical activity.

Authors	Population	Bouts used	Cutoff used	Accelerometer brand	Days	Main outcome
Mielke et al. (2022)	Mid-age adults living in Brisbane, Australia (mean age: 60.4; SD:7.1 years) n=700	non-bouted, 1-, 5- and 10-minute bouts	MVPA ≥ 100 mg	Non-dominant wrist, Actigraph wGT3X-BT	7	"Accumulation of physical activity among mid-age older adults occurs mostly through activities of light to moderate intensity, in short bouts." "Those that met the physical activity recommendation of at least 150 minutes per week in MVPA was 95.1%, 59.3%, 32.2% and 24.2%."
Menai et al. (2017)	UK adults 60–83years n=3,749	≥1 min bouts, short MVPA bouts (1 to 9.59 minutes), long MVPA bouts (≥10 minutes)	MVPA ≥ 100 mg	Non-dominant wrist, GENEActiv	9	"Higher proportion of successful agers was also observed in those practicing more MVPA, independently of the length of the MVPA bout". "Further analysis to test whether the pattern of MVPA mattered for those undertaking the recommended ≥150 minutes of MVPA per week showed similar associations with successful ageing in those undertaking MVPA in bouts of 1 minute or more or 10 minutes or more (OR = 1.92, 95% CI: 1.60, 2.30 and 1.74, 95% CI: 1.38, 2.18 respectively)".
Silva et al. (2014)	Children, adolescents and young adults from Brazil 6-30 years n=8,974	5- and 10-min bouts of MVPA	MVPA ≥ 100 mg	Non-dominant wrist, GENEActiv	4-7	Mean MVPA was on average 42% higher when using 5-min bouts.
Rowlands et al. (2021)	UK adults aged 40 to 69 years n=82,253	1-minute bouts of MVPA	MVPA ≥ 100 mg	Wris-wornt, Axivity AX3	7	"Odds of severe COVID-19 were lower by 37% in women and 16% in men per 30 minutes of daily MVPA." "Black adults are more active, and SA adults less active, than white adults, the age-related reduction appears to be delayed in black and SA adults. Sleep/rest quality is poorer in black and SA adults than in white adults."
Dawkins et al. (2022)	UK adults aged aged 45–79 years n=95,914	1-minute bouts of MVPA	MVPA ≥ 100 mg	dominant wrist, Axivity AX3	7	"Black adults are more active, and SA adults less active, than white adults, the age-related reduction appears to be delayed in black and SA adults." "Sleep/rest quality is poorer in black and SA adults than in white adults."
Ahn et al. (2024)	UK adults aged 40 to 69 years	5-minute bouts of MVPA	MVPA ≥ 100 mg	Wris-wornt, Axivity AX3	7	"In patients with AF, accelerometer- derived PA data supports lower risks of all- cause

	N=2324					mortality and HF according to a greater level of MVPA and adherence to PA guidelines. Among total patients with AF, 38.6% (n=896) adhere to MVPA ≥150 min/week PA guideline and 17.9% (n=415) adhere to the extended (MVPA ≥300 min/week) PA guideline."
Henson et al. (2024)	UK, DM2 > 6 months; aged 18 - 75 years N=564	1 and 5 minute bouts of MVPA	Sedentary <40mg; light 40 - 100; MVPA ≥ 100 mg	Non-dominant wrist, GENEActiv	7	"Those with obesity related DM2 have less PA and worse sleep habits than Age related DM2."
Ahmadi et al. (2023)	UK, DM2 > 6 months; aged 18 - 75 years N=25,241	< 1 min, 1- < 3 min, 3 - < 5 min, 5 - <10 min	not reported	Wris-wornt, Axivity AX3	7	"In adults who don't exercise, MVPA accrued through short bouts (1 - < 5 min) of ADL's was associated with decreased mortality and MACE rates compared to < 1 min bouts."

Sleep analysis

Van Hees et al. developed a nocturnal sleep detection algorithm used for sleep analysis in GGIR [82]. Sleep is characterized as a period of sustained inactivity with no changes in arm angle greater than 5° for 5 minutes or more in a 5-second epoch [82]. The sleep detection algorithm will be done in function g.part 3 [68]. The time spent in bed was automatically determined from accelerometer data as the interval between falling asleep and waking up. Sleep duration was also automatically extracted as the total sleep duration determined from accelerometer data, excluding detected waking episodes during the night. This was then compared with the times recorded by the participant on the Activity Monitor Log to ensure accuracy. If the values provided by the algorithm do not match the participant's Activity Monitor Log, the time will be manually corrected. The process will be done in function g.part4 [68]. Nap time during the day was coded as nighttime sleep and added to the total sleep time [75, 82]. The total sleep duration is part of the output from function g.part5 in the person summary[68]. The total sleep time is the sum of the average amount of sleep a participant gets during the valid wear

days, which was manually calculated using the average sleep time and average nap time (sleep_and_nap_pla_manual= dur_spt_sleep_min_pla + dur_day_srnap_min_pla).

2.3.4 Variables

Framingham Risk Score (FRS) and other Cardiovascular indicators

The Framingham Risk score is a primary outcome of this study, which calculates the 10-year risk of manifesting clinical CVD based on objective measures and self-reported information obtained at testing appointments [83]. In their medical history questionnaire, participants self-reported their age, gender, smoking status, and diabetes status. A blood sample was collected and later analyzed for total cholesterol (TC) and high-density lipoprotein (HDL) during their second appointment. Systolic blood pressure was also measured using a standardized ambulatory blood pressure monitoring device on Day 2.

Each participant had approximately 15 mL of blood drawn by a phlebotomist to determine blood parameters. Before the blood draw, participants were required to fast for 12 hours. The plasma was then isolated from the serum and tested for HDL and LDL cholesterol, fasting blood glucose, and triglycerides following a 10-minute centrifugation at 2,000 x g. The cut-off values utilized in this research were derived from the 2012 Canadian Cardiovascular Society guidelines for diagnosing and managing dyslipidemia and preventing CVD in adults [84].

Blood pressure was measured using the Mobil-O-Graph PWA, one of the most widely approved measuring devices for blood pressure [85]. All measurements were taken while participants were sitting at rest. Before beginning the procedure, participants were asked to sit for 5 minutes to ensure they rested. A blood pressure cuff connected to the Mobil-O-Graph was placed on the left arm, with two fingers above the antecubital fossa, and three measurements

were taken. Blood pressure was measured in millimetres of mercury (mmHg). According to Hypertension Canada's Guidelines, a blood pressure reading of 140/90 mmHg or higher is classified as high blood pressure and is considered to increase cardiovascular health risk [86].

Body Mass Index (BMI)

Participant height was accurately measured by a trained research assistant using a stadiometer, while weight and Body Mass Index (BMI) were determined as key anthropometric indices during the assessment. BMI, a basic measure of body fat derived from dividing a person's weight in kilograms by their height in meters squared (BMI = kg/m^2), is an easy and non-invasive way to estimate body fat levels. According to health guidelines by the WHO, BMI classifications are underweight (BMI < 18.5), normal weight (BMI 18.5–24.9), overweight (BMI 25–29.9), and obese (BMI ≥30) [87].

Frailty Index (FI)

Frailty is measured by calculating the Frailty Index (FI), which assesses frailty based on the ratio of present health deficits to the total considered health variables. This analysis adopted a tailored 34 items of FI from the WARM Heart cohort, excluding variables like resting systolic blood pressure, total cholesterol, high-density lipoprotein, Pasffenbargar PA questionnaire and *Pittsburgh Sleep Quality Index (*PSQI) from the FI index aligned with Searle's protocol [63]. The FI scores categorize individuals as robust (< 0.10), pre-frail (0.11 to 0.25), or frail (> 0.26)= Frail [88]. The complete list of the 34 items of the modified FI can be found in Appendix 3.

Covariates

Demographic variables that describe the characteristics of participants in this thesis were extracted from the WARM Hearts cohort, including self-reported age (55 years old and older), highest education ("No degree/certificate/diploma", "high school", "post-secondary"), and personal income ("less than $15,000", "$15,000 to $29,999", "$30,000 to $49,999", "$50,000 to 69,999", "$70,000 to $99,999", "more than $100,000", "do not know", "do not wish to answer"), which these variables were included as covariates based on previous studies examining meeting 24HMG movement behaviours components and health [57, 90, 91], as these variables are known to influence outcomes potentially.

Race

Participant characteristics also included self-reported race. To reduce the risk of inadvertently identifying participants in a population with a small sample size, we aggregated racial groups with low participation together. We only focused on reporting data from the "Caucasian" group, as they made up the majority of the sample.

2.3.5 Statistical Analysis

Descriptive statistics were used to summarize the characteristics of the WARM Hearts cohort, including means and standard deviations for continuous variables and frequencies for categorical variables. Multiple linear regression models were used to examine the relationships between adherence to specific (physical activity only, sedentary behaviour only, and sleep only) and different combinations (none, one of three, two of three, all three) of the Canadian 24HMG (independent variables) and the cardiovascular health risk indicators (FRS 10-year risk scores,

BMI, waist circumference, systolic blood pressure, diastolic blood pressure, total cholesterol, triglycerides, HDL, FI as dependent variables). The assumptions of the models were assessed using the Shapiro-Wilk test and visual methods (i.e. Q-Q plot, scatterplot). Continuous outcome variables were log-transformed to meet the assumption of normality of the residuals in the regression models. Initially, we examined the impact of the Canadian 24HMG on the outcome variables using unadjusted linear regression models. Then, we further adjusted the models for age, highest household education, and personal income. However, personal income was excluded from the adjusted model for analysis because 7 out of 9 associations showed no statistical significance, and the two that did were only present in category 8 (do not wish to answer). We initially used the "None" group as the reference group and then repeated the analysis by changing the reference group to specific or general combinations to address our hypotheses. Regression coefficients (β) and 95% confidence intervals (CI) were reported for each independent variable in the models. The study used a significance level $\alpha = 5\%$ to test research hypotheses. The statistical analyses were conducted using R (Version 4.4.0).

Chapter 3: Results

3.1 Participants Characteristics

Nine-hundred and sixty-one (961) eligible female participants aged 55 and older from the WARM Hearts cohort were included in the research. In general, the data indicate that adherence to the Canadian 24HMG, particularly meeting general and specific combinations (one, two or all three) of physical activity, sedentary behaviour and sleep, was associated with favourable cardiovascular health outcomes. Table 6 shows the characteristics of all participants included in the study. Within the full sample, the mean age was 65 ± 6 years, and 912 (94.9%) participants self-reported their race as Caucasian. In this cohort, 763 (79.4 %) of participants completed post-secondary education, and 216 (22.5%) of participants reported a personal income of $30,000 to $49,999. Additionally, within the cohort, the mean daily MVPA was 26 ± 21 min/day, and the mean daily sedentary time and nightly sleep were 12.1 ± 1.6 hr/day and 6.4 ± 1.2 hr/night, respectively. The primary cardiovascular health risk indicator for this research was the FRS score, and the mean was 7.0 ± 4.1 %, with 209 (27.7%) of participants considered to have an elevated CVD risk due to an FRS score greater than 10%. The mean waist circumference was 94.5 ± 13.4 cm, mean BMI was 26.8 ± 5.3 kg/m². The mean systolic and diastolic blood pressure were 122 ± 14 and 77 ± 10 mmHg, respectively. Blood parameters in this cohort show the mean total cholesterol (5.3 ± 0.9 mmol/L), mean triglycerides (1.1 ± 0.6 mmol/L) and HDL Cholesterol (1.7 ± 0.4 mmol/L). The mean FI score was 0.15 ± 0.08. Individuals with scores above 0.12 were classified as pre-frail, and those with scores above 0.21 were categorized as frail [89]. Out of the total participants, 578 (62.2%) had FI scores greater than 0.12, and 183 (19%) had FI scores greater than 0.21. The proportion of the cohort meeting general and specific combinations of Canadian 24HMG recommendations was 39.7% for the participants who met

none of the components of the guideline, 44.8% of the participants who met one of the components of the guideline, 13.5% of participants met two of the components of the guideline; whereas, only 20 (2.1%) of participants met all three of the components of the guideline. For the specific combination of participants who met one of the components of the guideline, MVPA was the most prevalent (32.5%), followed by sleep (11.8%) and sedentary time (0.5%). For participants who met two of the components of the guideline, MVPA and sleep was the most prevalent (10.7%), followed by MVPA and sedentary time (2.3%) and sedentary time and sleep (0.5%).

Table 6. Characterization of all participants included in the analysis.

Variables	All participants (n=961)
Age (years)	65 ± 6
Race (%)	
White/ Caucasian	912 (94.9%)
Highest household education (%)	
No degree/certificate/diploma	29 (3%)
High school	169 (7.6%)
Post-secondary	763 (79.4%)
Personal income (%)	
Less than $15,000	35 (3.6%)
$15,000 to $29,999	100 (10.4%)
$30,000 to $49,999	216 (22.5%)
$50,000 to 69,999	194 (20.2%)
$70,000 to $99,999	145 (15.1%)
More than $100,000	112 (11.7%)
Do not know	11 (1.1%)
Do not wish to answer	148 (15.4 %)
Movement behaviours	
Average daily MVPA (min/day)	26 ± 21
Average daily sedentary time (hr/day)	12.1 ± 1.6
Average nightly sleep (hr/night)	6.4 ± 1.2
Cardiovascular health risk indicators	
FRS 10-year risk score (%)	7.0 ± 4.1
Waist circumference (cm)	94.5 ± 13.4
BMI (kg/m²)	26.8 ± 5.3
Systolic blood pressure (mmHg)	122 ± 14
Diastolic blood pressure (mmHg)	77 ± 10
Total cholesterol (mmol/L)	5.3 ± 0.9
Triglycerides (mmol/L)	1.1 ± 0.6
HDL Cholesterol (mmol/L)	1.7 ± 0.4
WH Frailty Index	0.15 ± 0.08
Meeting recommendation	
General combination (%)	
None	381 (39.7 %)
One out of three	430 (44.8 %)
Two out of three	130 (13.5%)
All three	20 (2.1%)
Specific combination (%)	
None	381 (39.7 %)
MVPA only	312 (32.5 %)
ST only	5 (0.5%)
Sleep only	113 (11.8%)
MVPA and ST only	22 (2.3%)
MVPA and sleep only	103 (10.7%)
ST and sleep only	5 (0.5%)
MVPA and ST and sleep	20 (2.1%)

Continuous variables are expressed as Mean ± standard deviation; categorical variables are expressed as n (%). ***BMI****=Body Mass Index;* ***HDL****=High-Density Lipoprotein;* ***FRS****=Framingham Risk Score;* ***WH****=WARM Hearts;* ***MVPA****=Moderate to vigorous intensity physical activity;* ***ST****=Sedentary time.*

3.2 General Groups

The data presented in Table 7 characterizes participants across four general groups based on their adherence to the Canadian 24HMG: none of the guidelines (n=381), one out of three guidelines (n=430), two out of three guidelines (n=130), and all three guidelines (n=20). The mean age of participants ranged from 66 ± 7 years in the "None" group to 61 ± 3 years in the "All three" group. Average daily MVPA ranged from 10 ± 6 minutes in the "None" group to 49 ± 23 minutes in the "All three" group. Conversely, average daily sedentary time ranged from 13 ± 1.4 hours in the "None" group to 8.7 ± 0.7 hours in the "All three" group. Average nightly sleep duration was 7.6 ± 0.5 hours in the “All three” group and 6.1 ± 0.8 hours in the “None” group. Cardiovascular health risk, as measured by the FRS score, ranged from 7.7 ± 4.6 to 6.7 ± 3.0 in the"None" and "All three" groups, respectively. The mean waist circumference and BMI were 90.2 ± 11.4 cm and 25.0 ± 4.3 kg/m² in the "Two out of three" group. Systolic blood pressure ranges between 120 ± 14 mmHg and 126 ± 13 mmHg across the groups, and diastolic blood pressure ranges between 76 ± 10 mmHg and 83 ± 10 mmHg across the groups. Total cholesterol level was 5.1 ± 1 mmol/L in the "None" group and was the same value in the "Two out of three" and "All three” groups. Triglycerides and HDL cholesterol were similar in the "None" group and the "All three" group and were 1.2 ± 0.6 mmol/L, 1.2 ± 0.7 mmol/L, and 1.7 ± 0.4 mmol/L, 1.8 ± 0.5 mmol/L, respectively. The mean FI scores ranged from 0.18 ± 0.09 in the "None" group to 0.14 ± 0.06 in the "Two out of three" group. Due to small sample sizes in some groups, race data for Table 7 is not being reported to avoid the risk of inadvertently identifying a participant.

Table 7. Characterization of all participants in each general group.

Variables	None (n=381)	One out of three (n=430)	Two out of three (n=130)	All three (n=20)
Age (years)	66 ± 7	64 ± 6	63 ± 5	61 ± 3
Highest household education (%)				
No degree/certificate/diploma	15 (3.9%)	12 (2.8%)	2 (1.5%)	0 (0.0%)
High school	67 (17.6%)	83 (19.3%)	17 (13.1%)	2 (10.0%)
Post-secondary	299 (78.5%)	335 (77.9%)	111 (85.4%)	18 (90.0%)
Personal income (%)				
Less than $15,000	13 (3.5%)	18 (4.2%)	4 (3.1%)	0 (0.0%)
$15,000 to $29,999	44 (11.7%)	42 (9.9%)	11 (8.5%)	3 (15%)
$30,000 to $49,999	77 (20.5%)	106 (25.0%)	31 (24.0%)	2 (10%)
$50,000 to 69,999	79 (21.0%)	90 (21.2%)	21 (16.3%)	4 (20%)
$70,000 to $99,999	65 (17.3%)	65 (15.3%)	14 (10.9%)	1 (5%)
More than $100,000	42 (11.2%)	47 (11.1%)	20 (15.5%)	3 (15%)
Do not know	6 (1.6%)	3 (0.7%)	1 (0.8%)	1 (5%)
Do not wish to answer	55 (14.4%)	59 (13.7%)	28 (21.5%)	6 (30%)
Movement behaviours				
Average daily MVPA (min/day)	10 ± 6	33 ± 21	43± 21	49 ± 23
Average daily sedentary time (hr/day)	13 ± 1.4	11.9 ± 1.3	10.6 ± 1.2	8.7 ± 0.7
Average daily sleep (hr/day)	6.1 ± 0.8	6.4 ± 1.5	7.2 ± 0.5	7.6 ± 0.5
Cardiovascular health risk indicators				
FRS 10-year risk (%)	7.7 ± 4.6	6.7 ± 3.9	6.3 ± 3.1	6.7 ± 3.0
Waist circumference (cm)	98.2 ±14.6	92.7 ± 12.1	90.2 ± 11.4	91.8 ± 11.3
BMI (kg/m²)	28.2 ± 6	26.1 ± 4.6	25.0 ± 4.3	25.9 ± 3.8
Systolic blood pressure (mmHg)	123 ± 14	121 ± 14	120 ± 14	126 ± 13
Diastolic blood pressure (mmHg)	77 ± 10	76 ± 10	77 ± 11	83 ± 10
Total cholesterol (mmol/L)	5.1 ± 1	5.3 ± 0.9	5.6 ± 0.9	5.6 ± 0.9
Triglycerides (mmol/L)	1.2 ± 0.6	1.1 ± 0.6	1.0 ± 0.4	1.2 ± 0.7
HDL Cholesterol (mmol/L)	1.7 ± 0.4	1.7 ± 0.4	1.9 ± 0.4	1.8 ± 0.5
WH Frailty Index	0.18 ± 0.09	0.14 ± 0.07	0.14 ± 0.06	0.16 ± 0.06

Continuous variables are expressed as Mean ± standard deviation; categorical variables are expressed as n (%). ***BMI****=Body Mass Index;* ***HDL****=High-Density Lipoprotein;* ***FRS****=Framingham Risk Score;* ***WH****=WARM Hearts;* ***MVPA****=Moderate to vigorous intensity physical activity;* ***ST****=Sedentary time.*

3.3 Association between meeting the general combinations of these recommendations with cardiovascular health indicators

The associations between the general combination of Canadian 24HMG movement behaviour and the cardiovascular indicators are presented in Table 8. The analysis sorted participants into groups based on their adherence to none, one, two, or all three guidelines, with "None" as the reference group for all data presented in Table 8. In general, meeting one out of three and two out of three was significantly associated with better health for six out of nine compared to the "None" group, including log waist circumference, log BMI, log total cholesterol, log HDL and log FI score. In addition to those outcomes, only log FRS was significant when the "One out of three" group was compared to the "None" group. Likewise, log triglycerides were significant for the "Two out of three" group compared to the "None" group. For the unadjusted model, meeting one or two out of the three guidelines was significantly associated with the log FRS score, with β coefficients of -0.12 (95% CI [-0.19, -0.04]) and -0.14 (95% CI [-0.25, -0.04]), respectively, which represents a reduction in FRS score of 0.89% and 0.87%, respectively. The "All three" group showed no association with the "None" group for log FRS (β = -0.08, 95% CI [-0.31, 0.16]). For the adjusted model, only the "One out of three" group showed a significantly lower log FRS score, with β coefficients of -0.08 (95% CI [-0.15, -0.02]) being a change of 0.92 % in raw FRS score compared to the "None" group. In comparison, the "Two out of three" group had a β of -0.07 (95% CI [-0.16, 0.03]), and the "All three" group's β coefficient is 0.17 (95% CI [-0.06, 0.39]) were not significantly different than the "None" group.

Participants who met all three guidelines, compared to those who met none of the recommendations, had lower log waist circumference ((β = -0.08, 95% CI [-0.14, -0.02]), which corresponded to a reduction of 0.92 cm in waist circumference, and lower log BMI (β = -0.09,

95% CI [-0.17, -0.05]), changing 0.91 kg/m² in BMI, compared to those who met none of the recommendations. In addition, participants in the "All three" group showed significant associations compared to the "None" group in log diastolic blood pressure (β = 0.07, 95% CI [0.01, 0.13]), which represented an increase in diastolic blood pressure by 1.07 mmHg.

Table 8. Associations between meeting the general combinations of these recommendations with cardiovascular health indicators (Adjusted for age and highest education).

Meeting Recommendation	Log_ FRS score	Log_WC	Log_BMI	Log_SBP	Log_DBP	Log_TC	Log_ Triglycerides	Log_HDL	Log_ WH Frailty Index
	β (95%CI)	β (95%CI)	β (95%CI)	β (95%CI)	β (95%CI)	β (95%CI)	β (95%CI)	β (95%CI)	β (95%CI)
General combination (Unadjusted model)									
None	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
One out of three	**-0.12 (-0.19, -0.04)**	**-0.06 (-0.07, -0.04)**	**-0.07 (-0.10, -0.05)**	**-0.02 (-0.03, 0.00)**	-0.01 (-0.03, 0.01)	**0.03 (0.00, 0.05)**	-0.03 (-0.09, 0.03)	**0.05 (0.01, 0.08)**	**-0.09 (-0.17, -0.01)**
Two out of three	**-0.14 (-0.25, -0.04**	**-0.08 (-0.11, -0.05)**	**-0.11 (-0.15, -0.08)**	**-0.03 (-0.05, 0.00)**	-0.01 (-0.04, 0.02)	**0.08 (0.05, 0.12)**	-0.08 (-0.17, 0.00)	**0.13 (0.08, 0.18)**	**-0.16 (-0.28, -0.05**
All three	-0.08 (-0.31, 0.16)	**-0.06 (-0.12, -0.00)**	-0.07 (-0.16, 0.01)	0.02 (-0.03, 0.07)	**0.08 (0.02, 0.14)**	**0.09 (0.00, 0.17)**	0.03 (-0.17, 0.22)	0.04 (-0.07, 0.15)	-0.11 (-0.36, 0.14)
General combination (Adjusted model)									
None	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
One out of three	**-0.08 (-0.15, -0.01)**	**-0.06 (-0.08, -0.04)**	**-0.08 (-0.10, -0.05)**	-0.01 (-0.03, 0.00)	-0.01 (-0.03, 0.01)	**0.03 (0.00, 0.05)**	-0.03 (-0.09, 0.03)	**0.05 (0.02, 0.09)**	**-0.08 (-0.15, 0.00)**
Two out of three	-0.07 (-0.16, 0.03)	**-0.09 (-0.11, -0.06)**	**-0.12 (-0.16, -0.08)**	-0.02 (-0.04, 0.00)	-0.01 (-0.03, 0.02)	**0.08 (0.05, 0.12)**	**-0.09 (-0.18, 0.00)**	**0.14 (0.09, 0.18)**	**-0.14 (-0.25, -0.03)**
All three	0.10 (-0.12, 0.31)	**-0.08 (-0.14, -0.02)**	**-0.09 (-0.17, 0.01)**	0.04 (-0.01, 0.09)	**0.07 (0.01, 0.13)**	0.08 (-0.01, 0.16)	0.01 (-0.18, 0.21)	0.05 (-0.05, 0.16)	-0.05 (-0.30, 0.20)

β (95%CI) = unstandardized beta coefficients (95% Confidence Intervals); ***FRS****=Framingham Risk Score;* ***BMI*** *= Body Mass Index;* ***WC*** *=Waist Circumference;* ***SBP*** *= Systolic Blood Pressure;* ***DBP*** *= Diastolic Blood Pressure;* ***TD****=Total cholesterol;* ***HDL****=High-Density Lipoprotein;* ***WH****=WARM Hearts. Statistically significant associations (p<0.05) are highlighted in bold.*

To determine if meeting more components of the 24HMG is associated with lower CVD risk, we repeated the analysis by changing the reference group ("One out of three" vs. "Two out of three," "One of three" vs. "All three," and "Two out of three" vs. "All three"). Table 9 reports the outcomes of those analyses in matrices. Significant associations were found in "One out of three" compared to "Two out of three," with four out of nine associations, including log waist circumference, log BMI, log total cholesterol, and log HDL. Specifically, the analysis showed that individuals meeting two out of the three components of the 24HMG had significantly lower log waist circumference (β = -0.03, 95% CI [-0.05, 0.00]) by 0.97 cm compared to those meeting only one component. Similarly, the "Two out of three" group exhibited a lower log BMI (β = -0.04, 95% CI[-0.08, -0.01]) and higher log HDL levels (β = 0.08, 95% CI [0.04, 0.13]), indicating a decrease of 0.96 kg/m^2 in BMI and an increase of 1.08 mmol/L in HDL level compared to the "One out of three" group. However, we found the "Two out of three" group had higher log total cholesterol (β = 0.05, 95% CI [0.02, 0.09]) compared to the "One out of three" group. Additional significant associations were observed in log systolic and diastolic blood pressure when comparing the "One out of three" and "Two out of three" groups with the "All three" groups. The β coefficients for these comparisons indicate an increase in log systolic blood pressure and log diastolic blood pressure between the "One out of three " and the "All three" groups," as well as between the "Two out of three " and the "All three" groups.

Table 9. Coefficient values of the general group for each cardiovascular health indicator while different groups were used as reference (Adjusted for age and highest education).

Cardiovascular health indicators	Meeting recommendations	Unadjusted Model				Adjusted Model			
		None	One out of three	Two out of the three	All three	None	One out of three	Two out of the three	All three
		β (95%CI)	β (95%CI)	β (95%CI)	β (95%CI)	β (95%CI)	β (95%CI)	β (95%CI)	β (95%CI)
log_FRS 10-year risk score	None	-	**-0.12 (-0.19, -0.04)**	**-0.14 (-0.25, -0.04)**	*-0.08 (-0.31, 0.16)*	-	**-0.08 (-0.15, -0.01)**	-0.07 (-0.16, 0.03)	0.10 (-0.12, 0.31)
	One out of three	-	-	-0.03 (-0.13, 0.08）	0.04 (-0.19, 0.27)	-	-	0.01 (-0.08, 0.11)	0.17 (-0.04, 0.39)
	Two out of the three	-	-	-	0.07 (-0.18, 0.31)	-	-	-	0.16 (-0.06, 0.39)
	All three	-	-	-	-	-	-	-	-
log_WC	None	-	**-0.06 (-0.07, -0.04)**	**-0.08 (-0.11, -0.05)**	**-0.06 (-0.12, 0.00)**	-	**-0.06 (-0.08, -0.04)**	**-0.09 (-0.11, -0.06)**	**-0.08 (-0.14, -0.02)**
	One out of three	-	-	-0.03 (-0.05, 0.00)	-0.03 (-0.07, 0.05)	-	-	**-0.03 -0.05, 0.00**	-0.02 (-0.08, 0.04)
	Two out of the three	-	-	-	0.02 (-0.05, 0.08)	-	-	-	0.01 (-0.05, 0.07)
	All three	-	-	-	-	-	-	-	-
log_BMI	None	-	**-0.07 (-0.10, -0.05)**	**-0.11 (-0.15, -0.08)**	-0.07 (-0.16, 0.01)	-	**-0.08 (-0.10, -0.05)**	**-0.12 (-0.16, -0.09)**	**-0.09 (-0.17, -0.01)**
	One out of three	-	-	**-0.04 (-0.08, -0.01)**	0.00 (-0.08, 0.08)	-	-	**-0.04 (-0.08, -0.01)**	-0.02 (-0.10, 0.06)
	Two out of the three	-	-	-	0.04 (-0.04, 0.13)	-	-	-	0.03 (-0.06, 0.11)
	All three	-	-	-	-	-	-	-	-
log_SBP	None	-	**-0.02 (-0.03, 0.00)**	**-0.03 (-0.05, 0.00)**	0.02 (-0.03, 0.07)	-	-0.01 (-0.03, 0.00)	-0.02 (-0.04, 0.00)	0.04 (-0.01, 0.09)
	One out of three	-	-	-0.01 (-0.03, 0.01)	0.04 (-0.01, 0.09)	-	-	-0.01 (-0.03, 0.01)	**0.05 (0.00, 0.10)**
	Two out of the three	-	-	-	0.05 (0.00, 0.10)	-		-	**0.06 (0.01, 0.11)**
	All three	-	-	-	-	-	-	-	-
log_DBP	None	-	-0.01 (-0.03, 0.01)	-0.11 (-0.04, 0.02)	**0.08 (0.02, 0.14)**	-	-0.01 (-0.03, 0.01)	-0.01 (-0.04, 0.02)	**0.07 (0.01, 0.13)**
	One out of three	-	-	0.00 (-0.02, 0.03)	**0.09 (0.03, 0.15)**	-	-	0.00 (-0.02, 0.03)	**0.09 (0.03, 0.15)**
	Two out of the three	-	-	-	**0.09 (0.03, 0.15)**	-	-	-	**0.08 (0.02, 0.15)**
	All three	-	-	-	-	-	-	-	-

log_TC	None	-	**0.03 (0.00, 0.05)**	**0.08 (0.05, 0.12)**	**0.09 (0.00, 0.17)**	-	**-0.03 (0.00, 0.05)**	**-0.08 (0.04, 0.12)**	0.08 (-0.01, 0.16)
	One out of three	-	-	**0.06 (0.02, 0.09)**	0.06 (-0.02, 0.14)	-	-	**0.05 (0.02, 0.09)**	0.05 (-0.03, 0.13)
	Two out of the three	-	-	-	0.00 (-0.09, 0.09)	-	-	-	0.00 (-0.09, 0.08)
	All three	-	-	-	-	-	-	-	-
Log_ Triglycerides	None	-	-0.03 (-0.09, 0.03)	-0.08 (-0.17, 0.00)	0.03 (-0.17, 0.22)	-	-0.03 (-0.09, 0.03)	**-0.09 (-0.17, 0.00)**	0.01 (-0.18, 0.21)
	One out of three	-	-	-0.05 (-0.14, 0.03)	0.06 (-0.14, 0.25)	-	-	-0.05 (-0.14, 0.03)	0.05 (-0.15, 0.24)
	Two out of the three	-	-	-	0.11 (-0.09, 0.31)	-	-	-	0.10 (-0.10, 0.30)
	All three	-	-	-	-	-	-	-	-
Log_HDL	None	-	**0.05 (0.01, 0.08)**	**0.13 (0.08, 0.18)**	0.04 (-0.07, 0.15)	-	**0.05 (0.02, 0.08)**	**0.14 (0.09, 0.18)**	0.05 (-0.05, 0.16)
	One out of three	-	-	**0.08 (0.04, 0.13)**	-0.01 (-0.12, 0.10)	-	-	**0.08 (0.04, 0.13)**	0.00 (-0.10, 0.11)
	Two out of the three	-	-	-	-0.09 (-0.21, 0.02)	-	-	-	-0.08 (-0.19, 0.03)
	All three	-	-	-	-	-	-	-	-
Log_ WH Frailty Index	None	-	**-0.09 (-0.17, -0.01)**	**-0.16 (-0.28, -0.05)**	-0.11 (-0.36, 0.14)	-	**-0.08 (-0.16, 0.00)**	**-0.14 (-0.25, -0.03)**	-0.05 (-0.30, 0.20)
	One out of three	-	-	-0.08 (-0.19, 0.04)	-0.02 (-0.27, 0.23)	-	-	0.06 (-0.17, 0.05)	0.03 (-0.22, 0.28)
	Two out of the three	-	-	-	0.06 (-0.21, 0.32)	-	-	-	0.09 (-0.18, 0.35)
	All three	-	-	-	-	-	-	-	-

β = unstandardized beta coefficients (95% Confidence Intervals); ***FRS****=Framingham Risk Score;* ***BMI*** *= Body Mass Index;* ***WC*** *=Waist Circumference;* ***SBP*** *= Systolic Blood Pressure;* ***DBP*** *= Diastolic Blood Pressure;* ***TD****=Total cholesterol;* ***HDL****=High-Density Lipoprotein;* ***FRS****=Framingham Risk Score;* ***WH****=WARM Hearts. Statistically significant associations (p<0.05) are highlighted in bold.*

3.4 Specific Groups

Table 10 provides a detailed characterization of participants based on their adherence to specific components of the Canadian 24-hour Movement Guidelines. These components include none, MVPA only, ST only, sleep only, combinations of two (MVPA & ST, MVPA & Sleep, ST & Sleep), and adherence to all three components. The mean age ranged between the "None" group of 66 ± 7 years and the "All three" group of 61 ± 3 years. Specifically, the mean age for those meeting only one of the components was the same in the "MVPA only" and "ST only" groups of 64 ± 5 years, as well as the mean age for the "sleep only" group was 66 ± 7 years. Participants in the "ST only," "ST & sleep," and "All three" groups all had at least a high school degree. The "None" group averaged 10 ± 6 minutes of MVPA per day and 61 ± 33 minutes of MVPA per day in the "MVPA & ST" group, respectively. Participants adhering to "ST only" and "ST & sleep" reported an average range of 8.7 ± 0.5 hours per night and 8.7 ± 0.7 hours per night of sedentary time. The "None" group had a mean FRS score of 7.7 ± 4.6 %, and the "ST only" group reported an average FRS score of 4.8 ± 1.8 %, classified as having lower CVD risk in 10 years. The mean waist circumference ranged from 86.8 ± 7.6 cm in the "ST & Sleep" group and 98.2 ± 14.6 cm in the "None" group. The average BMI ranged from 24.0 ± 3.4 kg/m² in the "ST and sleep only" groups and 28.2 ± 6 kg/m² in the "None" group. The "ST only" group showed an average systolic and diastolic blood pressure of 113 ± 15 mmHg and 73 ± 13 mmHg, respectively. The average total cholesterol was 5.1 ± 1 mmol/L in the "None" and "ST only" groups. The mean HDL level was 2.0 ± 0.4 mmol/L in the "MVPA & ST" group and 1.7 ± 0.4 mmol/L in the "None" and "Sleep only" groups. The mean FI score ranged from 0.18 ± 0.09 in the "None" group and 0.12 ± 0.06 in the "ST and sleep only" group. Race data for Table 10 is not

being reported because some of the groups had a sample size of less than 5. This decision was made in order to prevent the inadvertent identification of any participant.

Table 10. Characterization of all participants in each specific group.

Variables	None (n=381)	MVPA only (n=312)	ST only (n=5)	Sleep only (n=113)	MVPA & ST(n=22)	MVPA & Sleep (n=103)	ST & Sleep (n=5)	All three (n=20)
Age (years)	66 ± 7	64 ± 5	64 ± 5	66 ± 7	63 ± 5	63 ± 5	65 ± 4	61 ± 3
Highest household education (%)								
No degree/ certificate/diploma	15 (3.9%)	6 (1.9%)	0 (0.0%)	6 (5.3%)	1 (4.5%)	1(1.0%)	0 (0.0%)	0 (0.0%)
High school	67 (17.6%)	59 (18.9%)	2 (40.0%)	22 (19.5%)	6 (27.3%)	9 (8.7%)	2 (40.0%)	2 (10.0%)
Post-secondary	299 (78.5%)	247 (79.2%)	3 (60.0%)	85 (75.2%)	15 (68.2%)	93 (90.3%)	3 (60.0%)	18 (90.0%)
Personal income (%)								
Less than $15,000	13 (3.5%)	12 (3.9%)	0 (0.0%)	6 (5.3%)	0 (0.0%)	4 (3.9%)	0 (0.0%)	0 (0.0%)
$15,000 to $29,999	44 (11.7%)	28 (9.2%)	1 (20.0%)	13 (11.5%)	3 (13.6%)	6 (5.9%)	2 (40.0%)	3 (15%)
$30,000 to $49,999	77 (20.5%)	76 (24.8%)	1 (20.0%)	29 (25.7%)	2 (9.1%)	27 (26.5%)	2 (40.0%)	2 (10%)
$50,000 to 69,999	79 (21.0%)	63 (20.6%)	1 (20.0%)	26 (23.0%)	4 (18.2%)	16 (15.7%)	1 (20.0%)	4 (20%)
$70,000 to $99,999	65 (17.3%)	47 (15.4%)	1 (20.0%)	17 (15.0%)	2 (9.1%)	12 (11.8%)	0 (0.0%)	1 (5%)
More than $100,000	42 (11.2%)	37 (12.1%)	1 (20.0%)	9 (8.0%)	2 (9.1%)	18 (17.6%)	0 (0.0%)	3 (15%)
Do not know	6 (1.6%)	2 (0.7%)	0 (0.0%)	1 (0.9%)	0 (0.0%)	1 (1.0%)	0 (0.0%)	1 (5%)
Do not wish to answer	55 (14.4%)	47 (15.1%)	0 (0.0%)	12 (10.6%)	9 (40.9%)	19 (18.4%)	0 (0.0%)	6 (30.0%)
Movement behaviours								
Average daily MVPA (min/day)	10 ± 6	41 ± 17	15 ± 3	9 ± 7	61 ± 33	40 ± 15	18 ± 1	49 ± 23
Average daily sedentary time (hr/day)	13 ± 1.4	12 ± 1.3	8.7 ± 0.5	11.9 ± 1.1	9.1 ± 0.6	11.1 ± 1	9.1 ± 0.2	8.7 ± 0.7
Average daily sleep (hr/day)	6.1 ± 0.8	6.1 ± 1.5	6.5 ± 1.2	7.4 ± 0.4	6.4 ± 0.7	7.4 ± 0.3	7.3 ± 0.2	7.6 ± 0.5
Cardiovascular health risk indicators								
FRS 10-year risk (%)	7.7 ± 4.6	6.4 ± 3.6	4.8 ± 1.8	7.8 ± 4.5	7.0 ± 3.4	6.1 ± 3.1	7.4 ± 2.7	6.7 ± 3.0
Waist circumference (cm)	98.2 ± 14.6	91.7 ± 11.2	98.0 ± 9.9	95.2 ± 13.9	92.8 ± 12.5	89.9 ± 11.3	86.8 ± 7.6	91.8 ± 11.3
BMI (kg/m2)	28.2 ± 6	25.7 ± 4.2	27.4 ± 5	27.1 ± 5.5	25.4 ± 4.2	25.0 ± 4.4	24.0 ± 3.4	25.9 ± 3.8
Systolic blood pressure (mmHg)	123 ± 14	120 ± 13	113 ± 15	123 ± 14	124 ± 14	119 ± 14	124 ± 4	126 ± 13
Diastolic blood pressure (mmHg)	77 ± 10	76 ± 10	73 ± 13	77 ± 10	79 ± 9	76 ± 11	75 ± 4	83 ± 10
Total cholesterol (mmol/L)	5.1 ± 1	5.3 ± 1	5.1 ± 1	5.2 ± 1	5.9 ± 0.9	5.5 ± 0.9	5.1 ± 0.8	5.6 ± 0.9
Triglycerides (mmol/L)	1.2 ± 0.6	1.1 ± 0.6	1.2 ± 0.4	1.3 ± 0.6	1.1 ± 0.5	1.0 ± 0.4	0.9 ± 0.4	1.2 ± 0.7
HDL Cholesterol (mmol/L)	1.7 ± 0.4	1.8 ± 0.4	1.8 ± 0.2	1.7 ± 0.4	2.0 ± 0.4	1.9 ± 0.4	1.9 ± 0.5	1.8 ± 0.5
WH Frailty Index	0.18 ± 0.09	0.14 ± 0.06	0.17 ± 0.05	0.14 ± 0.08	0.14 ± 0.07	0.16 ± 0.06	0.12 ± 0.06	0.16 ± 0.06

Continuous variables are expressed as Mean ± standard deviation; categorical variables are expressed as n (%).
***FRS**=Framingham Risk Score; **BMI** = Body Mass Index; **HDL** = High-Density Lipoprotein**; FRS** = Framingham Risk Score**; WH** = WARM Hearts**; MVPA** = Moderate to Vigorous Intensity Physical Activity**; ST** = Sedentary Time.*

3.5 Association between meeting the specific combinations of these recommendations with cardiovascular health indicators

The data presented in Table 11 reports the associations between adherence to specific combinations of Canadian 24HMG recommendations and various cardiovascular health indicators, including unadjusted models and adjusted for age and education. All the data reported in Table 11 utilizes "None" as the reference group. Participants who met "MVPA only" showed significant benefit for eight out of nine cardiovascular health indicators (log FRS score, log waist circumference, log BMI, log systolic blood pressure, log total cholesterol, log triglycerides, log HDL, log frailty index), In contrast, meeting the "Sedentary time only" component showed no significant associations from meeting the "None" group. Meeting the "Sleep only" compared to the "None" group identified one significantly different association, which is log waist circumference (β = -0.03, 95% CI [-0.06, -0.00]), indicating a decrease of 0.97 cm in waist circumference for participants in this group compared to meeting the "None" group.

Comparing the group who met "MVPA and ST only" to the "None" group identified significant associations in four out of nine associations of cardiovascular health indicators (log waist circumference, log BMI, log total cholesterol, and log HDL). More specifically, it was found that decrease in log waist circumference (β = -0.06, 95% CI [-0.12, 0.00]), log BMI (β = -0.12, 95% CI [-0.19, -0.04]), which reduced waist circumference by 0.94cm and BMI by 0.89 kg/m². Meeting "MVPA and sleep only" recommendations group was significantly associated with better health for seven out of nine associations to the "None" group, where indicated reductions in log waist circumference (β = -0.09, 95% CI [-0.12, -0.06]), log BMI (β = -0.12, 95% CI [-0.16, -0.08]), and log systolic blood pressure (β = -0.03, 95% CI [-0.06, -0.01]). Those represented a change in 0.91 cm of waist circumference, 0.89 kg/m² of BMI, and 0.97 mmol/L of

systolic blood pressure. No significant associations were found in log FRS scores (β = -0.10, 95% CI [-0.21, -0.01]) and logged diastolic blood pressure (β = -0.02, 95% CI [-0.04, -0.01]) than the "None" group. Participants who met "ST and sleep only" showed significant associations in one out of nine associations compared to the "None" group, which was log waist circumference (β = -0.12, 95% CI [-0.24, 0.00]) and showed a decrease of 0.89 cm in waist circumference.

Finally, the "MVPA and ST and sleep" recommendations group identified significant associations for four out of nine outcomes compared to the "None" group, including log waist circumference (β = -0.08, 95% CI [-0.14, -0.02]), log BMI (β = -0.09, 95% CI [-0.18, 0.01]), log diastolic blood pressure (β = 0.07, 95% CI [0.01, 0.13]) and log total cholesterol (β = 0.08, 95% CI [0.00, 0.16]). Participants in the "MVPA and ST and sleep" group had lower waist circumference by 0.92 cm and BMI by 0.91 kg/m² but higher diastolic blood pressure by 1.07mmHg and 1.08 mmol/L in total cholesterol level.

Table 11. Associations between meeting the MVPA, sedentary time, and sleep recommendations and combinations of these recommendations with cardiovascular health indicators ((Adjusted for age and highest education).

Meeting Recommendation	Log_ FRS 10-year risk score	Log_WC	Log_BMI	Log_SBP	Log_DBP	Log_TC	Log_ Triglycerides	Log_HDL	Log_ WH Frailty Index
	β (95%CI)	β (95%CI)	β (95%CI)	β (95%CI)	β (95%CI)	β (95%CI)	β (95%CI)	β (95%CI)	β (95%CI)
Specific combination (Unadjusted model)									
None	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
MVPA only	**-0.16 (-0.24, -0.08)**	**-0.06 (-0.09, -0.04)**	**-0.08 (-0.11, -0.06)**	**-0.02 (-0.04, 0.00)**	-0.01 (-0.03, 0.01)	**0.03 (0.00, 0.06)**	**-0.07 (-0.13, -0.01)**	**0.06 (0.03, 0.10)**	**-0.13 (-0.21, -0.05)**
ST only	-0.37 (-0.83, 0.08)	0.00 (-0.11, 0.12)	-0.02 (-0.18, 0.14)	-0.09 (-0.19, 0.01)	-0.05 (-0.17, 0.06)	0.00 (-0.16, 0.16)	0.11 (-0.27, 0.49)	0.07 (-0.14, 0.29)	0.35 (-0.15, 0.84)
Sleep only	0.02 (-0.09, 0.13)	**-0.03 (-0.06, 0.00)**	-0.04 (-0.08, 0.00)	0.00 (-0.02, 0.02)	0.00 (-0.03, 0.03)	0.02 (-0.02, 0.06)	0.07 (-0.02, 0.16)	0.00 (-0.05, 0.05)	0.00 (-0.12, 0.12)
MVPA and ST only	-0.03 (-0.25, 0.19)	-0.05 (-0.11, 0.00)	**-0.10 (-0.17, -0.02)**	0.01 (-0.04, 0.06)	0.03 (-0.03, 0.09)	**0.15 (0.07, 0.23)**	-0.03 (-0.22, 0.15)	**0.21 (0.10, 0.31)**	-0.20 (-0.45, 0.04)
MVPA and sleep only	**-0.18 (-0.29, -0.07)**	**-0.09 (-0.12, -0.06)**	**-0.12 (-0.16, -0.08)**	**-0.04 (-0.06, -0.01)**	-0.02 (-0.05, 0.01)	**0.07 (0.03, 0.11)**	-0.09 (-0.18, 0.00)	**0.11 (0.06, 0.17)**	**-0.16 (-0.28, -0.04)**
ST and sleep only	0.07 (-0.38, 0.53)	-0.12 (-0.23, 0.00)	-0.13 (-0.29, 0.03)	0.02 (-0.08, 0.11)	-0.02 (-0.13, 0.10)	0.00 (-0.16, 0.17)	-0.19 (-0.57, 0.19)	0.14 (-0.07, 0.36)	-0.05 (-0.55, 0.44)
MVPA and ST and sleep	-0.08 (-0.31, 0.16)	-0.06 (-0.12, 0.00)	-0.07 (-0.15, 0.01)	0.02 -0.03, 0.07)	**0.08 (0.02, 0.14)**	**0.09 (0.00, 0.17)**	0.03 (-0.17, 0.22)	0.04 (-0.07, 0.15)	-0.11 (-0.36, 0.14)
Specific combination (Adjusted model)									
None	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
MVPA only	**-0.10 (-0.18, -0.03)**	**-0.07 (-0.09, -0.05)**	**-0.09 (-0.12, -0.07)**	**-0.02 (-0.03, 0.00)**	-0.02 (-0.04, 0.00)	**0.03 (0.00, 0.06)**	**-0.08 (-0.14, -0.01)**	**0.07 (0.04, 0.11)**	**-0.11 (-0.20, -0.03)**
ST only	-0.33 (-0.75, 0.09)	0.01 (-0.12, 0.11)	-0.04 (-0.20, 0.12)	-0.09 (-0.18, 0.01)	-0.06 (-0.18, 0.05)	0.00 (-0.17, 0.16)	0.10 (-0.27, 0.48)	0.09 (-0.12, 0.29)	0.35 (-0.14, 0.84)
Sleep only	0.01 (-0.11, 0.09)	**-0.03 (-0.06, 0.00)**	-0.04 (-0.07, 0.00)	0.00 (-0.03, 0.02)	0.00 (-0.03, 0.03)	0.02 (-0.02, 0.06)	0.07 (-0.02, 0.16)	0.00 (-0.05, 0.05)	0.01 (-0.12, 0.11)
MVPA and ST only	-0.04 (-0.17, 0.24)	**-0.06 (-0.12, 0.00)**	**-0.12 (-0.19, -0.04)**	0.01 (-0.04, 0.06)	0.03 (-0.02, 0.09)	**0.15 (0.07, 0.23)**	-0.05 (-0.24, 0.13)	**0.23 (0.12, 0.33)**	-0.19 (-0.43, 0.05)
MVPA and sleep only	-0.10 (-0.20, -0.01)	**-0.09 (-0.12, -0.06)**	**-0.12 (-0.16, -0.08)**	**-0.03 (-0.05, -0.01)**	-0.02 (-0.04, 0.01)	**0.07 (0.03, 0.11)**	**-0.09 (-0.19, 0.00)**	**0.12 (0.07, 0.17)**	**-0.13 (-0.25, -0.01)**
ST and sleep only	0.08 (-0.35, 0.50)	**-0.12 (-0.24, 0.00)**	-0.14 (-0.30, 0.01)	0.01 (-0.09, 0.11)	-0.02 (-0.13, 0.10)	0.00 (-0.16, 0.17)	-0.19 (-0.56, 0.19)	0.15 (-0.06, 0.36)	-0.06 (-0.56, 0.43)
MVPA and ST and sleep	-0.16 (-0.13, 0.31)	**-0.08 (-0.14, 0.02)**	**-0.09 (-0.17, 0.01)**	0.04 (-0.01, 0.09)	**0.07 (0.01, 0.13)**	0.08 (0.00, 0.16)	0.06 (-0.19, 0.20)	0.06 (-0.05, 0.16)	-0.05 (-0.31, 0.20)

β (95%CI) = unstandardized beta coefficients (95% Confidence Intervals); ***BMI*** *= Body Mass Index;* ***WC*** *=Waist Circumference;* ***SBP*** *= Systolic Blood Pressure;* ***DBP*** *= Diastolic Blood Pressure;* ***TD****=Total cholesterol;* ***HDL****=High-Density Lipoprotein;* ***FRS****=Framingham Risk Score;* ***WH****=WARM Hearts.* ***MVPA*** *=moderate- to vigorous-intensity physical activity;* ***ST****=Sedentary time. All models are adjusted for age, education, and personal income. Statistically significant associations (p<0.05) are highlighted in bold.*

To determine if meeting the MVPA component is more strongly associated with lower CVD risk than meeting the ST component or sleep component when only one component is met, and if meeting the physical activity and sedentary behaviour guidelines is associated with lower CVD risk than other combinations of two components. We repeated the analysis by changing the reference group (i.e., MVPA only vs. ST only, MVPA only vs. Sleep only, and ST only vs. Sleep only) and (MVPA and ST only vs. MVPA and sleep only, MVPA and ST only vs. ST and sleep only, and MVPA and sleep only vs. ST and sleep only). Table 12 reports the outcomes of those analyses in matrices.

Among the comparisons, significant associations were observed in log waist circumference, log BMI, log triglycerides, and log HDL levels when comparing the "MVPA only" and "Sleep only" groups. The findings showed that individuals meeting only the sleep guidelines had significantly higher waist circumference and BMI compared to those meeting only the MVPA guidelines. The beta coefficients for log waist circumference and log BMI were 0.04 (95% CI [0.01, 0.07]) and 0.06 (95% CI [0.02, 0.10]), respectively, indicating that adherence to the sleep component only is associated with higher anthropometric measures than the "MVPA only" group. Those changes indicated an increase in waist circumference by 1.04 cm and BMI by 1.06 kg/m^2. A similar pattern was found in the log triglycerides and log HDL levels. The data indicated that the "Sleep only" group had higher triglyceride levels ($\beta = 0.15$, 95% CI [0.06, 0.24]) compared to the "MVPA only" group, suggesting that meeting MVPA guidelines may be associated with lower triglyceride levels. Additionally, the "MVPA only" group had lower HDL levels ($\beta = -0.07$, 95% CI[-0.12, -0.02]) than the "Sleep only" group, which increased the HDL level by 0.32 mmol/L.

No significant associations were detected between "MVPA only" vs. "ST only" and "ST only" vs. "Sleep only" in the assessed variables. Additionally, no significant associations were found in all groups that met two components of 24HMG. More specifically, no associations were detected when comparisons were made between "MVPA and ST only vs. "MVPA and sleep only," "MVPA and ST only "vs. "ST and sleep only," and "MVPA and sleep only" vs. "ST and sleep in the assessed variables.

Table 12. Coefficient values of the specific group for each cardiovascular health indicator while different groups were used as reference (Adjusted for age and highest education).

Cardiovascular health indicators	Meeting recommendations	None	MVPA only	ST only	Sleep only	MVPA + ST	MVPA + sleep	ST + sleep	MVPA + ST + sleep
		B (95%CI)	B (95%CI)	B (95%CI)	B (95%CI)	B (95%CI)	B (95%CI)	B (95%CI)	B (95%CI)
Unadjusted Model									
log_FRS 10-year risk score	None	-	**-0.16 (-0.24, -0.08)**	-0.37 (-0.83, 0.08)	0.02 (-0.09, 0.13)	-0.03 (-0.25, 0.19)	**-0.18 (-0.29, -0.07)**	0.07 (-0.38, 0.53)	-0.08 (-0.31, 0.16)
	MVPA only	-	-	-0.21 (-0.67, 0.25)	**0.19 (0.07, 0.30)**	0.13 (-0.09, 0.36)	-0.02 (-0.13, 0.10)	0.24 (-0.22, 0.70)	0.09 (-0.15, 0.32)
	ST only	-	-	-	0.40 (-0.07, 0.86)	0.35 (-0.16, 0.85	0.20 (-0.27, 0.66)	0.45 (-0.20, 1.09)	0.30 (-0.21, 0.81)
	Sleep only	-	-	-	-	-0.05 (-0.29, 0.19)	-0.20 (-0.34, -0.06)	0.05 (-0.41 0.52)	-0.10 (-0.35 0.15)
	MVPA + ST	-	-	-	-	-	-0.15 (-0.39, 0.09)	0.10 (-0.40, 0.61)	-0.05 (-0.36, 0.27)
	MVPA + sleep	-	-	-	-	-	-	0.25 (-0.21, 0.72)	0.10 (-0.15, 0.35)
	ST + Sleep	-	-	-	-	-	-	-	-0.15 (-0.66, 0.36)
	MVPA + ST +sleep	-	-	-	-	-	-	-	-
log_WC	None	-	**-0.06 (-0.09, -0.04)**	0.00 (-0.11, 0.12)	**-0.03 (-0.06, 0.00)**	-0.05 (-0.11, 0.00)	**-0.09 (-0.12, -0.06)**	-0.12 (-0.23, 0.00)	-0.06 (-0.12, 0.00)
	MVPA only	-	-	0.07 (-0.05, 0.19)	**0.03 (0.00, 0.06)**	0.01 (-0.05, 0.07)	-0.02 (-0.05, 0.01)	-0.05 (-0.17, 0.07)	0.00 (-0.06, 0.06)
	ST only	-	-	-	-0.04 (-0.16, 0.09)	-0.06 (-0.19, 0.07)	-0.09 (-0.21, 0.03)	-0.12 (-0.29, 0.05)	-0.07 (-0.20, 0.06)
	Sleep only	-	-	-	-	-0.02 (-0.08, 0.04)	-0.05 (-0.09, -0.02)	-0.08 (-0.21, 0.04)	-0.03 (-0.10, 0.03)
	MVPA + ST	-	-	-	-	-	-0.03 (-0.09, 0.03)	-0.06 (-0.19, 0.07)	-0.01 (-0.09, 0.07)
	MVPA + sleep	-	-	-	-	-	-	-0.03 (-0.15, 0.09)	0.02 (-0.04, 0.09)
	ST + Sleep	-	-	-	-	-	-	-	0.05 (-0.08, 0.18)
	MVPA + ST +sleep	-	-	-	-	-	-	-	-
log_BMI	None	-	**-0.08 (-0.11, -0.06)**	-0.02 (-0.18, 0.14)	-0.04 (-0.08, 0.00)	**-0.10 (-0.17, -0.02)**	**-0.12 (-0.16, -0.08)**	-0.13 (-0.29, 0.03)	-0.07 (-0.15, 0.01)
	MVPA only	-	-	0.06 (-0.10, 0.22)	**0.05 (0.01, 0.09)**	-0.01 (-0.09, 0.07)	-0.03 (-0.07, 0.01)	-0.05 (-0.21, 0.11)	0.01 (-0.07, 0.09)
	ST only	-	-	-	-0.01 (-0.18, 0.15)	-0.07 (-0.25, 0.10)	-0.09 (-0.26, 0.07)	-0.11 (-0.33, 0.12)	-0.05 (-0.23, 0.13)
	Sleep only	-	-	-	-	-0.06	-0.08	-0.09	-0.04

						(-0.14, 0.02)	(-0.13, -0.03)	(-0.26, 0.07)	(-0.12, 0.05)
	MVPA + ST	-	-	-	-	-	-0.02 (-0.10, 0.06)	-0.04 (-0.21, 0.14)	0.02 (-0.09, 0.13)
	MVPA + sleep	-	-	-	-	-	-	-0.02 (-0.18, 0.15)	0.04 (-0.04, 0.13)
	ST + Sleep	-	-	-	-	-	-	-	0.06 (-0.12, 0.24)
	MVPA + ST +sleep	-	-	-	-	-	-	-	-
log_SBP	None	-	**-0.02 (-0.04, 0.00)**	-0.09 (-0.19, 0.01)	0.00 (-0.02, 0.02)	0.01 (-0.04, 0.06)	**-0.04 (-0.06, -0.01)**	0.02 (-0.08 0.11)	0.02 (-0.03 0.07)
	MVPA only	-	-	-0.07 (-0.17, 0.03)	0.02 (0.00, 0.05)	0.03 (-0.02, 0.08)	-0.02 (-0.04 , 0.01)	0.04 (-0.06 0.14)	0.05 (-0.01 0.10)
	ST only	-	-	-	0.09 (-0.01, 0.19)	0.09 (-0.02, 0.20)	0.05 (-0.05, 0.15)	0.10 (-0.04, 0.24)	0.11 (0.00, 0.22)
	Sleep only	-	-	-	-	0.01 (-0.03, 0.08)	-0.04 (-0.09, 0.12)	0.01 (-0.07, -0.01)	0.02 (-0.04, 0.06)
	MVPA + ST	-	-	-	-	-	-0.04 (-0.10, 0.01)	0.01 (-0.10, 0.12)	0.02 (-0.05, 0.09)
	MVPA + sleep	-	-	-	-	-	-	0.05 (-0.05, 0.15)	0.06 (0.01, 0.11)
	ST + Sleep	-	-	-	-	-	-	-	0.01 (-0.10, 0.12)
	MVPA + ST +sleep	-	-	-	-	-	-	-	-
log_DBP	None	-	-0.01 (-0.03, 0.01)	-0.05 (-0.17, 0.06)	0.00 (-0.03, 0.03)	0.03 (-0.03, 0.09)	-0.02 (-0.05, 0.01)	-0.02 (-0.13, 0.10)	**0.08 (0.02, 0.14)**
	MVPA only	-	-	-0.04 (-0.15, 0.08)	0.01 (-0.02, 0.04)	0.05 (-0.01, 0.10)	0.00 (-0.03, 0.03)	0.00 (-0.12, 0.11)	0.09 (0.03, 0.15)
	ST only	-	-	-	0.05 (-0.07, 0.17)	0.08 (-0.04 , 0.21)	0.03 (-0.08, 0.15)	0.03 (-0.13, 0.20)	0.13 (0.00, 0.26)
	Sleep only	-	-	-	-	0.03 (-0.03, 0.09)	-0.02 (-0.05, 0.02)	-0.02 (-0.14, 0.10)	0.08 (0.02, 0.14)
	MVPA + ST	-	-	-	-	-	-0.05 (-0.11, 0.01)	-0.05 (-0.18, 0.08)	0.05 (-0.03, 0.13)
	MVPA + sleep	-	-	-	-	-	-	0.00 (-0.12, 0.12)	0.10 (0.03, 0.16)
	ST + Sleep	-	-	-	-	-	-	-	0.10 (-0.03, 0.23)
	MVPA + ST +sleep	-	-	-	-	-	-	-	-
log_TC	None	-	**0.03 (0.00, 0.06)**	0.00 (-0.16, 0.16)	0.02 (-0.02, 0.06)	**0.15 (0.07, 0.23**)	**0.07 (0.03, 0.11)**	0.00 (-0.16, 0.17)	**0.09 (0.00, 0.17)**
	MVPA only	-	-	-0.03	-0.01	0.12	0.04	-0.03	0.05

				(-0.20, 0.13)	(-0.05, 0.03)	(0.04 , 0.20)	(0.00, 0.08)	(-0.19, 0.14)	(-0.03, 0.14)
	ST only	-	-	-	0.02 (-0.14, 0.19)	0.15 (-0.03, 0.33)	0.08 (-0.09, 0.24)	0.01 (-0.22, 0.23)	0.09 (-0.09, 0.27)
	Sleep only	-	-	-	-	0.13 (0.05, 0.21)	0.05 (0.00, 0.10)	-0.02 (-0.18, 0.15)	0.06 (-0.02, 0.15)
	MVPA + ST	-	-	-	-	-	-0.08 (-0.16, 0.01)	-0.14 (-0.32, 0.03)	-0.06 (-0.17, 0.05)
	MVPA + sleep	-	-	-	-	-	-	-0.07 (-0.23, 0.09)	0.01 (-0.08, 0.10)
	ST + Sleep	-	-	-	-	-	-	-	0.08 (-0.10, 0.26)
	MVPA + ST +sleep	-	-	-	-	-	-	-	-
Log_ Triglycerides	None	-	**-0.07 (-0.13, -0.01)**	0.11 (-0.27, 0.49)	0.07 (-0.02, 0.16)	-0.03 (-0.22, 0.15)	-0.09 (-0.18, 0.00)	-0.19 (-0.57, 0.19)	0.03 (-0.17, 0.22)
	MVPA only	-	-	0.18 (-0.20, 0.56)	**0.14 (0.05, 0.23)**	0.04 (-0.15, 0.22)	-0.02 (-0.11, 0.08)	-0.12 (-0.50, 0.26)	0.10 (-0.10, 0.29)
	ST only	-	-	-	-0.04 (-0.42, 0.34)	-0.15 (-0.56, 0.27)	-0.20 (-0.58, 0.19)	-0.30 (-0.83, 0.23)	-0.08 (-0.51, 0.34)
	Sleep only	-	-	-	-	-0.11 (-0.30, 0.09)	-0.16 (-0.27, -0.05)	-0.26 (-0.64, 0.12)	-0.05 (-0.25, 0.16)
	MVPA + ST	-	-	-	-	-	-0.05 (-0.25, 0.14)	-0.15 (-0.57, 0.26)	0.06 (-0.20 , 0.32)
	MVPA + sleep	-	-	-	-	-	-	-0.10 (-0.49, 0.29)	0.11 (-0.09, 0.32)
	ST + Sleep	-	-	-	-	-	-	-	0.21 (-0.21, 0.64)
	MVPA + ST +sleep	-	-	-	-	-	-	-	-
Log_HDL	None	-	**0.06 (0.03, 0.10)**	0.07 (-0.14, 0.29)	0.00 (-0.05, 0.05)	**0.21 (0.10, 0.31)**	**0.11 (0.06, 0.17)**	0.14 (-0.07, 0.36)	0.04 (-0.07, 0.15)
	MVPA only	-	-	0.01 (-0.21, 0.22)	**-0.06 (-0.11, -0.01)**	0.14 (0.04, 0.25)	0.05 (0.00, 0.10)	0.08 (-0.13, 0.30)	-0.03 (-0.14, 0.08)
	ST only	-	-	-	-0.07 (-0.29, 0.15)	0.13 (-0.10, 0.37)	0.04 (-0.18, 0.26)	0.07 (-0.23, 0.37)	-0.04 (-0.27, 0.20)
	Sleep only	-	-	-	-	0.21 (0.10 , 0.32)	0.11 (0.05, 0.18)	0.14 (-0.07, 0.36)	0.04 (-0.08, 0.15)
	MVPA + ST	-	-	-	-	-	-0.09 (-0.20, 0.02)	-0.06 (-0.30, 0.17)	-0.17 (-0.32, -0.02)
	MVPA + sleep	-	-	-	-	-	-	0.03 (-0.19, 0.25)	-0.08 (-0.19, 0.04)
	ST + Sleep	-	-	-	-	-	-	-	-0.11 (-0.35, 0.13)

	MVPA + ST +sleep	-	-	-	-	-	-	-	-
Log_ WH Frailty Index	None	-	**-0.13 (-0.21, -0.05)**	0.35 (-0.15, 0.84)	0.00 (-0.12, 0.12)	-0.20 (-0.45, 0.04)	**-0.16 (-0.28, -0.04)**	-0.05 (-0.55, 0.44)	-0.11 (-0.36, 0.14)
	MVPA only	-	-	0.48 (-0.02, 0.98)	**0.13 (0.01, 0.25)**	-0.07 (-0.32, 0.17)	-0.03 (-0.16, 0.09)	0.08 (-0.42, 0.57)	0.02 (-0.23, 0.27)
	ST only	-	-	-	-0.35 (-0.85, 0.16)	-0.55 (-1.10 , -0.01)	-0.51 (-1.01, -0.01)	-0.40 (-1.10 , 0.29)	-0.46 (-1.01, 0.09)
	Sleep only	-	-	-	-	-0.21 (-0.46, 0.05)	-0.16 (-0.31, -0.01)	-0.05 (-0.56, 0.45)	-0.11 (-0.38, 0.16)
	MVPA + ST	-	-	-	-	-	0.04 (-0.22, 0.30)	0.15 (-0.39, 0.70)	0.10 (-0.24, 0.44)
	MVPA + sleep	-	-	-	-	-	-	0.11 (-0.39, 0.61)	0.05 (-0.22, 0.32)
	ST + Sleep	-	-	-	-	-	-	-	-0.06 (-0.61, 0.49)
	MVPA + ST +sleep	-	-	-	-	-	-	-	-
Adjusted Model									
log_FRS 10-year risk score	None	-	**-0.10 (-0.18, -0.03)**	-0.33 (-0.75, 0.10)	-0.01 (-0.11, 0.09)	0.04 (-0.17, 0.24)	-0.10 (-0.20, 0.01)	0.08 (-0.35, 0.50)	0.09 (-0.13, 0.31)
	MVPA only	-	-	-0.22 (-0.65, 0.20)	0.10 (-0.01, 0.20)	0.14 (-0.07, 0.35)	0.00 (-0.10, 0.11)	0.18 (-0.25, 0.61)	0.19 (-0.02, 0.41)
	ST only	-	-	-	0.32 (-0.11, 0.75)	0.36 (-0.10, 0.83)	0.23 (-0.21, 0.66)	0.40 (-0.19, 1.00)	0.42 (-0.05, 0.89)
	Sleep only	-	-	-	-	0.04 (-0.18, 0.26)	-0.09 (-0.22, 0.04)	0.08 (-0.35, 0.52)	0.10 (-0.13, 0.33)
	MVPA + ST	-	-	-	-	-	-0.14 (-0.36, 0.09)	0.04 (-0.43, 0.51)	0.05 (-0.24, 0.35)
	MVPA + sleep	-	-	-	-	-	-	0.18 (-0.26, 0.61)	0.19 (-0.04, 0.42)
	ST + Sleep	-	-	-	-	-	-	-	0.01 (-0.46, 0.49)
	MVPA + ST +sleep	-	-	-	-	-	-	-	-
log_WC	None	-	**-0.07 (-0.09, -0.05)**	-0.01 (-0.12, 0.11)	**-0.03 (-0.06, 0.00)**	**-0.06 (-0.12, -0.01)**	**-0.09 (-0.12, -0.06)**	**-0.12 (-0.24, 0.00)**	**-0.08 (-0.14, -0.02)**
	MVPA only	-	-	0.06 (-0.05, 0.18)	**0.04 (0.01, 0.07)**	0.01 (-0.05, 0.06)	-0.02 (-0.05, 0.01)	-0.05 (-0.17, 0.07)	-0.01 (-0.07, 0.05)
	ST only	-	-	-	-0.02 (-0.14, 0.10)	-0.06 (-0.19, 0.07)	-0.08 (-0.20, 0.04)	-0.12 (-0.28, 0.05)	-0.07 (-0.20, 0.06)
	Sleep only	-	-	-	-	-0.05 (-0.11, 0.02)	-0.09 (-0.21, 0.03)	-0.06 (-0.10, -0.03)	-0.04 (-0.10, 0.03)
	MVPA + ST	-	-	-	-	-	-0.03 (-0.09, 0.04)	-0.06 (-0.19 , 0.07)	-0.01 (-0.09, 0.07)

	MVPA + sleep	-	-	-	-	-	-	-0.03 (-0.15, 0.09)	0.01 (-0.05, 0.08)
	ST + Sleep	-	-	-	-	-	-	-	0.04 (-0.09, 0.18)
	MVPA + ST +sleep	-	-	-	-	-	-	-	-
log_BMI	None	-	**-0.09 (-0.12, -0.07)**	-0.04 (-0.20, 0.12)	-0.03 (-0.07, 0.00)	**-0.12 (-0.19, -0.04)**	**-0.12 (-0.16, -0.08)**	-0.14 (-0.30, 0.01)	**-0.09 (-0.17, 0.01)**
	MVPA only	-	-	0.05 (-0.10, 0.21)	**0.06 (0.02, 0.10)**	-0.02 (-0.10, 0.06)	-0.03 (-0.07, 0.01)	-0.05 (-0.21, 0.11)	0.00 (-0.08, 0.08)
	ST only	-	-	-	0.01 (-0.15, 0.17)	-0.07 (-0.25, 0.10)	-0.08 (-0.24, 0.08)	-0.10 (-0.32, 0.12)	-0.05 (-0.23, 0.12)
	Sleep only	-	-	-	-	-0.08 (-0.16, 0.00)	-0.09 (-0.14, -0.04)	-0.11 (-0.27, 0.05)	-0.06 (-0.15, 0.02)
	MVPA + ST	-	-	-	-	-	-0.01 (-0.09, 0.07)	-0.03 (-0.20, 0.15)	0.02 (-0.09, 0.13)
	MVPA + sleep	-	-	-	-	-	-	-0.02 (-0.18, 0.14)	0.03 (-0.06, 0.11)
	ST + Sleep	-	-	-	-	-	-	-	0.05 (-0.13, 0.22)
	MVPA + ST +sleep	-	-	-	-	-	-	-	-
log_SBP	None	-	**-0.02 (-0.03, 0.00)**	-0.09 (-0.18, 0.01)	0.00 (-0.03, 0.02)	0.01 (-0.04, 0.06)	**-0.03 (-0.05, -0.01**	0.01 -0.09, 0.11	0.04 -0.01, 0.09
	MVPA only	-	-	-0.07 (-0.17, 0.03)	0.02 (-0.01, 0.04)	0.03 (-0.02, 0.08)	-0.01 (-0.04, 0.01)	0.03 (-0.07, 0.13)	0.05 (0.00, 0.10)
	ST only	-	-	-	0.08 (-0.02, 0.18)	0.10 (-0.01, 0.21)	0.06 (-0.05, 0.16)	0.10 (-0.04, 0.24)	0.12 (0.01, 0.23)
	Sleep only	-	-	-	-	0.01 (-0.04, 0.06)	-0.03 (-0.06, 0.00)	0.01 (-0.09, 0.12)	0.04 (-0.02, 0.09)
	MVPA + ST	-	-	-	-	-	-0.04 (-0.09, 0.01)	0.00 (-0.11, 0.11)	0.03 (-0.04, 0.09)
	MVPA + sleep	-	-	-	-	-	-	0.04 (-0.06, 0.14)	0.07 (0.01, 0.12)
	ST + Sleep	-	-	-	-	-	-	-	0.02 (-0.09, 0.13)
	MVPA + ST +sleep	-	-	-	-	-	-	-	-
log_DBP	None	-	-0.02 (-0.04, 0.00)	-0.06 (-0.18, 0.06)	0.00 (-0.03, 0.03)	0.03 (-0.03, 0.08)	-0.02 (-0.05, 0.01)	-0.02 (-0.14, 0.10)	**0.07 (0.01, 0.13)**
	MVPA only	-	-	-0.04 (-0.16, 0.08)	0.02 (-0.01, 0.05)	0.04 (-0.01, 0.10)	0.00 (-0.03, 0.03)	0.00 (-0.12, 0.11)	0.09 (0.03, 0.15)
	ST only	-	-	-	0.06 (-0.06, 0.18)	0.08 (-0.04, 0.21)	0.04 (-0.08, 0.16)	0.04 (-0.13, 0.20)	0.13 (0.00, 0.26)
	Sleep only	-	-	-	-	0.03	-0.02	-0.02	0.07

						(-0.03, 0.09)	(-0.05, 0.02)	(-0.14, 0.10)	(0.01, 0.14)
	MVPA + ST	-	-	-	-	-	-0.04 (-0.11, 0.02)	-0.05 (-0.18, 0.08)	0.05 (-0.03, 0.13)
	MVPA + sleep	-	-	-	-	-	-	0.00 (-0.12, 0.12)	0.09 (0.03, 0.16)
	ST + Sleep	-	-	-	-	-	-	-	0.10 (-0.03, 0.23)
	MVPA + ST +sleep	-	-	-	-	-	-	-	-
log_TC	None	-	**0.03 (0.00, 0.06)**	0.00 (-0.17, 0.16)	0.02 (-0.02, 0.06)	**0.15 (0.07, 0.23)**	**0.07 (0.03, 0.11)**	0.00 (-0.16, 0.17)	0.08 (0.00, 0.16)
	MVPA only	-	-	-0.03 (-0.19, 0.13)	-0.01 (-0.05, 0.03)	0.12 (0.04, 0.20)	0.04 (0.00, 0.08)	-0.02 (-0.19, 0.14)	0.05 (-0.03, 0.13)
	ST only	-	-	-	0.03 (-0.14, 0.19)	0.15 (-0.03, 0.33)	0.07 (-0.09, 0.24)	0.01 (-0.22, 0.24)	0.08 (-0.10, 0.26)
	Sleep only	-	-	-	-	0.13 (0.04, 0.21)	0.05 (0.00, 0.10)	-0.02 (-0.18, 0.15)	0.06 (-0.03, 0.14)
	MVPA + ST	-	-	-	-	-	-0.08 (-0.16, 0.01)	-0.14 (-0.32, 0.03)	-0.07 (-0.18, 0.04)
	MVPA + sleep	-	-	-	-	-	-	-0.07 (-0.23, 0.10)	0.01 (-0.08, 0.10)
	ST + Sleep	-	-	-	-	-	-	-	0.07 (-0.11, 0.25)
	MVPA + ST +sleep	-	-	-	-	-	-	-	-
Log_ Triglycerides	None	-	**-0.08 (-0.14, -0.01)**	0.10 (-0.27, 0.48)	0.07 (-0.02, 0.16)	-0.05 (-0.24, 0.13)	**-0.09 (-0.19, 0.00)**	-0.19 (-0.56, 0.19)	0.01 (-0.19, 0.20)
	MVPA only	-	-	0.18 (-0.20, 0.56)	**0.15 (0.06, 0.24)**	0.02 (-0.16, 0.21)	-0.02 (-0.11, 0.08)	-0.11 (-0.49, 0.27)	0.08 (-0.11, 0.28)
	ST only	-	-	-	-0.03 (-0.41, 0.35)	-0.16 (-0.57, 0.26)	-0.20 (-0.58, 0.19)	-0.29 (-0.82, 0.24)	-0.10 (-0.51, 0.32)
	Sleep only	-	-	-	-	-0.13 (-0.32, 0.07)	-0.16 (-0.28, -0.05)	-0.26 (-0.64, 0.12)	-0.07 (-0.27, 0.14)
	MVPA + ST	-	-	-	-	-	-0.04 (-0.24 , 0.16)	-0.13 (-0.55, 0.28)	0.06 (-0.20, 0.32)
	MVPA + sleep	-	-	-	-	-	-	-0.10 (-0.48, 0.29)	0.10 (-0.11, 0.30)
	ST + Sleep	-	-	-	-	-	-	-	0.19 (-0.22, 0.61)
	MVPA + ST +sleep	-	-	-	-	-	-	-	-
Log_HDL	None	-	**0.07 (0.04, 0.11)**	0.09 (-0.12, 0.29)	0.00 (-0.05, 0.05)	**0.23 (0.12, 0.33)**	**0.12 (0.07, 0.17)**	0.15 (-0.06, 0.36)	0.06 (-0.05, 0.16)
	MVPA only	-	-	0.01	**-0.07 (-0.12,**	0.16	0.05	0.08	-0.01

				(-0.20, 0.22)	**-0.02)**	(0.05, 0.26)	(-0.01, 0.10)	(-0.13, 0.29)	(-0.12, 0.09)
	ST only	-	-	-	-0.09 (-0.30, 0.13)	0.14 (-0.09, 0.37)	0.03 (-0.18, 0.25)	0.06 (-0.23, 0.36)	-0.03 (-0.26, 0.20)
	Sleep only	-	-	-	-	0.23 (0.12, 0.34)	0.12 (0.05, 0.18)	0.15 (-0.06, 0.36)	0.06 (-0.06, 0.17)
	MVPA + ST	-	-	-	-	-	-0.11 (-0.22 0.00)	-0.08 (-0.31, 0.15)	-0.17 (-0.31, -0.03)
	MVPA + sleep	-	-	-	-	-	-	0.03 (-0.18, 0.24)	-0.06 (-0.18, 0.05)
	ST + Sleep	-	-	-	-	-	-	-	-0.09 (-0.33, 0.14)
	MVPA + ST +sleep	-	-	-	-	-	-	-	-
Log_ WH Frailty Index	None	-	**-0.11 (-0.20, -0.03)**	0.35 (-0.14, 0.85)	-0.01 (-0.12, 0.11)	-0.19 (-0.43, 0.05)	**-0.13 (-0.25, -0.01)**	-0.06 (-0.56, 0.43)	-0.05 (-0.31, 0.20)
	MVPA only	-	-	0.46 (-0.03, 0.96)	0.10 (-0.02, 0.23)	-0.08 (-0.32, 0.16)	-0.02 (-0.15, 0.10)	0.05 (-0.44, 0.54)	0.06 (-0.19, 0.31)
	ST only	-	-	-	-0.36 (-0.86, 0.14)	-0.54 (-1.08, 0.00)	-0.48 (-0.99, 0.02)	-0.41 (-1.11, 0.28)	-0.41 (-0.95, 0.14)
	Sleep only	-	-	-	-	-0.18 (-0.44, 0.07)	-0.12 (-0.28, 0.03)	-0.06 (-0.56, 0.45)	-0.05 (-0.31, 0.22)
	MVPA + ST	-	-	-	-	-	0.06 (-0.20, 0.31)	0.13 (-0.42, 0.67)	0.14 (-0.20, 0.48)
	MVPA + sleep	-	-	-	-	-	-	0.07 (-0.43, 0.57)	0.08 (-0.19, 0.35)
	ST + Sleep	-	-	-	-	-	-	-	0.01 (-0.54, 0.56)
	MVPA + ST +sleep	-	-	-	-	-	-	-	-

β = unstandardized beta coefficients (95% Confidence Intervals); ***BMI*** *= Body Mass Index;* ***WC*** *=Waist Circumference;* ***SBP*** *= Systolic Blood Pressure;* ***DBP*** *= Diastolic Blood Pressure;* ***TD****=Total cholesterol;* ***HDL****=High-Density Lipoprotein;* ***FRS****=Framingham Risk Score;* ***WH****=WARM Hearts. Statistically significant associations (p<0.05) are highlighted in bold.*

Chapter 4: Discussion

4.1 Main Findings

Based on my literature search, only three studies have investigated the relationship between meeting the Canadian 24HMG and health outcomes for adults and older adults [65, 90, 91]. This is primarily due to the release of the Canadian 24HMG for this demographic in 2020 [52]. No prior study has examined cardiovascular health parameters in the context of the Canadian 24HMG. Therefore, this study is the first to explore the associations between adherence to the Canadian 24HMG and cardiovascular health indicators in this population, specifically for middle-aged and older females. Identifying this association for middle-aged and older females may improve awareness of meeting the 24HMG recommendations, and it will be invaluable for health policymakers, practitioners, and researchers, enabling them to develop targeted interventions and policies to address the specific health needs of this demographic. The objective of this thesis was to 1) examine the associations of cardiovascular health risk indicators with meeting none, one, two or three components of the Canadian 24HMG (i.e., physical activity, sedentary behaviour, and sleep recommendations) among community-dwelling middle-aged and older females; 2) identify which specific component or combination of Canadian 24HMG is most strongly associated with cardiovascular health outcomes in this population. Notably, only 2.1% of the participants in the WARM Hearts cohort met all three guidelines, with the majority meeting one out of three components (44.8%), followed by 13.5 % of the females meeting two out of three components. The findings are consistent with the study by Rollo et al., which revealed that only 2.6% of the cohort of adults aged 18 to 79 successfully met all three components [91], and Luo et al. reported that adherence to all three components was even lower at 1.6% for older adults aged 60 to 80 years [92].

Results for the first objective indicate that meeting one of the three recommendations is associated with better cardiovascular health, including lower FRS 10 years risk, waist circumference and lower BMI, and improved cardiovascular biomarkers such as total cholesterol and HDL level and frailty index). Specifically, participants who met one out of three recommendations presented a significantly lower FRS score by 0.92% compared to the groups that met none of the recommendations in the adjusted model. In contrast, in the group that met two out of three or met all three, there was no significant association in FRS score from the group compared to the group that met none of the recommendations. The reduction in continuous FRS score translates to a proportional reduction in the estimated 10-year risk of cardiovascular diseases [84]. A 0.92% reduction in the FRS compared to the "None" group might seem small. Still, an FRS decrease of 1% or more in the absolute risk can be considered significant, especially for individuals moving from a higher to a lower-risk category (e.g., from an intermediate to a low risk) [93]. In a research study conducted by Richardson et al., a modest decrease in the Framingham Risk Score (FRS) was observed in the 10-year risk of cardiovascular disease (CVD). The FRS scores decreased from 10.65% to 10.34%, representing a relative decrease of 2.9%. This decrease in the risk score has the potential to lead to significant clinical benefits [94]. This reduction was associated with improvements in systolic and diastolic blood pressure and HDL cholesterol levels [94]. Another study by Ruijter et al. evaluated using FRS and new biomarkers to predict cardiovascular mortality in older populations [95]. This study highlighted that improvements in traditional risk factors like blood pressure and HDL cholesterol levels, which contribute to the FRS, effectively reduce cardiovascular mortality. The study supports the notion that even minor improvements in the FRS can yield substantial benefits in reducing future heart attack or stroke risk [95]. In addition, the "All three" group had more

favourable waist circumference and BMI than groups that met one out of three and two out of three recommendations. These findings support the initial hypothesis that an association exists between meeting the Canadian 24HMG and cardiovascular health indicators.

Moreover, the findings are generally consistent with the findings of Carson et al., who examined health associations with meeting 24HMG for both male and female Canadian children and youth aged 6 to 17 years [56]. In comparison, both Carson et al.'s study and this thesis reported that most of the cohort met one and two out of three recommendations, representing 71.9% of Carson's cohort and 58.3% of the cohort in this study, and highlighted the cumulative health benefits of adhering to multiple components of the 24HMG. They found that children and youth who met all three guidelines had better health indicators, such as lower BMI by 0.38 kg/m² and waist circumference by 0.89 cm, than those who met fewer guidelines [56]. Carson et al.'s findings are similar to our study, where we report a decrease in BMI by 0.91 kg/m² and a waist circumference of 0.93 cm in the WARM Hearts cohort of adults and older adults. They also identified significant associations between individuals who met one of three recommendations and those who met all three recommendations, which reduced systolic blood pressure by 0.97 mmHg and triglycerides level by 0.78 mmol/L and found no differences for diastolic blood pressure [56]. In the WARM Hearts cohort, we did not find significant associations between meeting one or two of three components of the guidelines and meeting none of the guidelines in systolic and diastolic blood pressure. The only significant association was found between the "All three" group and the "None" group, which showed an increase in diastolic blood pressure by 1.07 mmHg in our cohort. Damen et al. stated even a small increase in diastolic blood pressure is associated with a higher risk of heart disease [96]. They found a 2mmHg increase in diastolic blood pressure was associated with a 6% increase in the risk of coronary heart disease and a 15%

increase in the risk of stroke [96]. This increase may be due to age-related changes in vascular biology that significantly contribute to increased arterial stiffness, accelerating the pulse wave return. This can elevate systolic blood pressure while altering diastolic blood pressure dynamics among middle-aged and older adults despite adherence to movement behaviours [97]. Another study by Rollo et al. investigated the association between meeting the Canadian 24HMG and general health indicators for males and females aged 18 to 79. Rollo et al. found that 2.6% of their group met all three recommendations of the 24HMG, a percentage similar to the 2.1% in our WARM Hearts cohort [91]. They also noted that participants improved health indicators when they met more of the guidelines. For example, waist circumference and BMI improved by 0.94 cm and 0.16 kg/m² and improved triglyceride levels by 0.82 mmol/L when compared to individuals who met three components and those who met none of the components. No differences were found in systolic and diastolic blood pressure with more adherence to the guidelines [91].

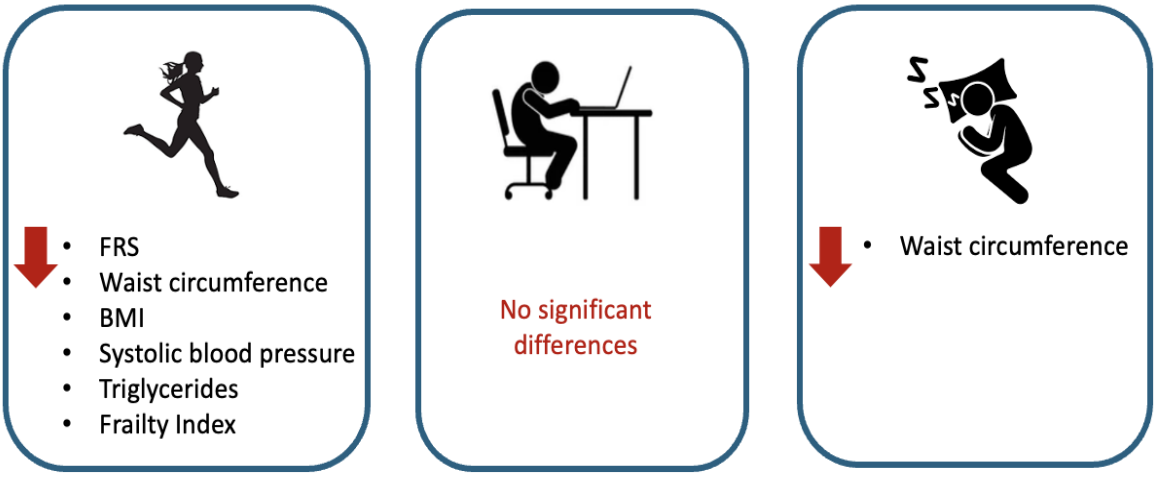
The findings in this thesis were consistent with most studies that examined similar health indicators such as waist circumference, BMI, blood pressure, HDL cholesterol level, and triglycerides [57, 92]. Additionally, we revealed that meeting one of three components was significantly associated with low FRS scores, a factor that had not been previously investigated in other studies. While several studies have demonstrated that adherence to all three 24-hour movement guidelines yields significant health benefits for both children and adults [47, 56, 57, 90], our results indicate that even meeting one or two components of the guidelines can show significant associations with CVD risk factors. This suggests that the magnitude of health improvements may depend on meeting all guidelines and highlighting the importance of each component, contributing meaningfully to cardiovascular health even when only partially adhered

to. The health improvements from meeting each additional guideline could be additive, meaning that each guideline a person meets adds a certain amount of benefit. The effects could be synergistic, where the combination of meeting multiple guidelines leads to even greater benefits than the sum of individual behaviours. For example, good sleep might enhance the benefits of physical activity, thereby leading to more significant overall improvements in health. This nuanced understanding underscores the value of incremental changes in lifestyle and their impact on reducing CVD risk.

The secondary objectives consist of two parts: 1) determine if meeting the physical activity guidelines is associated with lower CVD risk compared to individually meeting the sedentary behaviour or the sleep guidelines. 2) determine if meeting the physical activity and sedentary behaviour guidelines is strongly associated with lower CVD risk than other combinations of two components (physical activity and sleep, sedentary behaviour and sleep). First, we observed the associations between meeting only one component of the three that make up the 24HMG compared to meeting none of the guidelines and cardiovascular health indicators. Next, we examined the differences between associations between each component and the others. The findings indicated that eight out of nine associations in cardiovascular health outcomes in the group that met MVPA only compared to the group that met none of the recommendations. Conversely, no significant associations were found in the group that met sedentary time only compared to the "None" group, and only one association was found in the group that met sleep only compared to the group that met none of the three components of the guidelines. This is in contrast to previous studies that reported individuals with low levels of sedentary time have a lower risk of mortality and a lower prevalence of Alzheimer's disease than people who spend more time being sedentary [81].

Furthermore, our study revealed that the sedentary and sleep guidelines were the most difficult for the women in our cohort to achieve, with a significant number meeting the physical activity guidelines. This pattern suggests that while physical activity may be more readily adopted, reducing sedentary behaviour and improving sleep present greater challenges, possibly due to societal and lifestyle factors [98, 99]. Specifically, it is important to consider that participants who met the physical activity guidelines might still engage in prolonged periods of sedentary behaviour throughout the rest of the day, a phenomenon sometimes referred to as the "active couch potato" effect [99]. This means that while they achieve the recommended amount of MVPA, they may spend much of their remaining time sitting, either at work or during leisure activities, thereby failing to meet the sedentary behaviour guidelines. This trend is common and can be attributed to several factors, including lifestyle demands, work-related sitting time, and psychosocial stressors affecting sleep quality. These findings emphasize the importance of prioritizing physical activity in health counselling while recognizing the significant challenges women face in reducing sedentary behaviour and achieving adequate sleep, which may require more targeted interventions. Also, specific recommendations should be made based on individuals' existing habits. For instance, individuals who already meet physical activity guidelines can benefit significantly from targeted strategies to improve their sleep or reduce sedentary behaviours. This personalized approach could help maximize the overall health benefits of adhering to the 24-hour movement guidelines. Figure 2 is a summary of meeting one component and CVD risk compared to meeting none of the components of the guidelines**.**

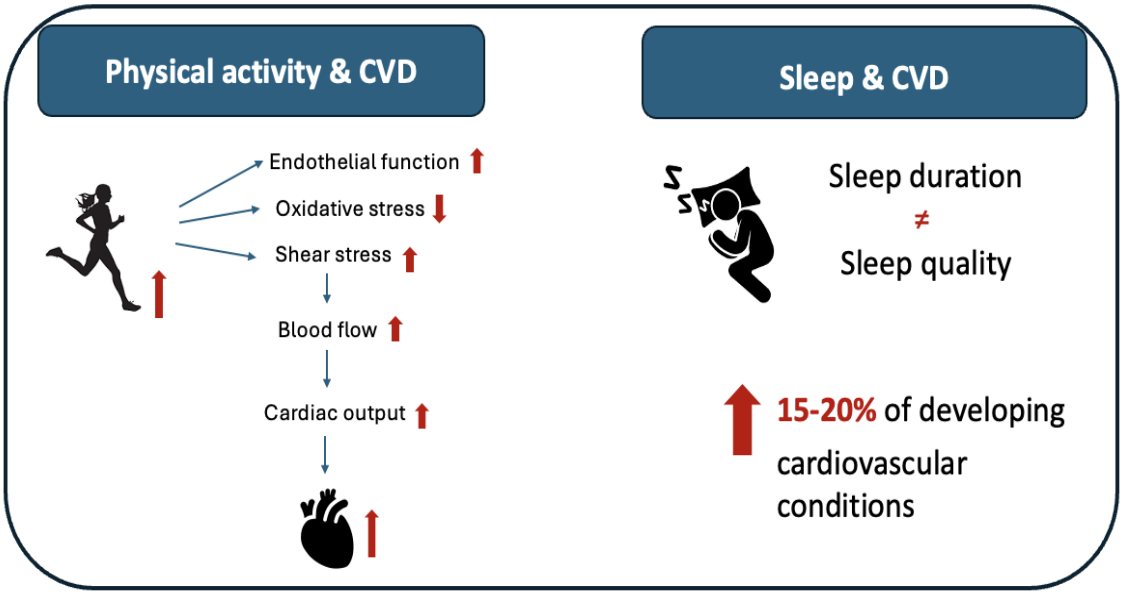
Figure 2. Summary of meeting one component and CVD risk compared to meeting none of the components of the guidelines.



Then, when different groups were used as references, we found significant associations between specific groups for each cardiovascular health indicator; more specifically, the "Sleep only" group was significantly associated with unfavourable associations when comparing the "MVPA only," including an increase in waist circumference by1.04 cm and BMI by 1.06 kg/m², triglycerides by 1.16 mmol/L. These findings were aligned with the initial hypothesis that the group that met physical activity guidelines presented associations of lower cardiovascular health indicators than the "None" and "Sleep only" groups. Rollo et al. also reported data aligned with the results of this thesis [47], where they observed 7/10 significant associations when comparing the "Sleep only" group to the group that met none of the components. For example, BMI, waist circumference, aerobic fitness, triglycerides, C-reactive protein, insulin, and serum glucose were deleteriously associated [47]. Similarly, one of the previous studies by McGregor et al. supported meeting sleep recommendations only associated with worse health indicators, such as lower HDL by 0.12 mmol/L and lower aerobic fitness by 5.210e-08 in the cohort aged 18-79 [100]. This may be due to the lack of understanding of the participants' sleep quality in this cohort, which a few studies have reported [50, 98]. Sleep quality is equally important as sleep duration.

A study showed that individuals with poor sleep quality had a 15-20% higher risk of developing cardiovascular conditions than those with good sleep quality [101]. See Figure 3 for the infographic on physical activity and sleep with CVD.

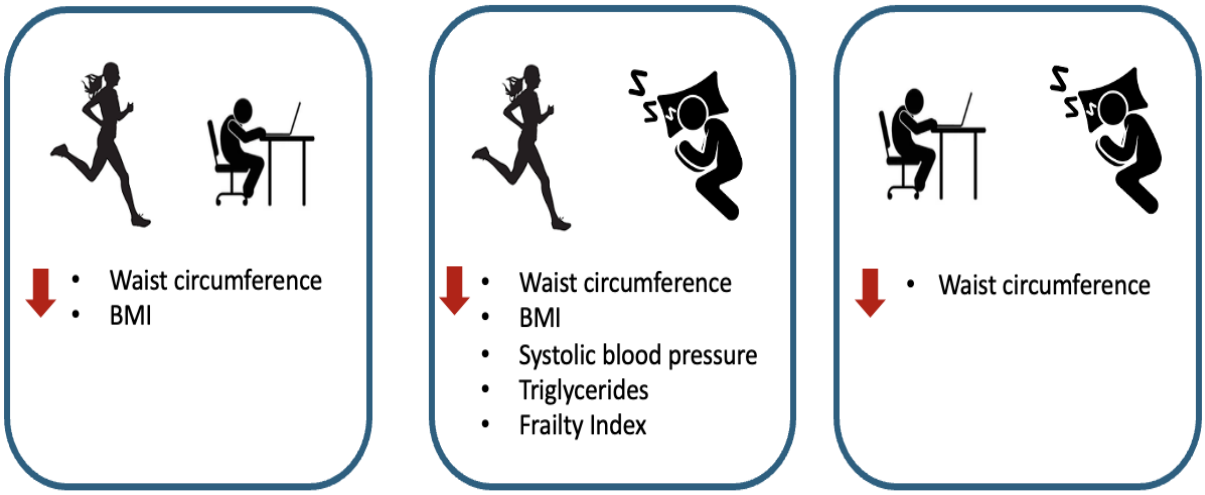
Figure 3. Infographic on physical activity and sleep with CVD



It was found that meeting or not meeting specific combinations of guidelines in insolation was less important for overall cardiovascular health compared to the number of guidelines met. The results showed that the group that met "MVPA and sedentary time only" were significantly associated with better cardiovascular health indicators for four out of nine associations compared to the "None" group, which are waist circumference, BMI, total cholesterol and HDL level. However, it was less than the group that met "MVPA and sleep only" for seven out of nine associations compared to the group that did not meet any of the recommendations in the adjusted model. These findings partially supported our initial hypothesis that meeting the physical activity and sedentary behaviour guidelines is strongly associated with better cardiovascular health indicators than other combinations of the two components. However, the data also highlight the critical role of sleep, as meeting both MVPA and sleep guidelines was associated with even

greater cardiovascular benefits than meeting MVPA and sedentary behaviour guidelines. This suggests that while reducing sedentary time is important, prioritizing adequate sleep alongside physical activity may provide more substantial health benefits. The literature corroborates these findings, showing that sleep quality and duration significantly impact cardiovascular outcomes, likely due to the restorative processes that occur during sleep, which affect metabolic and cardiovascular function [102]. Clinicians should encourage patients to stay active and prioritize sleep as part of a comprehensive approach to cardiovascular health. Integrating both MVPA and sleep into daily routines could enhance health outcomes more effectively than focusing on physical activity alone. There were no significant differences between adhering to the two components compared to the other two combinations. See Figure 4 for a summary of meeting two components and CVD risk compared to meeting none of the components of the guidelines.

Figure 4. Summary of meeting two components and CVD risk compared to meeting none of the components of the guidelines.



My thesis identified that older females who adhered to the 24-hour movement guidelines (24HMG) experienced significantly better cardiovascular health outcomes. The study underscores the critical role of physical activity in reducing cardiovascular risk while also highlighting the independent contributions of reducing sedentary behaviour and ensuring

adequate sleep. When time constraints limit the ability to meet all three guidelines, prioritizing physical activity alone is beneficial in lowering the risk of cardiovascular disease. However, the combination of physical activity with adequate sleep yields even greater health benefits, emphasizing the need for a balanced approach to all components of the 24HMG for optimal cardiovascular health. However, while Carson et al. focused on a pediatric population, our study extends these findings to an older demographic, demonstrating that the benefits of these guidelines are relevant across different age groups [56]. Previous research indicates that adherence to multiple components of the 24HMG is associated with better health outcomes than meeting only one or none of the guidelines. Baillot et al. found a strong association between meeting two of three components of 24 HMG and lower CVD risk (waist circumference, systolic blood pressure, diastolic blood pressure) in Canadian adults aged 18 to 79 [64], consistent with our findings in the WARM Hearts cohort of female adults and older adults. Another study by Porter et al. reported that adults meeting more components of the guidelines had significantly reduced psychological distress in university students with chronic health conditions and disabilities [90]. Additionally, Kettle et al. reported that middle-aged and older adults who engage in regular physical activity (even in short bouts) have significant health benefits [103]. This supports the notion that the intensity and regularity of physical activity are crucial for cardiovascular health, particularly in reducing the risk of conditions such as hypertension, obesity, and type 2 diabetes [103].

In addition to reducing CVD risk, adhering to the 24HMG offers various additional health benefits. Research has shown that meeting these guidelines is associated with improved mental health, including reductions in symptoms of depression and anxiety, better cognitive function, and enhanced sleep quality [104]. Regular physical activity, a core component of the 24HMG,

has been linked to a lower risk of developing type 2 diabetes and certain types of cancer as well as improved bone health by reducing the risk of osteoporosis and fractures in older adults [52]. Furthermore, maintaining adequate sleep and minimizing sedentary behaviour is critical for metabolic health, supporting insulin sensitivity, and reducing the risk of obesity. These broader health benefits underscore the importance of the 24HMG as a comprehensive approach to improving overall health and well-being, not just for cardiovascular health but for multiple aspects of physical and mental health [102, 104].

4.2 Strengths and Limitations

This study has several notable strengths that enhance the validity and relevance of its findings. One of the primary strengths is using accelerometers to objectively measure physical activity, sedentary behaviour, and sleep. This methodological approach reduces the reliance on self-reported data, which can be subject to recall bias and inaccuracies. By using objective measurements, the study provides more accurate assessments of the participants' movement behaviours, strengthening the validity of the associations observed with cardiovascular health indicators. Additionally, the study focuses on older females and addresses a significant gap in the literature, as this demographic is often underrepresented in research related to physical activity and cardiovascular health. By targeting this specific group, the study offers valuable insights into the health impacts of adherence to the 24HMG in an aging population.

Despite these strengths, the study has limitations that should be considered when interpreting the results. The cross-sectional design limits the ability to establish causality between adherence to the movement guidelines and the observed health outcomes. While associations can be identified, the directionality and causation of these relationships can only be definitively determined with longitudinal data. Convenience sampling effectively recruits participants for a

large sample size like WARM Hearts (n=1018). However, this method resulted in a sample of predominantly Caucasian females (94.7%), which limited the generalisability of these findings, as participants who volunteered did not have a representative composition of Manitoba's general population for race.

Like other studies [57, 65, 91, 92, 99], this thesis was only able to include MVPA, sedentary time, and total sleep time from the Canadian 24HMG. Other recommended behaviours, like muscle-strengthening activities, light physical activity, and screen time, were not included in the analysis because they were not collected in the original WARM Hearts study. A meta-analysis reported an increase above a threshold of 3 to 4 hours per day of recreational screen time led to a significant increase in the risk of all-cause mortality, cardiovascular disease, and type 2 diabetes [107].

Log-transformation of the outcome variables was applied to treat the heteroscedasticity. While the transformation helps stabilize variance and meet the assumptions of statistical tests, the transformed coefficients do not directly correspond to the original units of measurement [108]. Moreover, the analysis included small group sizes (n=5) for certain combinations of guidelines, particularly for the groups "ST only" and "ST and sleep only." This small sample size can limit the statistical power to detect significant associations and may result in less reliable estimates for these groups.

A limitation of using accelerometer-measured movement behaviours in this study is their inability to differentiate between certain sedentary behaviours, such as sitting vs standing still, which could lead to inaccuracies in assessing sedentary time. Additionally, accelerometers are not designed to track water-based activities, like swimming, because participants typically need to remove the device before engaging. This may underestimate physical activity levels,

particularly for individuals who regularly swim or participate in other water sports [109]. These limitations suggest that while accelerometers provide valuable objective data, they need to capture the full range of physical activities contributing to overall health. To address this, future studies could incorporate self-reported activity logs or waterproof wearable devices to capture these activities better. Combining accelerometer data with self-report measures could offer a more comprehensive assessment of adherence to the 24HMG, ensuring that all forms of physical activity are accurately represented in the analysis. This approach would enhance the accuracy and reliability of the findings, providing a fuller understanding of participants' physical activity patterns and their impact on cardiovascular health.

Finally, the study's findings may be limited in generalizability, as the sample may not represent some older adults, particularly those with different cultural and ethnic backgrounds, people with health conditions, or socioeconomic statuses. Further research is needed to confirm these findings across diverse populations and to explore the interactions between these variables and adherence to the 24-hour Movement Guidelines.

4.3 Practical Implications

The findings of this study have important implications for public health policies and interventions aimed at improving cardiovascular health among older adults. Given the aging population and the increasing prevalence of chronic diseases, it is essential to promote adherence to the 24HMG among older adults. However, with a small proportion of the cohort meeting all three recommendations, health professionals should raise awareness among stakeholders and the general public of the need for a balanced approach to physical activity, sedentary behaviour, and

sleep in their recommendations, where the message is that meeting more components of the 24HMG is associated with better cardiovascular health.

When time constraints prevent a person from meeting all three guidelines, a message to focus on physical activity alone can reduce the risk of cardiovascular disease to a greater extent than sleep alone or sedentary behaviour alone. Even so, a person should work to improve one or more health behaviours in order to improve their health (i.e., changing one behaviour is a good start, but improving more behaviours is even better). Additionally, combining physical activity with sufficient sleep yields even greater health benefits. To encourage adherence to these guidelines, community-based programs can promote regular physical activity in short bouts tailored to adults and older adults' mobility levels. Initiatives to reduce sedentary time, such as promoting standing desks or regular movement breaks, can also be effective. Public health campaigns should educate older adults about the benefits of adequate sleep duration and quality to help them establish healthy sleep habits. Furthermore, public health guidelines should emphasize the importance of mental health, stress management, and a balanced diet. For example, integrating recommendations for regular mindfulness practices, social connectedness, and stress reduction techniques like meditation or yoga can help manage stress and improve mental health. A comprehensive approach that highlights the interdependent benefits of physical activity reduced sedentary behaviour, and sufficient sleep can significantly improve cardiovascular health outcomes among older adults while also contributing to broader health improvements, including enhanced cognitive function, mental health, and longevity.

4.4 Conclusion

In conclusion, this study is the fourth study to examine the health benefits of adhering to the Canadian 24HMG in adults [65, 90, 91], and it uniquely contributes to the literature by focusing on middle-aged and older females within a Canadian cohort, which addresses a significant gap in this underrepresented demographic. Our findings demonstrate that meeting one or two components of the 24HMG is associated with better cardiovascular health results. Specifically, individuals who met the physical activity component alone or combined physical activity and sufficient sleep showed improved cardiovascular health indicators such as reduced FRS, waist circumference, BMI and better cardiovascular biomarkers. In contrast, those who met the sedentary time component alone did not show significant cardiovascular benefits compared to those who did not meet any of the components. Additionally, all three movement behaviours were measured objectively, which enhanced the accuracy and reliability of the data and provided a daily activity pattern of the individuals to understand how these behaviours interact to influence cardiovascular health. In general, the data highlight the importance of promoting the use of the 24HMG to support public health. Further studies should continue to explore other health outcomes for people who adhere or do not adhere to the 24HMG, with a particular effort to recruit diverse populations and examine long-term health outcomes.

References

[1] "Cardiovascular Health - National Association of Chronic Disease Directors." Accessed: Aug. 07, 2023. [Online]. Available: https://chronicdisease.org/page/cardiovascularhealth/
[2] P. H. A. of Canada, "Heart Disease in Canada." Accessed: Aug. 07, 2023. [Online]. Available: https://www.canada.ca/en/public-health/services/publications/diseases-conditions/heart-disease-canada.html
[3] "What is Atherosclerosis?," www.heart.org. Accessed: Aug. 08, 2023. [Online]. Available: https://www.heart.org/en/health-topics/cholesterol/about-cholesterol/atherosclerosis
[4] C. W. Tsao *et al.*, "Heart Disease and Stroke Statistics—2022 Update: A Report From the American Heart Association," *Circulation*, vol. 145, no. 8, Feb. 2022, doi: 10.1161/CIR.0000000000001052.
[5] W. M. Schultz *et al.*, "Socioeconomic Status and Cardiovascular Outcomes: Challenges and Interventions," *Circulation*, vol. 137, no. 20, pp. 2166–2178, May 2018, doi: 10.1161/CIRCULATIONAHA.117.029652.
[6] Y. Gerber, S. A. Weston, J. M. Killian, T. M. Therneau, S. J. Jacobsen, and V. L. Roger, "Neighborhood income and individual education: effect on survival after myocardial infarction," *Mayo Clin. Proc.*, vol. 83, no. 6, pp. 663–669, Jun. 2008, doi: 10.4065/83.6.663.
[7] M. Woodward *et al.*, "Socioeconomic status in relation to cardiovascular disease and cause-specific mortality: a comparison of Asian and Australasian populations in a pooled analysis," *BMJ Open*, vol. 5, no. 3, p. e006408, Mar. 2015, doi: 10.1136/bmjopen-2014-006408.
[8] D. M. Lloyd-Jones *et al.*, "Framingham risk score and prediction of lifetime risk for coronary heart disease," *Am. J. Cardiol.*, vol. 94, no. 1, pp. 20–24, Jul. 2004, doi: 10.1016/j.amjcard.2004.03.023.
[9] "General Cardiovascular Risk Profile for Use in Primary Care | Circulation." Accessed: Aug. 28, 2023. [Online]. Available: https://www.ahajournals.org/doi/10.1161/CIRCULATIONAHA.107.699579?url_ver=Z39.88-2003&rfr_id=ori:rid:crossref.org&rfr_dat=cr_pub%20%200pubmed
[10] M. May, D. A. Lawlor, P. Brindle, R. Patel, and S. Ebrahim, "Cardiovascular disease risk assessment in older women: can we improve on Framingham? British Women's Heart and Health prospective cohort study," *Heart*, vol. 92, no. 10, pp. 1396–1401, Oct. 2006, doi: 10.1136/hrt.2005.085381.
[11] I. Vuori, "World Health Organization and Physical Activity," *Prog. Prev. Med.*, vol. 3, no. 1, p. e0012, Mar. 2018, doi: 10.1097/pp9.0000000000000012.
[12] D. E. R. Warburton and S. S. D. Bredin, "Reflections on Physical Activity and Health: What Should We Recommend?," *Can. J. Cardiol.*, vol. 32, no. 4, pp. 495–504, Apr. 2016, doi: 10.1016/j.cjca.2016.01.024.
[13] M. Sellami *et al.*, "Effects of Acute and Chronic Exercise on Immunological Parameters in the Elderly Aged: Can Physical Activity Counteract the Effects of Aging?," *Front. Immunol.*, vol. 9, p. 2187, Oct. 2018, doi: 10.3389/fimmu.2018.02187.
[14] K. B. Hagen *et al.*, "Exercise therapy for bone and muscle health: an overview of systematic reviews," *BMC Med.*, vol. 10, p. 167, Dec. 2012, doi: 10.1186/1741-7015-10-167.
[15] B. Grässler, B. Thielmann, I. Böckelmann, and A. Hökelmann, "Effects of Different Training Interventions on Heart Rate Variability and Cardiovascular Health and Risk Factors in Young and Middle-Aged Adults: A Systematic Review," *Front. Physiol.*, vol. 12, p. 657274, Apr. 2021, doi: 10.3389/fphys.2021.657274.

[16] T. S. Church, C. P. Earnest, J. S. Skinner, and S. N. Blair, “Effects of Different Doses of Physical Activity on Cardiorespiratory Fitness Among Sedentary, Overweight or Obese Postmenopausal Women With Elevated Blood PressureA Randomized Controlled Trial,” *JAMA*, vol. 297, no. 19, pp. 2081–2091, May 2007, doi: 10.1001/jama.297.19.2081.
[17] I.-M. Lee, “Dose-Response Relation Between Physical Activity and FitnessEven a Little Is Good; More Is Better,” *JAMA*, vol. 297, no. 19, pp. 2137–2139, May 2007, doi: 10.1001/jama.297.19.2137.
[18] D. Tian and J. Meng, “Exercise for Prevention and Relief of Cardiovascular Disease: Prognoses, Mechanisms, and Approaches,” *Oxid. Med. Cell. Longev.*, vol. 2019, p. 3756750, Apr. 2019, doi: 10.1155/2019/3756750.
[19] R. B. Batacan, M. J. Duncan, V. J. Dalbo, G. L. Buitrago, and A. S. Fenning, “Effect of different intensities of physical activity on cardiometabolic markers and vascular and cardiac function in adult rats fed with a high-fat high-carbohydrate diet,” *J. Sport Health Sci.*, vol. 7, no. 1, pp. 109–119, Jan. 2018, doi: 10.1016/j.jshs.2016.08.001.
[20] W. R. Organ, *Official Royal Canadian Air Force Exercise Plans for physical fitness*. Pocket Books, 1962.
[21] R. Duhamel, *Royal Canadian Air Force Exercise Plans for Physical Fitness: Two Books in One / Two Famous Basic Plans*, 84 vols. Echo Point Books and Media, 2016.
[22] V. Seliger, “The influence of sports training on the efficiency of juniors,” *Int. Z. Für Angew. Physiol. Einschließlich Arbeitsphysiologie*, vol. 26, no. 4, pp. 309–322, Dec. 1968, doi: 10.1007/BF00698307.
[23] American Heart Association. Committee on Exercise, *Exercise Testing and Training of Apparently Healthy Individuals*. American Heart Association, 1972.
[24] S. N. Blair, Y. Cheng, and J. Scott Holder, “Is physical activity or physical fitness more important in defining health benefits?,” *Med. Sci. Sports Exerc.*, vol. 33, no. 6, p. S379, Jun. 2001, Accessed: Jul. 17, 2023. [Online]. Available: https://journals.lww.com/acsm-msse/Fulltext/2001/06001/Is_physical_activity_or_physical_fitness_more.7.aspx
[25] “American College of Sports Medicine Position Stand. The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness, and flexibility in healthy adults,” *Med. Sci. Sports Exerc.*, vol. 30, no. 6, pp. 975–991, Jun. 1998, doi: 10.1097/00005768-199806000-00032.
[26] A. K. Chomistek, S. E. Chiuve, A. H. Eliassen, K. J. Mukamal, W. C. Willett, and E. B. Rimm, “Healthy Lifestyle in the Primordial Prevention of Cardiovascular Disease Among Young Women,” *J. Am. Coll. Cardiol.*, vol. 65, no. 1, pp. 43–51, Jan. 2015, doi: 10.1016/j.jacc.2014.10.024.
[27] C. J. Crespo, S. J. Keteyian, G. W. Heath, and C. T. Sempos, “Leisure-time physical activity among US adults. Results from the Third National Health and Nutrition Examination Survey,” *Arch. Intern. Med.*, vol. 156, no. 1, pp. 93–98, Jan. 1996.
[28] P. T. Katzmarzyk, N. Gledhill, and R. J. Shephard, “The economic burden of physical inactivity in Canada,” *CMAJ Can. Med. Assoc. J.*, vol. 163, no. 11, pp. 1435–1440, Nov. 2000, Accessed: Aug. 27, 2023. [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC80410/
[29] M. T. Sharratt and W. E. Hearst, “Canada’s physical activity guides: background, process, and developmentThis article is part of a supplement entitled Advancing physical activity measurement and guidelines in Canada: a scientific review and evidence-based foundation for the future of Canadian physical activity guidelines co-published by Applied Physiology,

Nutrition, and Metabolism and the Canadian Journal of Public Health. It may be cited as Appl. Physiol. Nutr. Metab. 32(Suppl. 2E) or as Can. J. Public Health 98(Suppl. 2).," *Appl. Physiol. Nutr. Metab.*, vol. 32, no. S2E, pp. S9–S15, Nov. 2007, doi: 10.1139/H07-124.
[30] P. S. and P. C. Government of Canada, "Canada's physical activity guide to healthy active living : H39-429/1998-1E-PDF - Government of Canada Publications - Canada.ca." Accessed: Aug. 27, 2023. [Online]. Available: https://publications.gc.ca/site/eng/9.694382/publication.html
[31] P. S. and P. C. Government of Canada, "Canada's physical activity guide for youth : H39-611/2002-1E - Government of Canada Publications - Canada.ca." Accessed: Aug. 27, 2023. [Online]. Available: https://publications.gc.ca/site/eng/109429/publication.html
[32] M. S. Tremblay *et al.*, "New Canadian Physical Activity Guidelines," *Appl. Physiol. Nutr. Metab.*, vol. 36, no. 1, pp. 36–46, Jan. 2011, doi: 10.1139/H11-009.
[33] J. H. Park, J. H. Moon, H. J. Kim, M. H. Kong, and Y. H. Oh, "Sedentary Lifestyle: Overview of Updated Evidence of Potential Health Risks," *Korean J. Fam. Med.*, vol. 41, no. 6, pp. 365–373, Nov. 2020, doi: 10.4082/kjfm.20.0165.
[34] V. J. Poitras *et al.*, "Systematic review of the relationships between sedentary behaviour and health indicators in the early years (0–4 years)," *BMC Public Health*, vol. 17, no. 5, p. 868, Nov. 2017, doi: 10.1186/s12889-017-4849-8.
[35] "Canadian Physical Activity Guidelines for the Early Years (aged 0–4 years)." Accessed: Aug. 27, 2023. [Online]. Available: https://cdnsciencepub.com/doi/10.1139/h2012-018
[36] "Physical activity strategy for the WHO European Region 2016–2025".
[37] "BACKGROUND," in *WHO Guidelines on Physical Activity and Sedentary Behaviour*, World Health Organization, 2020. Accessed: Oct. 30, 2023. [Online]. Available: https://www.ncbi.nlm.nih.gov/books/NBK566039/
[38] J. Henson *et al.*, "Associations of objectively measured sedentary behaviour and physical activity with markers of cardiometabolic health," *Diabetologia*, vol. 56, no. 5, pp. 1012–1020, May 2013, doi: 10.1007/s00125-013-2845-9.
[39] A. García-Hermoso *et al.*, "Sedentary behaviour patterns and arterial stiffness in a Spanish adult population – The EVIDENT trial," *Atherosclerosis*, vol. 243, no. 2, pp. 516–522, Dec. 2015, doi: 10.1016/j.atherosclerosis.2015.10.004.
[40] M. H. Kryger, T. Roth, and W. C. Dement, *Principles and Practice of Sleep Medicine - E-Book: Expert Consult - Online and Print*. Elsevier Health Sciences, 2010.
[41] *Sleep Disorders and Sleep Deprivation: An Unmet Public Health Problem*. Washington, D.C.: National Academies Press, 2006. doi: 10.17226/11617.
[42] M. A. GRANDNER, "Addressing sleep disturbances: An opportunity to prevent cardiometabolic disease?," *Int. Rev. Psychiatry Abingdon Engl.*, vol. 26, no. 2, pp. 155–176, Apr. 2014, doi: 10.3109/09540261.2014.911148.
[43] M. T. Smith *et al.*, "Use of Actigraphy for the Evaluation of Sleep Disorders and Circadian Rhythm Sleep-Wake Disorders: An American Academy of Sleep Medicine Clinical Practice Guideline," *J. Clin. Sleep Med. JCSM Off. Publ. Am. Acad. Sleep Med.*, vol. 14, no. 7, pp. 1231–1237, Jul. 2018, doi: 10.5664/jcsm.7230.
[44] D. J. Buysse, "Sleep Health: Can We Define It? Does It Matter?," *Sleep*, vol. 37, no. 1, pp. 9–17, Jan. 2014, doi: 10.5665/sleep.3298.
[45] M. S. Tremblay *et al.*, "Canadian 24-Hour Movement Guidelines for Children and Youth: An Integration of Physical Activity, Sedentary Behaviour, and Sleep," *Appl. Physiol. Nutr. Metab.*, vol. 41, no. 6 (Suppl. 3), pp. S311–S327, Jun. 2016, doi: 10.1139/apnm-2016-0151.

[46] A. A. Ramírez-Coronel *et al.*, "Childhood obesity risk increases with increased screen time: a systematic review and dose–response meta-analysis," *J. Health Popul. Nutr.*, vol. 42, p. 5, Jan. 2023, doi: 10.1186/s41043-022-00344-4.
[47] S. Rollo, O. Antsygina, and M. S. Tremblay, "The whole day matters: Understanding 24-hour movement guideline adherence and relationships with health indicators across the lifespan," *J. Sport Health Sci.*, vol. 9, no. 6, pp. 493–510, Dec. 2020, doi: 10.1016/j.jshs.2020.07.004.
[48] J. A. Okely, A. Weiss, and C. R. Gale, "The interaction between individualism and wellbeing in predicting mortality: Survey of Health Ageing and Retirement in Europe," *J. Behav. Med.*, vol. 41, no. 1, pp. 1–11, 2018, doi: 10.1007/s10865-017-9871-x.
[49] "Sit less, move more, sleep well - HE2312," HealthEd. Accessed: Aug. 27, 2023. [Online]. Available: https://healthed.govt.nz/products/sit-less-move-more-sleep-well
[50] "Erratum: Draper et al. (2020)," *J. Phys. Act. Health*, vol. 17, no. 4, pp. 491–491, Feb. 2020, doi: 10.1123/jpah.2020-0067.
[51] *Guidelines on Physical Activity, Sedentary Behaviour and Sleep for Children under 5 Years of Age*. in WHO Guidelines Approved by the Guidelines Review Committee. Geneva: World Health Organization, 2019. Accessed: Aug. 27, 2023. [Online]. Available: http://www.ncbi.nlm.nih.gov/books/NBK541170/
[52] R. Ross *et al.*, "Canadian 24-Hour Movement Guidelines for Adults aged 18–64 years and Adults aged 65 years or older: an integration of physical activity, sedentary behaviour, and sleep," *Appl. Physiol. Nutr. Metab.*, vol. 45, no. 10 (Suppl. 2), pp. S57–S102, Oct. 2020, doi: 10.1139/apnm-2020-0467.
[53] E. C. McLaughlin *et al.*, "Balance and functional training and health in adults: an overview of systematic reviews," *Appl. Physiol. Nutr. Metab.*, vol. 45, no. 10 (Suppl. 2), pp. S180–S196, Oct. 2020, doi: 10.1139/apnm-2020-0279.
[54] C. Sherrington *et al.*, "Exercise for preventing falls in older people living in the community," *Cochrane Database Syst. Rev.*, vol. 2019, no. 1, 2019, doi: 10.1002/14651858.cd012424.pub2.
[55] H. Sampasa-Kanyinga *et al.*, "Associations between meeting combinations of 24-h movement guidelines and health-related quality of life in children from 12 countries," *Public Health*, vol. 153, pp. 16–24, Dec. 2017, doi: 10.1016/j.puhe.2017.07.010.
[56] V. Carson, J.-P. Chaput, I. Janssen, and M. S. Tremblay, "Health associations with meeting new 24-hour movement guidelines for Canadian children and youth," *Prev. Med.*, vol. 95, pp. 7–13, Feb. 2017, doi: 10.1016/j.ypmed.2016.12.005.
[57] D. Dumuid *et al.*, "Adiposity and the isotemporal substitution of physical activity, sedentary time and sleep among school-aged children: a compositional data analysis approach," *BMC Public Health*, vol. 18, no. 1, p. 311, Dec. 2018, doi: 10.1186/s12889-018-5207-1.
[58] J. J. Walsh *et al.*, "Associations between 24-hour movement behaviours and global cognition in a cross-sectional sample of US children," *Lancet Child Adolesc. Health*, vol. 2, no. 11, pp. 783–791, Nov. 2018, doi: 10.1016/S2352-4642(18)30278-5.
[59] A. E. Clarke *et al.*, "Meeting Canadian 24-Hour Movement Guideline recommendations and risk of all-cause mortality," *Appl. Physiol. Nutr. Metab.*, vol. 46, no. 12, pp. 1487–1494, Dec. 2021, doi: 10.1139/apnm-2021-0010.
[60] J. L. Rodgers *et al.*, "Cardiovascular Risks Associated with Gender and Aging," *J. Cardiovasc. Dev. Dis.*, vol. 6, no. 2, p. 19, Apr. 2019, doi: 10.3390/jcdd6020019.

[61] L. M. Vanderloo *et al.*, “Associations Between Meeting the 24-Hour Movement Guidelines and Cardiometabolic Risk in Young Children,” *Pediatr. Exerc. Sci.*, vol. 33, no. 3, pp. 112–119, May 2021, doi: 10.1123/pes.2020-0249.
[62] M. Garcia, S. L. Mulvagh, C. N. B. Merz, J. E. Buring, and J. E. Manson, “Cardiovascular Disease in Women: Clinical Perspectives,” *Circ. Res.*, vol. 118, no. 8, pp. 1273–1293, Apr. 2016, doi: 10.1161/CIRCRESAHA.116.307547.
[63] A. V. Rose, K. F. Boreskie, J. L. Hay, L. Thompson, R. C. Arora, and T. A. Duhamel, “Protocol for the WARM Hearts study: examining cardiovascular disease risk in middle-aged and older women - a prospective, observational cohort study,” *BMJ Open*, vol. 11, no. 5, p. e044227, May 2021, doi: 10.1136/bmjopen-2020-044227.
[64] A. Baillot, J.-P. Chaput, S. A. Prince, A. J. Romain, R. C. Colley, and J. J. Lang, “Health associations with meeting the new Canadian 24-Hour Movement Guidelines recommendations according to body mass index classes in Canadian adults.” Accessed: Aug. 04, 2023. [Online]. Available: https://www150.statcan.gc.ca/n1/pub/82-003-x/2022011/article/00001-eng.htm
[65] S. K. Keadle, E. J. Shiroma, P. S. Freedson, and I.-M. Lee, “Impact of accelerometer data processing decisions on the sample size, wear time and physical activity level of a large cohort study,” *BMC Public Health*, vol. 14, no. 1, p. 1210, Nov. 2014, doi: 10.1186/1471-2458-14-1210.
[66] T. L. Hart, A. M. Swartz, S. E. Cashin, and S. J. Strath, “How many days of monitoring predict physical activity and sedentary behaviour in older adults?,” *Int. J. Behav. Nutr. Phys. Act.*, vol. 8, p. 62, Jun. 2011, doi: 10.1186/1479-5868-8-62.
[67] J. Pasanen *et al.*, “Effects of physical activity intervention on 24-h movement behaviors: a compositional data analysis,” *Sci. Rep.*, vol. 12, no. 1, Art. no. 1, May 2022, doi: 10.1038/s41598-022-12715-2.
[68] J. H. Migueles, A. V. Rowlands, F. Huber, S. Sabia, and V. T. van Hees, “GGIR: A Research Community–Driven Open Source R Package for Generating Physical Activity and Sleep Outcomes From Multi-Day Raw Accelerometer Data,” *J. Meas. Phys. Behav.*, vol. 2, no. 3, pp. 188–196, Sep. 2019, doi: 10.1123/jmpb.2018-0063.
[69] S. J. Fairclough, L. Clifford, D. Brown, and R. Tyler, “Characteristics of 24-hour movement behaviours and their associations with mental health in children and adolescents,” *J. Act. Sedentary Sleep Behav.*, vol. 2, no. 1, p. 11, Jun. 2023, doi: 10.1186/s44167-023-00021-9.
[70] H. Eke, S. E. Bonn, and Y. Trolle Lagerros, “Wrist-worn accelerometers: Influence of decisions during data collection and processing: A cross-sectional study,” *Health Sci. Rep.*, vol. 7, no. 1, p. e1810, Jan. 2024, doi: 10.1002/hsr2.1810.
[71] V. T. van Hees *et al.*, “Autocalibration of accelerometer data for free-living physical activity assessment using local gravity and temperature: an evaluation on four continents,” *J. Appl. Physiol.*, vol. 117, no. 7, pp. 738–744, Oct. 2014, doi: 10.1152/japplphysiol.00421.2014.
[72] G. J. Sanders *et al.*, “Evaluation of wrist and hip sedentary behaviour and moderate-to-vigorous physical activity raw acceleration cutpoints in older adults,” *J. Sports Sci.*, vol. 37, no. 11, pp. 1270–1279, Jun. 2019, doi: 10.1080/02640414.2018.1555904.
[73] K. Bammann, N. K. Thomson, B. M. Albrecht, D. S. Buchan, and C. Easton, “Generation and validation of ActiGraph GT3X+ accelerometer cut-points for assessing physical activity intensity in older adults. The OUTDOOR ACTIVE validation study,” *PLOS ONE*, vol. 16, no. 6, p. e0252615, Jun. 2021, doi: 10.1371/journal.pone.0252615.

[74] M. Hildebrand, V. T. Van Hees, B. H. Hansen, and U. Ekelund, "Age Group Comparability of Raw Accelerometer Output from Wrist- and Hip-Worn Monitors," *Med. Sci. Sports Exerc.*, vol. 46, no. 9, p. 1816, Sep. 2014, doi: 10.1249/MSS.0000000000000289.
[75] M. Hildebrand, B. H. Hansen, V. T. van Hees, and U. Ekelund, "Evaluation of raw acceleration sedentary thresholds in children and adults," *Scand. J. Med. Sci. Sports*, vol. 27, no. 12, pp. 1814–1823, 2017, doi: 10.1111/sms.12795.
[76] J. Lošťák, A. Gába, J. Dygrýn, Ľ. Baláž, N. Štefelová, and J. Gallo, "Twenty-Four-Hour Movement Behaviors in Adults and Older Adults before Total Knee Arthroplasty: a Study Based on Compositional Data Analysis," *Acta Chir. Orthop. Traumatol. Cech.*, vol. 89, no. 1, pp. 9–15, Feb. 2022, doi: 10.55095/achot2022/001.
[77] M. N. Ahmadi *et al.*, "Brief bouts of device-measured intermittent lifestyle physical activity and its association with major adverse cardiovascular events and mortality in people who do not exercise: a prospective cohort study," *Lancet Public Health*, vol. 8, no. 10, pp. e800–e810, Oct. 2023, doi: 10.1016/S2468-2667(23)00183-4.
[78] P.-W. Ku, A. Steptoe, Y. Liao, M.-C. Hsueh, and L.-J. Chen, "A cut-off of daily sedentary time and all-cause mortality in adults: a meta-regression analysis involving more than 1 million participants," *BMC Med.*, vol. 16, p. 74, May 2018, doi: 10.1186/s12916-018-1062-2.
[79] P.-W. Ku, A. Steptoe, Y. Liao, M.-C. Hsueh, and L.-J. Chen, "A Threshold of Objectively-Assessed Daily Sedentary Time for All-Cause Mortality in Older Adults: A Meta-Regression of Prospective Cohort Studies," *J. Clin. Med.*, vol. 8, no. 4, p. 564, Apr. 2019, doi: 10.3390/jcm8040564.
[80] R. Patterson *et al.*, "Sedentary behaviour and risk of all-cause, cardiovascular and cancer mortality, and incident type 2 diabetes: a systematic review and dose response meta-analysis," *Eur. J. Epidemiol.*, vol. 33, no. 9, pp. 811–829, 2018, doi: 10.1007/s10654-018-0380-1.
[81] T. J. Saunders *et al.*, "Sedentary behaviour and health in adults: an overview of systematic reviews," *Appl. Physiol. Nutr. Metab.*, vol. 45, no. 10 (Suppl. 2), pp. S197–S217, Oct. 2020, doi: 10.1139/apnm-2020-0272.
[82] V. T. van Hees *et al.*, "A Novel, Open Access Method to Assess Sleep Duration Using a Wrist-Worn Accelerometer," *PLoS ONE*, vol. 10, no. 11, p. e0142533, Nov. 2015, doi: 10.1371/journal.pone.0142533.
[83] N. Rodondi *et al.*, "Framingham Risk Score and Alternatives for Prediction of Coronary Heart Disease in Older Adults," *PLoS ONE*, vol. 7, no. 3, p. e34287, Mar. 2012, doi: 10.1371/journal.pone.0034287.
[84] T. J. Anderson *et al.*, "2012 Update of the Canadian Cardiovascular Society Guidelines for the Diagnosis and Treatment of Dyslipidemia for the Prevention of Cardiovascular Disease in the Adult," *Can. J. Cardiol.*, vol. 29, no. 2, pp. 151–167, Feb. 2013, doi: 10.1016/j.cjca.2012.11.032.
[85] D. Benas *et al.*, "Pulse wave analysis using the Mobil-O-Graph, Arteriograph and Complior device: a comparative study," *Blood Press.*, vol. 28, no. 2, pp. 107–113, Mar. 2019, doi: 10.1080/08037051.2018.1564236.
[86] K. A. Nerenberg *et al.*, "Hypertension Canada's 2018 Guidelines for Diagnosis, Risk Assessment, Prevention, and Treatment of Hypertension in Adults and Children," *Can. J. Cardiol.*, vol. 34, no. 5, pp. 506–525, May 2018, doi: 10.1016/j.cjca.2018.02.022.
[87] CDC, "All About Adult BMI," Centers for Disease Control and Prevention. Accessed: Mar. 29, 2024. [Online]. Available: https://www.cdc.gov/healthyweight/assessing/bmi/adult_bmi/index.html

[88] S. D. Searle, A. Mitnitski, E. A. Gahbauer, T. M. Gill, and K. Rockwood, “A standard procedure for creating a frailty index,” *BMC Geriatr.*, vol. 8, p. 24, Sep. 2008, doi: 10.1186/1471-2318-8-24.
[89] E. H. Gordon, N. Reid, I. S. Khetani, and R. E. Hubbard, “How frail is frail? A systematic scoping review and synthesis of high impact studies,” *BMC Geriatr.*, vol. 21, p. 719, Dec. 2021, doi: 10.1186/s12877-021-02671-3.
[90] C. D. Porter, P. G. McPhee, M. Y. Kwan, B. W. Timmons, and D. M. Y. Brown, “24-hour movement guideline adherence and mental health: A cross-sectional study of emerging adults with chronic health conditions and disabilities,” *Disabil. Health J.*, vol. 16, no. 3, p. 101476, Jul. 2023, doi: 10.1016/j.dhjo.2023.101476.
[91] S. Rollo, “Health Associations with Meeting the Canadian 24-Hour Movement Guidelines for Adults: Results from the Canadian Health Measures Survey,” *Health Rep.*, vol. 33, no. 82, 2022.
[92] L. Luo *et al.*, “The Associations between Meeting 24-Hour Movement Guidelines (24-HMG) and Self-Rated Physical and Mental Health in Older Adults—Cross Sectional Evidence from China,” *Int. J. Environ. Res. Public. Health*, vol. 19, no. 20, p. 13407, Oct. 2022, doi: 10.3390/ijerph192013407.
[93] D. K. Arnett *et al.*, “2019 ACC/AHA Guideline on the Primary Prevention of Cardiovascular Disease: A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines,” *Circulation*, vol. 140, no. 11, pp. e596–e646, Sep. 2019, doi: 10.1161/CIR.0000000000000678.
[94] BrJCardiol, “Community-based cardiovascular risk reduction: age and the Framingham risk score - The British Journal of Cardiology.” Accessed: Aug. 05, 2024. [Online]. Available: https://bjcardio.co.uk/2011/08/community-based-cardiovascular-risk-reduction-age-and-the-framingham-risk-score/
[95] W. de Ruijter *et al.*, “Use of Framingham risk score and new biomarkers to predict cardiovascular mortality in older people: population based observational cohort study,” *BMJ*, vol. 338, p. a3083, Jan. 2009, doi: 10.1136/bmj.a3083.
[96] J. A. Damen *et al.*, “Performance of the Framingham risk models and pooled cohort equations for predicting 10-year risk of cardiovascular disease: a systematic review and meta-analysis,” *BMC Med.*, vol. 17, no. 1, p. 109, Jun. 2019, doi: 10.1186/s12916-019-1340-7.
[97] T. Pereira and T. Costa, “Determinants of Arterial Stiffness and Vascular Aging in the Older Adult: Arterial stiffness in the older adult,” *Int. J. Cardiovasc. Sci.*, 2020, doi: 10.36660/ijcs.20190068.
[98] P. C. Dempsey *et al.*, “New global guidelines on sedentary behaviour and health for adults: broadening the behavioural targets,” *Int. J. Behav. Nutr. Phys. Act.*, vol. 17, no. 1, p. 151, Nov. 2020, doi: 10.1186/s12966-020-01044-0.
[99] A. P. Society, “Why Being an ‘Active Couch Potato’ Is Bad for Your Health,” I Spy Physiology Blog. Accessed: Aug. 22, 2024. [Online]. Available: https://ispyphysiology.com/2019/01/30/why-being-an-active-couch-potato-is-bad-for-your-health/
[100] D. E. McGregor, V. Carson, J. Palarea-Albaladejo, P. M. Dall, M. S. Tremblay, and S. F. M. Chastin, “Compositional Analysis of the Associations between 24-h Movement Behaviours and Health Indicators among Adults and Older Adults from the Canadian Health Measure Survey,” *Int. J. Environ. Res. Public. Health*, vol. 15, no. 8, p. 1779, Aug. 2018, doi: 10.3390/ijerph15081779.

[101] N. Covassin and P. Singh, “Sleep Duration and Cardiovascular Disease Risk: Epidemiologic and Experimental Evidence,” *Sleep Med. Clin.*, vol. 11, no. 1, pp. 81–89, Mar. 2016, doi: 10.1016/j.jsmc.2015.10.007.
[102] W. Wang *et al.*, “Assoication between self-reported sleep duration, physcial activity and the risk of all cause and cardiovascular diseases mortality from the NHANES database,” *BMC Cardiovasc. Disord.*, vol. 23, no. 1, p. 467, Sep. 2023, doi: 10.1186/s12872-023-03499-y.
[103] V. E. Kettle *et al.*, “Effectiveness of physical activity interventions delivered or prompted by health professionals in primary care settings: systematic review and meta-analysis of randomised controlled trials,” *The BMJ*, vol. 376, p. e068465, Feb. 2022, doi: 10.1136/bmj-2021-068465.
[104] A. Kandola, G. Ashdown-Franks, J. Hendrikse, C. M. Sabiston, and B. Stubbs, “Physical activity and depression: Towards understanding the antidepressant mechanisms of physical activity,” *Neurosci. Biobehav. Rev.*, vol. 107, pp. 525–539, Dec. 2019, doi: 10.1016/j.neubiorev.2019.09.040.
[105] M. J. Duncan, L. Murphy, S. Oftedal, M. J. Fenwick, G. E. Vincent, and S. Fenton, “The associations between physical activity, sedentary behaviour, and sleep with mortality and incident cardiovascular disease, cancer, diabetes and mental health in adults: a systematic review and meta-analysis of prospective cohort studies,” *J. Act. Sedentary Sleep Behav.*, vol. 2, no. 1, p. 19, Sep. 2023, doi: 10.1186/s44167-023-00026-4.
[106] L. D. Delfino, W. R. Tebar, and D. G. D. Christofaro, “Prevalence and association of compliance with the Canadian 24-hour movement guidelines with sociodemographic aspects in Brazilian adults: a cross-sectional epidemiological study,” *BMC Public Health*, vol. 24, no. 1, p. 262, Jan. 2024, doi: 10.1186/s12889-024-17720-w.
[107] “Association Between Television Viewing Time and All-Cause Mortality: A Meta-Analysis of Cohort Studies | American Journal of Epidemiology | Oxford Academic.” Accessed: Aug. 22, 2024. [Online]. Available: https://academic.oup.com/aje/article/182/11/908/112195?login=false
[108] T. J. Cleophas and A. H. Zwinderman, “Logarithmic Transformations, a Great Help to Statistical Analyses,” in *Clinical Data Analysis on a Pocket Calculator*, Cham: Springer International Publishing, pp. 243–247. doi: 10.1007/978-3-319-27104-0_43.
[109] J. H. Migueles *et al.*, “Accelerometer Data Collection and Processing Criteria to Assess Physical Activity and Other Outcomes: A Systematic Review and Practical Considerations,” *Sports Med. Auckl. NZ*, vol. 47, no. 9, pp. 1821–1845, Sep. 2017, doi: 10.1007/s40279-017-0716-0.

Appendix 1: STROBE Checklist

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies.***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/ rationale	2	Explain the scientific background and rationale for the investigation being reported	28
Objectives	3	State specific objectives, including any prespecified hypotheses	28
Methods			
Study design	4	Present key elements of study design early in the paper	29
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	30
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	30
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	42
Data sources/ measurement	8	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	30
Bias	9	Describe any efforts to address potential sources of bias	30
Study size	10	Explain how the study size was arrived at	33
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	30

Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	44
		(*b*) Describe any methods used to examine subgroups and interactions	44
		(*c*) Explain how missing data were addressed	44
		(*d*) If applicable, explain how loss to follow-up was addressed	
		(*e*) Describe any sensitivity analyses	
Results			
Participants	13	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	46
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	48
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) Summarise follow-up time (eg, average and total amount)	
Outcome data	15	Report numbers of outcome events or summary measures over time	
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	53
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			

Key results	18	Summarise key results with reference to study objectives	73
Limitations	19	Dissuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	83
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	73
Gemeralisability	21	Discuss the generalisability (external validity) of the study results	75
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	29

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

Appendix 2: GGIR Input codes

```
library(GGIR)
GGIR(datadir="~",
    outputdir="~",
    overwrite=TRUE,
    mode=c(1:5),
    idloc=2,
    maxdur=7,
    dayborder=6,
    printsummary=TRUE,
    boutdur.mvpa=1,
    boutdur.lig=1,
    boutdur.in=1,
    mvpathreshold=104,
    threshold.lig=57,
    threshold.mod=104,
    threshold.vig=245,
    timewindow="MM",
    loglocation="~",
    colid=1,
    coln1=2,
    sleepwindowType="TimeInBed",
    do.sibreport=TRUE)
```

Appendix 3: GGIR standardized operating procedure for 24-hour movement guideline analysis

GGIR SOP

Fall 2023/Winter 2024

1

Setting Up: Files & Software

Skip to next section if you already have raw .csv files, R, and R studio downloaded

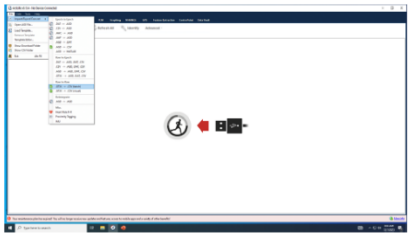
2

Export raw data from ActiLife

- Open ActiLife
- File → Import/Export/Convert →raw to raw → .GT3X to .csv (batch)

3

Export raw data from ActiLife



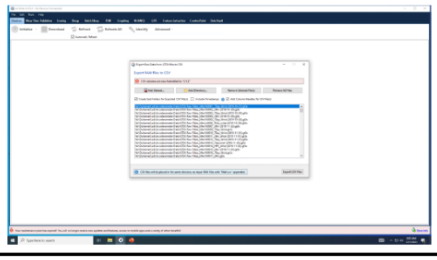
4

Export raw data from ActiLife

- ADD dataset
  - Add all .GT3X files
- 3 checkboxes
  - Create subfolders for exported CSV file(s) = recommended but optional, for convenience
  - Include timestamps = **DO NOT CHECK!!!!!!!**
  - Add column headers to CSV files = CHECK!!!!!

5

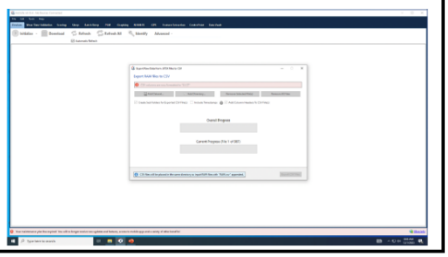
Export raw data from ActiLife



6

Export raw data from ActiLife

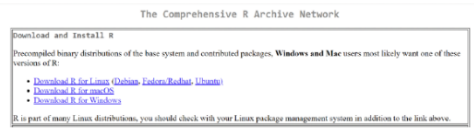
- Wait ☺



7

Download R

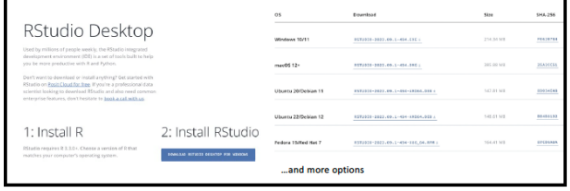
- https://cran.r-project.org/
- Pick the option that fits your computer



8

Download R Studio

- https://posit.co/download/rstudio-desktop/
- Pick the option that fits your computer



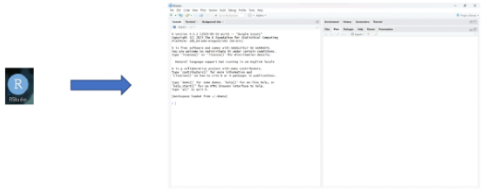
9

Setting up: GGIR

Skip to next section if GGIR package and dependencies are already installed on R & all converted .csv files are in one folder

10

Open R Studio

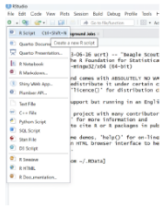


It might look like this when it opens

11

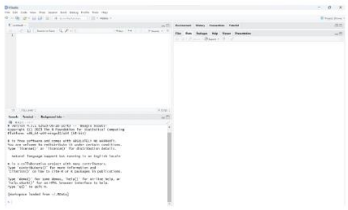
Open an R script

File → R script



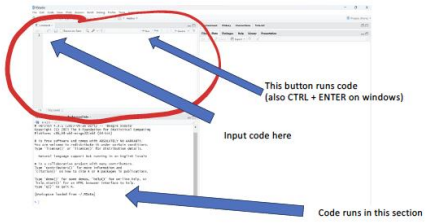
12

You're ready when UI looks like this



13

You're ready when UI looks like this



14

Install packages

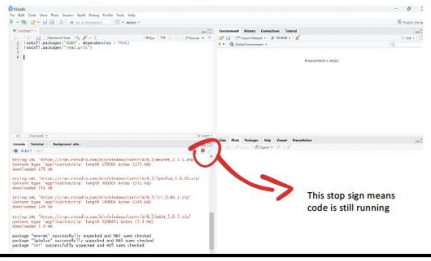
```
install.packages("GGIR", dependencies = TRUE)
```

Assuming you're using ActiGraph accelerometers/ActiLife software, you need this one too:

```
install.packages("read.gt3x")
```

15

Installing will look like this



16

Prepare folder structure

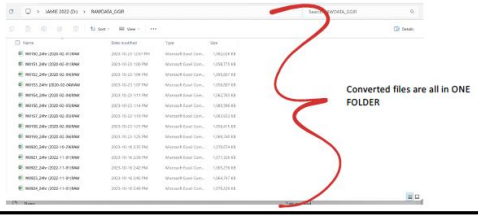
- Find LOCATION ON computer of exported ActiGraph .csv (or .gt3x) files

1. All accelerometer data that needs to be analysed should be stored in one folder, or subfolders of that folder.
2. Give the folder an appropriate name, preferable with a reference to the study or project it is related to rather than just 'data', because the name of this folder will be used later on as an identifier of the dataset.
   - E.g., "RAWDATA_GGIR"

17

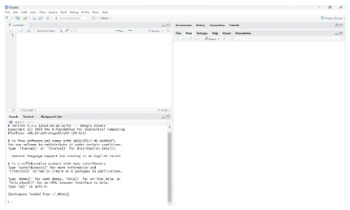
Prepare folder structure

Example:



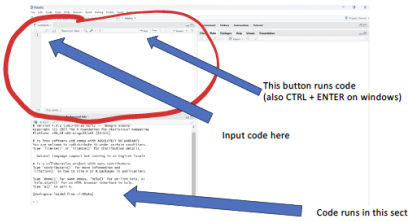
18

You're ready when UI looks like this



25

You're ready when UI looks like this



26

Base Code

- Replace datadir with location of accelerometer files
- Replace outputdir with location of where you want to save GGIR output
- Examples:

Generic Windows:

```
library(GGIR)
GGIR(datadir="C:/mystudy/mydata", outputdir="D:/myresults")
```

Example for Windows on my personal laptop:

```
library(GGIR)
GGIR(datadir="D:/RAWDATA_GGIR", outputdir="D:/OUTPUT_GGIR")
```

Example for LAB COMPUTER:

```
library(GGIR)
GGIR(datadir="W:/Duhamel Lab/Accelerometer Data/GT3X Raw Files_24hr/csv",
outputdir="W:/Duhamel Lab/Accelerometer Data/GGIR_OUTPUT")
```

27

Base Code

- Replace datadir with location of accelerometer files
- Replace outputdir with location of where you want to save GGIR output

Use this path for datadir in lab computer
Outputdir should be changed if we run a new analysis
- make sure you make a new folder to direct output files to

Example for LAB COMPUTER:

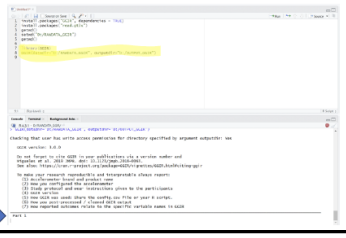
```
library(GGIR)
GGIR(datadir="W:/Duhamel Lab/Accelerometer Data/GT3X Raw Files_24hr/csv",
outputdir="W:/Duhamel Lab/Accelerometer Data/GGIR_OUTPUT")
```

28

Base Code:

- **Input the base code into the R script and press run**

Note - Entering getwd() and setwd() are not necessary for the code, but is used to double-check where the working directory is located



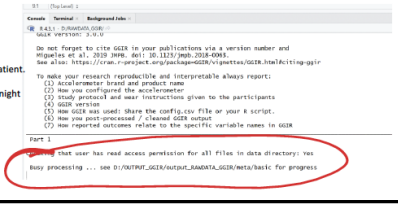
When this appears, it's running

29

Base Code:

Running the base code will output all the default values for GGIR

Part 1 takes a while – be patient. With large datasets, it is recommended to run overnight



This is good!

30

Running GGIR

Skip this section if you already have results files

19

What happens in GGIR?

- Part 1: preparing all data to be analyzed
  - REQUIRED
  - Longest step
- Part 2: physical activity analysis
- Part 3: preparing data to be analyzed for SLEEP
- Part 4: sleep analysis
- Part 5: summarizes physical activity and sleep data

20

What happens in GGIR?

- Part 1: preparing all data to be analyzed
  - REQUIRED
  - Longest step
- **Part 2: physical activity analysis**
- Part 3: preparing data to be analyzed for SLEEP
- **Part 4: sleep analysis**
- **Part 5: summarizes physical activity and sleep data**

Only these parts will generate an output file

21

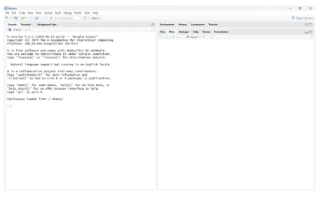
Outline of steps:

- Open R Studio
- Input code (see next slides) which specifies:
  - **Where .csv files are saved**
  - **Where you want to save GGIR output**
  - Which acceleration intensity cut-offs to use
  - # of minutes a bout of
  - If you want one day to be considered midnight to midnight vs wake-up to next wake-up
  - Etc. → see GGIR data dictionary
- Wait

Bare minimum – GGIR can run just using this

22

Open R Studio

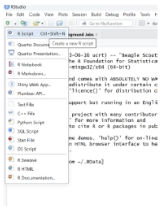


It might look like this when it opens

23

Open an R script

File → R script



24

GGIR Customizations

- See data dictionary for all possible ways to modify the code

https://cran.r-project.org/web/packages/GGIR/vignettes/GGIRParameters.html#1_Input_argumentsparameters_overview

https://cran.r-project.org/web/packages/GGIR/index.html

- This SOP will cover some of the most relevant and useful modifications

31

GGIR Input Customizations – SPECIFY FOR PART 1

Argument/Parameter	Recommended Input(s) / Example Input	GGIR Explanation	Lay Explanation
datadir	D:/RAWDATA_GGIR (example)	Character (default = c()). Directory where the accelerometer files are stored, e.g., "C:/mydata", or list of accelerometer filenames and directories, e.g. c("C:/mydata/myfile1.bin", "C:/mydata/myfile2.bin").	Pathway to the place on your computer where the raw .csv files are
outputdir	D:/OUTPUT_GGIR (example)	Character (default = c()). Directory where the output needs to be stored. Note that this function will attempt to create folders in this directory and uses those folder to keep output	Pathway to the place on your computer where you want the output of GGIR (Results) to go
mode	c(1:5) c(1,2) c(2:5)	Numeric (default = 1:5). Specify which of the five parts need to be run, e.g., mode = 1 makes that g.part1 is run; or mode = 1:5 makes that the whole GGIR pipeline is run, from g.part1 to g.part5	Tells GGIR which parts (from 1-5) to run. You have to run part 1 the first time. If you're making minor adjustments to the code after, you can just run any or all of parts 2-5). PA analysis = 2, sleep = 3&4, summary of PA and sleep = 5
idloc	2	Numeric (default = 1). If idloc = 1 the code assumes that ID number is stored in the obvious header field. Note that for ActiGraph data the ID is never stored in the file header. For value set to 2, 5, 6, and 7, GGIR looks at the filename and extracts the character string preceding the first occurance of a "_" (idloc = 2), " " (space, idloc = 5), "." (dot, idloc = 6), and "-" (idloc = 7), respectively. You may have noticed that idloc 3 and 4 are skipped, they were used for one study in 2012, and not actively maintained anymore, but because it is legacy code not omitted.	Tells GGIR how to name (ID) each participant. Putting 2 means that it will read the filenames and call each participant whatever comes before an underscore (_)
maxdur	7	Numeric (default = 0). How many DAYS after start of experiment did experiment definitely stop? (set to zero if unknown).	Max number of days we want to analyze
dayborder	6	Numeric (default = 0). Hour at which days start and end (dayborder = 4 would mean 4 am).	Tells GGIR what hour to start each day (accelerometer programmed to start at 6 am so put 6)

IMPORTANT

32

mvpathreshold	c(400, 500.6)	Numeric (default = 100). Acceleration threshold for MVPA estimation in GGIR g.part2. This can be a single number or an array of numbers, e.g., mvpathreshold = c(100, 120). In the later case the code for activity to be classified as MVPA. There are will estimate MVPA separately for each threshold. If this variable is left blank, e.g., mvpathreshold = c(), then MVPA is not estimated.	Magnitude of acceleration needed to be met different thresholds for different age groups (older or younger than 76)
threshold.lig	c(18, 44.8)	Numeric (default = 40). In g.part5: Threshold for light physical activity to separate inactivity from light. Value can be one number or an array of multiple numbers, e.g., threshold.lig =c(16,40). If multiple numbers are entered then analysis will be repeated for each combination of threshold values. Threshold is applied to the first metric in the milestone data, so if you have only specified do.enmo = TRUE then it will be applied to ENMO	Acceleration threshold for light activity.
threshold.mod	c(100, 100.8)	Numeric (default = 100). In g.part5: Threshold for moderate physical activity to separate light from moderate. Value can be one number or an array of multiple numbers, e.g., threshold.mod = c(100, 120). If multiple numbers are entered then analysis will be replicad for each combination of threshold values. Threshold is applied to the first metric in the milestone data, so if you have only specified do.enmo = TRUE then it will be applied to ENMO	Acceleration threshold for moderate-intensity activity.
threshold.vig	428.8	Numeric (default = 400). In g.part5: Threshold for vigorous physical activity to separate moderate from vigorous. Value can be one number or an array of multiple numbers, e.g., threshold.vig =c(400,500). If multiple numbers are entered then analysis will be replicad for each combination of threshold values. Threshold is applied to the first metric in the milestone data, so if you have only specified do.enmo = TRUE then it will be applied to ENMO	Acceleration threshold for vigorous intensity activity
boutdur.mvpa	10	Numeric (default = c(1, 5, 10)). Duration(s) of MVPA bouts in minutes to be extracted. It will start with the identification of the longest to the shortest duration. In the default setting, it will start with the 10 minute bouts, followed by 5 minute bouts in the rest of the data, and followed by 1 minute bouts in the rest of the data	Required duration for a bout of MVPA to be extracted
boutdur.in	60	Numeric (default = c(10, 20, 30)). Duration(s) of inactivity bouts in minutes to be extracted. Inactivity bouts are detected in the segments of the data which were not labelled as sleep or MVPA bouts. It will start with the identification of the longest to the shortest duration. In the default setting, it will start with the identification of 30 minute bouts, followed by 20 minute bouts in the rest of the data, and followed by 10 minute bouts in the rest of the data. Note that we use the term inactivity instead of sedentary behaviour for the lowest intensity level of behaviour. The reason for this is that GGIR does not attempt to classifying the activity type sitting at the moment, by which we feel that using the term sedentary behaviour would fall to communicate that.	Required duration for a bout of inactivity to be extracted
loglocation	enter pathway	Character (default = NULL). Path to csv file with sleep log information. See package vignette for how to format this file	Location of excel sleeping file in the correct format
timewindow	MM	Character (default = c("MM", "WW")). In g.part5: Timewindow over which summary statistics are derived. Value can be "MM" (midnight to midnight), "WW" (waking time to waking time), "OO" (sleep onset to sleep onset), or any combination of them.	Tells GGIR to look at data in days that start and end at midnight (i.e., normal calendar days)

See https://cran.r-project.org/web/packages/GGIR/vignettes/CutPoints.html
For list of studies with validated cut points

33

PART 1&2 CODE

Make sure directories are accurate

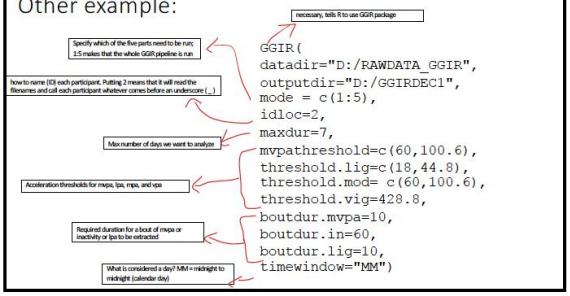
Input this into the R script and run the code

```
library(GGIR)
GGIR(datadir="W:/Duhamel Lab/Accelerometer Data/GT3X Raw Files_24hr/csv",
outputdir="W:/Duhamel Lab/Accelerometer Data/GGIR_MARCH2024,
overwrite=FALSE,
f0=1, f1=0,
mode=c(1),   ← Make sure to change mode depending on what parts you want to run
idloc=2,
maxdur=7,
dayborder=6,
printsummary=TRUE,
boutdur.mvpa=10,
boutdur.lig=10,
boutdur.in=60,
mvpathreshold=104,
threshold.lig=57,
threshold.mod=104,
threshold.vig=245,
timewindow="MM")
```

*** IMPORTANT*** YOU MIGHT HAVE TO CHANGE ALL THE QUOTATION MARKS SO THAT THEY ARE CONSISTENT IN ONE FONT**********

34

Other example:



35

Adding sleep logs

- To incorporate sleep logs into analyses, add this into your code (change directory):

loglocation="W:/Duhamel Lab/Accelerometer Data/advanced sleep log/WH_ADVANCEDSLEEPLOGS.csv",
colid=1, ← Column number with participant IDs
coln1=2, ← Column number with night 1 calendar dates
sleepwindowType="TimeInBed", ← Indicates that our "bedtime" is when they got into bed, not necessarily when they fell asleep
do.sibreport=TRUE ← Adds naps into results output in part 5

36

Note about overwriting

- If you want to run code with a different set of parameters but keep the original data (e.g., if you want to compare a 400 vigorous cut off vs a 245 cut-off)
- 2 options:
  - 1) Set overwrite to FALSE and use the same directory while changing parameters in the code (e.g., threshold.vig = 400 → threshold.vig = 245).
    - This will create a new set of output files within the folder.
    - If you've changed cut-off thresholds, you can tell the files apart from the name (see slide 62)
  - 2) Duplicate the folder with results (e.g., Mudra_OUTPUT) and change the name (e.g., Mudra_245). Set overwrite to TRUE, change the output directory listed in the code (along with the parameters to be changed) to your new folder (e.g., outputdir = …./Mudra_245).
    - Now you have 2 folders with the same part 1 data but different results files

37

INTERPRETING GGIR OUTPUT

38

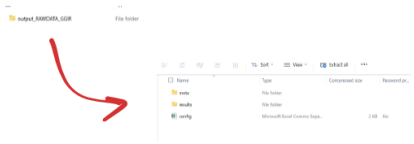
What will output from running base code:

- Part 2 Day Summary = PA levels for each day for each participant
- Part 2 Summary = summary of PA levels for each participant over the entire wear duration (i.e., ~7 days)
- Part 4 night summary sleep= summary of sleep for each night for each participant
- Part 4 summary sleep = summary of overall sleep for each participant

39

Where is the output?

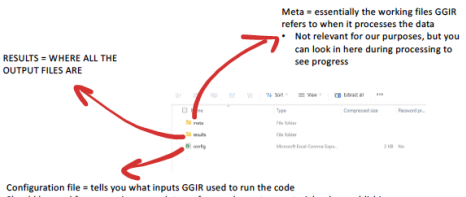
- The same place you specified in code in `outputdir`



40

Where is the output?

- The same place you specified in code in `outputdir`

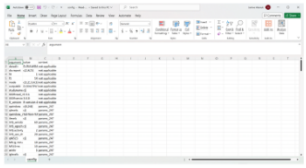


41

Meta folder

42

Configuration file

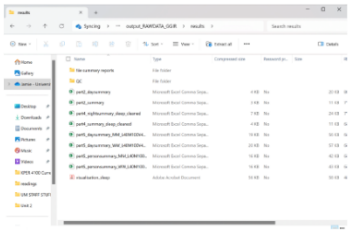


Essentially shows all the values used for all input options, including default values

43

RESULTS FOLDER

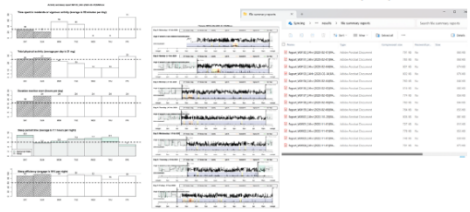
Each one will be mentioned (in order)



44

File summary reports

Visualization of each participant's data



45

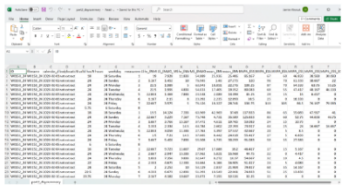
Results files:

- For full interpretation, see data dictionary

46

Part2_daysummary

Physical activity data for every participant for every day they wore the Actigraph

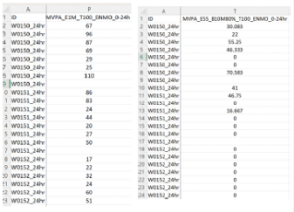


47

Part2_daysummary - Key results to look for (for 24hr movement guidelines:

Output file cell heading	Explanation
MVPA_E1M_T100_ENMO_0-24hr	Time spent in MVPA (in minutes in a 24-hour period) using 1 min epoch and MVPA threshold of 100 mg.
MVPA_E5S_BOUT80%_T100_ENMO_0-24hr	Time spent in MVPA in minutes in a 24-hour period where epoch size 5 seconds; MPVA threshold = 100mg; and to be counted, MVPA must have occurred in bouts of at least 10 minutes, where 80% of that bout is at the MVPA threshold

Note – 100 is the default MVPA threshold. Adjust based on validated cutoffs

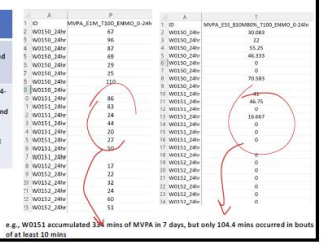


48

Part2_daysummary - Key results to look for (for 24hr movement guidelines:

Output file cell heading	Explanation
MVPA_E1M_T100_ENMO_0-24hr	Time spent in MVPA (in minutes in a 24-hour period) using 1 min epoch and MVPA threshold of 100 mg.
MVPA_ES5_B10MB0N_T100_ENMO_0-24hr	Time spent in MVPA in minutes in a 24-hour period where epoch size 5 seconds; MPVA threshold = 100mg; and to be counted, MVPA must have occurred in bouts of at least 10 minutes, where 80% of that bout is at the MVPA threshold

Note – 100 is the default MVPA threshold. Adjust based on validated cutoffs

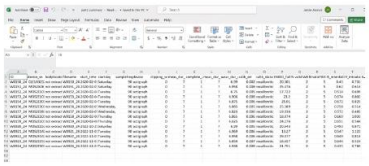


e.g., W0151 accumulated 330 mins of MVPA in 7 days, but only 104.4 mins occurred in bouts of at least 10 mins

49

Part2_summary

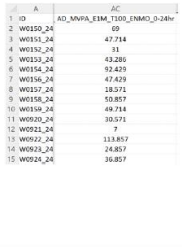
Summary of all participants, averaged over the whole wear period



50

Part2_summary - Key results to look for:

Output file cell heading	Explanation
AD_MVPA_E1M_T100_ENMO_0-24hr	Mean time spent in MVPA per day using 1 minute epoch, threshold 100, averaged over all days.
AD_MVPA_ES5_B10MB0N_T100.6_ENMO_0-24hr	Mean time spent in MVPA per day using 5s epoch, threshold 100, occuring in bouts of at least 10 minutes where 80% of bout is at required threshold, averaged across all days.

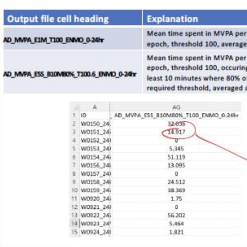


ID	AD_MVPA_ES5_B10MB0N_T100_ENMO_0-24hr
W0150_24	32.036
W0151_24	14.917
W0152_24	0
W0153_24	5.345
W0154_24	51.119
W0156_24	13.095
W0157_24	0
W0158_24	24.512
W0159_24	38.369
W0920_24	1.75
W0921_24	0
W0922_24	56.202
W0923_24	5.464
W0924_24	1.821

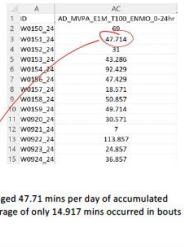
51

Part2_summary - Key results to look for:

Output file cell heading	Explanation
AD_MVPA_E1M_T100_ENMO_0-24hr	Mean time spent in MVPA per day using 1 minute epoch, threshold 100, averaged over all days.
AD_MVPA_ES5_B10MB0N_T100.6_ENMO_0-24hr	Mean time spent in MVPA per day using 5s epoch, threshold 100, occuring in bouts of at least 10 minutes where 80% of bout is at required threshold, averaged across all days.



ID	AD_MVPA_ES5_B10MB0N_T100_ENMO_0-24hr
W0150_24	32.036
W0151_24	14.917
W0152_24	0
W0153_24	5.345
W0154_24	51.119
W0156_24	13.095
W0157_24	0
W0158_24	24.512
W0159_24	38.369
W0920_24	1.75
W0921_24	0
W0922_24	56.202
W0923_24	5.464
W0924_24	1.821



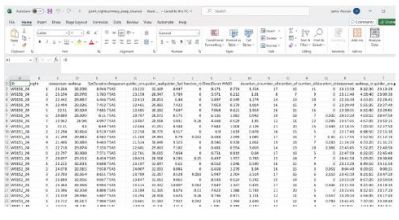
ID	AD_MVPA_E1M_T100_ENMO_0-24hr
W0150_24	69
W0151_24	47.714
W0152_24	31
W0153_24	43.286
W0154_24	92.429
W0156_24	47.429
W0157_24	18.571
W0158_24	50.857
W0159_24	49.714
W0920_24	30.571
W0921_24	7
W0922_24	113.857
W0923_24	24.857
W0924_24	36.857

e.g., W0151 averaged 47.71 mins per day of accumulated MVPA, but an average of only 14.917 mins occurred in bouts of 10+ mins

52

Part4_nightsummary_sleep_cleaned

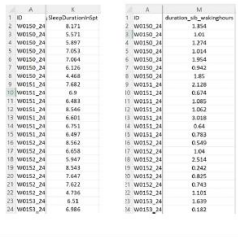
Sleep data for all participants for each night



53

Part4_nightsummary_sleep_cleaned - Key results to look for (relevant to Canadian PA guidelines:

Output file cell heading	Explanation
SleepDurationInSpt	Total sleep duration in hours for each day; equals the accumulated nocturnal sustained inactivity bouts within the Sleep Period Time.
duration_sib_wakinghours	Accumulated sustained inactivity bouts (SIB) during the day. These are the periods we would label during the night as sleep, but during the day they form a subclass of inactivity, which may represent day time sleep or wakefulness while being motionless for a sustained period of time



ID	SleepDurationInSpt
W0150_24	8.171
W0150_24	5.571
W0150_24	5.897
W0150_24	7.053
W0150_24	7.064
W0150_24	6.126
W0150_24	4.468
W0151_24	7.682
W0151_24	6.9
W0151_24	6.483
W0151_24	8.566
W0151_24	6.601
W0151_24	6.751
W0151_24	6.497
W0152_24	8.562
W0152_24	6.658
W0152_24	5.947
W0152_24	8.543
W0152_24	7.647
W0152_24	7.622
W0152_24	4.736
W0153_24	6.51
W0153_24	6.986

ID	duration_sib_wakinghours
W0150_24	1.854
W0150_24	1.65
W0150_24	1.274
W0150_24	1.014
W0150_24	1.954
W0150_24	0.942
W0150_24	1.85
W0151_24	2.128
W0151_24	0.674
W0151_24	1.085
W0151_24	1.062
W0151_24	3.018
W0151_24	0.64
W0151_24	0.783
W0152_24	0.549
W0152_24	1.04
W0152_24	2.514
W0152_24	0.242
W0152_24	0.825
W0152_24	0.743
W0152_24	1.101
W0153_24	1.639
W0153_24	0.182

54

Part4_nightsummary_sleep_cleaned - Key results to look for (relevant to Canadian PA guidelines:

Output file cell heading	Explanation
SleepDurationInSpt	Total sleep duration in hours for each day; equals the accumulated nocturnal sustained inactivity bouts within the Sleep Period Time.
duration_slb_wakinghours	Accumulated sustained inactivity bouts (SIB) during the day. These are the periods we would label during the night as sleep, but during the day they form a subclass of inactivity, which may represent day time sleep or wakefulness while being motionless for a sustained period of time

e.g., W0150 slept in a range of 4.468 to 8.171 hrs per night. They also spent between 0.942 to 1.954 hours per day motionless, which could indicate naps or just lie-down periods.

55

Part4_summary_sleep_cleaned

Average of sleep data across all days for each participant

56

Part4_summary_sleep_cleaned - Key results to look for (for C24HMG):

Output file cell heading	Explanation
SleepDurationInSpt_AD_T5A5_mn	Mean duration of sleep in the sleep window across all days (using sleep parameter T5A5; explained later)
SleepDurationInSpt_AD_T5A5_sd	Standard deviation of above
duration_slb_wakinghours_AD_T5A5_mn	Mean duration of time spent in SIB (motionless) during waking hours (i.e., outside of bed) across all days
duration_slb_wakinghours_AD_T5A5_sd	Standard deviation of above

57

Part4_summary_sleep_cleaned - Key results to look for (for C24HMG):

Output file cell heading	Explanation
SleepDurationInSpt_AD_T5A5_mn	Mean duration of sleep in the sleep window across all days (using sleep parameter T5A5; explained later)
SleepDurationInSpt_AD_T5A5_sd	Standard deviation of above
duration_slb_wakinghours_AD_T5A5_mn	Mean duration of time spent in SIB (motionless) during waking hours (i.e., outside of bed) across all days
duration_slb_wakinghours_AD_T5A5_sd	Standard deviation of above

e.g., W0150 averaged 6.336 ± 1.206 hours of sleep per night

And averaged 1.342 ± 0.411 hours of sustained inactivity bouts during waking hours

58

Part 5 files:

Summarizes BOTH physical activity AND sleep data

- Part5_daysummary_MM_L40M100V400_T5A5
- Part5_daysummary_WW_L40M100V400_T5A5
- Part5_personsummary_MM_L40M100V400_T5A5
- Part5_personsummary_WW_L40M100V400_T5A5

59

Part 5 files:

- Part5_daysummary_MM_L40M100V400_T5A5
- Part5_daysummary_WW_L40M100V400_T5A5
- Part5_personsummary_MM_L40M100V400_T5A5
- Part5_personsummary_WW_L40M100V400_T5A5

"day" = data for every single day for each person (summary of all days)

"person" = average data across all days for each person

60

Part 5 files:

- Part5_daysummary_MM_L40M100V400_T5A5
- Part5_daysummary_WW_L40M100V400_T5A5
- Part5_personsummary_MM_L40M100V400_T5A5
- Part5_personsummary_WW_L40M100V400_T5A5

MM = a day is considered Midnight to Midnight (this is what we want)

WW = a day is considered as the period from Waking to Waking (so a "day" could be +/- 24 hours)

61

Part 5 files:

- Part5_daysummary_MM_L40M100V400_T5A5
- Part5_daysummary_WW_L40M100V400_T5A5
- Part5_personsummary_MM_L40M100V400_T5A5
- Part5_personsummary_WW_L40M100V400_T5A5

Acceleration thresholds for light (L), moderate (M), and vigorous activity

In this example:
L = 40 mg
M = 100 mg
V = 400 mg

These can be changed by altering base code

62

Part 5 files:

- Part5_daysummary_MM_L40M100V400_T5A5
- Part5_daysummary_WW_L40M100V400_T5A5
- Part5_personsummary_MM_L40M100V400_T5A5
- Part5_personsummary_WW_L40M100V400_T5A5

Criteria for determining sleep

T5 = threshold 5 mg
A5 = 5 degree angle

When Actigraph detects movement < 5mg and with < 5 degree change in angle, periods are classified as sleep

This can also be changed in base code but we won't

63

Part5_daysummary_MM_LXMXVX_T5A5- Key results to look for:

Output file cell heading	Explanation
dur_spt_sleep_min	Duration of the sleep window actually spent asleep in minutes per night
dur_day_total_IN_min	Total minutes of inactivity during waking hours (using threshold <40 mg) per day
dur_day_total_LIG_min	Total minutes of light activity during waking hours (using threshold 40 mg) per day
dur_day_total_MOD_min	Total minutes of moderate activity during waking hours (using threshold 100 mg) per day
dur_day_total_VIG_min	Total minutes of vigorous activity during waking hours (using threshold 400 mg) per day
dur_day_MVPA_bts_10_min	Duration of MVPA in bouts of at least 10 mins per day
dur_day_IN_bts_60_min	Duration of inactivity during waking hours in bouts of at least 60 mins per day
dur_day_LIG_bts_10_min	Duration of the day in light activity in bouts of at least 10 min per day

64

Part5_daysummary_MM_LXMXVX_T5A5- Key results to look for:

Output file cell heading	Explanation
dur_spt_sleep_min	Duration of the sleep window actually spent asleep in minutes per night
dur_day_total_IN_min	Total minutes of inactivity during waking hours (using threshold <40 mg) per day
dur_day_total_LIG_min	Total minutes of light activity during waking hours (using threshold 40 mg) per day
dur_day_total_MOD_min	Total minutes of moderate activity during waking hours (using threshold 100 mg) per day
dur_day_total_VIG_min	Total minutes of vigorous activity during waking hours (using threshold 400 mg) per day
dur_day_MVPA_bts_10_min	Duration of MVPA in bouts of at least 10 mins per day
dur_day_IN_bts_60_min	Duration of inactivity during waking hours in bouts of at least 60 mins per day
dur_day_LIG_bts_10_min	Duration of the day in light activity in bouts of at least 10 min per day

ID	dur_spt_sleep_min
W0150_24	495.75
W0150_24	373.25
W0150_24	555
W0150_24	416.667
W0150_24	459.167
W0150_24	262.167
W0151_24	477.833
W0151_24	444.417
W0151_24	401.75
W0151_24	444.833
W0151_24	399.417
W0151_24	444.083
W0152_24	476.25
W0152_24	418.583
W0152_24	147
W0152_24	544.417
W0152_24	453.167
W0153_24	467.917
W0153_24	407.25
W0153_24	437.5
W0153_24	475.667
W0153_24	428.583
W0153_24	378.917

e.g., W0150 slept 262.167 – 495.75 mins per night

65

Part5_daysummary_MM_LXMXVX_T5A5- Key results to look for:

Output file cell heading	Explanation
dur_spt_sleep_min	Duration of the sleep window actually spent asleep in minutes per night
dur_day_total_IN_min	Total minutes of inactivity during waking hours (using threshold <40 mg) per day
dur_day_total_LIG_min	Total minutes of light activity during waking hours (using threshold 40 mg) per day
dur_day_total_MOD_min	Total minutes of moderate activity during waking hours (using threshold 100 mg) per day
dur_day_total_VIG_min	Total minutes of vigorous activity during waking hours (using threshold 400 mg) per day
dur_day_MVPA_bts_10_min	Duration of MVPA in bouts of at least 10 mins per day
dur_day_IN_bts_60_min	Duration of inactivity during waking hours in bouts of at least 60 mins per day
dur_day_LIG_bts_10_min	Duration of the day in light activity in bouts of at least 10 min per day

ID	dur_day_MVPA_bts_10_min
W0150_24	22
W0150_24	55.25
W0150_24	46.333
W0150_24	0
W0150_24	0
W0150_24	70.583
W0151_24	44.75
W0151_24	0
W0151_24	16.667
W0151_24	0
W0151_24	0
W0151_24	0
W0152_24	0
W0152_24	0
W0152_24	0
W0152_24	0
W0152_24	0
W0153_24	15.5
W0153_24	0
W0153_24	0
W0153_24	0
W0153_24	0

e.g., W0150 spent 22-70 mins per day in MVPA in bouts of at least 10 mins

W0152 did no MVPA in bouts of at least 10 mins

66

Part5_daysummary_MM_LXMXVX_T5A5- Key results to look for:

Output file cell heading	Explanation
dur_spt_sleep_min	Duration of the sleep window actually spent asleep in minutes per night
dur_day_total_IN_min	Total minutes of inactivity during waking hours (using threshold <40 mg) per day
dur_day_total_LIG_min	Total minutes of light activity during waking hours (using threshold 40 mg) per day
dur_day_total_MOD_min	Total minutes of moderate activity during waking hours (using threshold 100 mg) per day
dur_day_total_VIG_min	Total minutes of vigorous activity during waking hours (using threshold 400 mg) per day
dur_day_MVPA_bts_10_min	Duration of MVPA in bouts of at least 10 mins per day
dur_day_IN_bts_30_min	Duration of inactivity during waking hours in bouts of at least 30 mins per day
dur_day_LIG_bts_10_min	Duration of the day in light activity in bouts of at least 10 min per day

	A	AF
1	ID	dur_day_IN_bts_30_min
2	W0150_24	339.167
3	W0150_24	808.5
4	W0150_24	746.833
5	W0150_24	766
6	W0150_24	650.917
7	W0150_24	770.25
8	W0151_24	74.417
9	W0151_24	542.5
10	W0151_24	898.5
11	W0151_24	855.167
12	W0151_24	348.5
13	W0151_24	82.25
14	W0152_24	377.667
15	W0152_24	584.25
16	W0152_24	498.5
17	W0152_24	352.75
18	W0153_24	354.417
19	W0153_24	741.833
20	W0153_24	298.333
21	W0153_24	540.917
22	W0153_24	304.5
23	W0153_24	496.25
24	W0153_24	343.167

e.g., W0151 spent 74 to 542 minutes inactive in bouts of at least 30 mins

67

Part5_daysummary_MM_LXMXVX_T5A5- Key results to look for:

Output file cell heading	Explanation
dur_spt_sleep_min	Duration of the sleep window actually spent asleep in minutes per night
dur_day_total_IN_min	Total minutes of inactivity during waking hours (using threshold <40 mg) per day
dur_day_total_LIG_min	Total minutes of light activity during waking hours (using threshold 40 mg) per day
dur_day_total_MOD_min	Total minutes of moderate activity during waking hours (using threshold 100 mg) per day
dur_day_total_VIG_min	Total minutes of vigorous activity during waking hours (using threshold 400 mg) per day
dur_day_MVPA_bts_10_min	Duration of MVPA in bouts of at least 10 mins per day
dur_day_IN_bts_60_min	Duration of inactivity during waking hours in bouts of at least 60 mins per day
dur_day_LIG_bts_10_min	Duration of the day in light activity in bouts of at least 10 min per day

	A	AL	AM	AN	AO
1	ID	dur_day_total_IN_min	dur_day_total_LIG_min	dur_day_total_MOD_min	dur_day_total_VIG_min
2	W0150_24	612.083	167.083	111.417	8.583
3	W0150_24	817.667	130	99.583	0.583
4	W0150_24	853.083	123.333	79.167	0.833
5	W0150_24	846.833	102.917	45	0.25
6	W0150_24	751.25	94.167	35.75	0.5
7	W0150_24	847.167	159.917	123.917	6.833
8	W0151_24	476.25	316.25	124.75	0.417
9	W0151_24	671.917	148.417	48.5	0.25
10	W0151_24	700.167	159.417	71.667	0.25
11	W0151_24	775.583	132.25	41.75	0.167
12	W0151_24	767.417	192.75	54.583	0.667
13	W0151_24	699.25	282.833	87.333	0.333
14	W0152_24	757.25	111	41	0.917
15	W0152_24	768.167	130.083	47	0.667
16	W0152_24	760	122.25	49.25	0.583
17	W0152_24	630.25	156.417	77	0.833
18	W0152_24	621.917	147.5	71.667	1.167
19	W0152_24	793.667	84.667	29.583	0.167
20	W0153_24	677.917	222.5	79.833	1
21	W0153_24	765.417	156.75	54.917	0.75
22	W0153_24	661.75	166.083	48	0.833
23	W0153_24	731.75	188.917	59.917	0.667
24	W0153_24	665.25	291.667	82.5	0.5

IMPORTANT!!!
Numbers in these columns are MINUTES per DAY. You can add these up for total minutes over the recording period.

Minutes of inactivity | Light activity | Moderate activity | Vigorous activity

68

Part5_personsummary_MM_LXMXVX_T5A5- Key results to look for:

Output file cell heading	Explanation
dur_spt_sleep_min_pla	Plain average duration of actual sleep during the sleep window across all days
dur_day_MVPA_bts_10_min_pla	Plain average duration of day spent in 10 min bouts of MVPA
dur_day_IN_bts_60_min_pla	Plain average duration of day spent in inactivity in bouts of 60min
dur_day_total_IN_min_pla	Plain average of the total minutes of inactivity during waking hours
dur_day_total_LIG_min_pla	Plain average of the total minutes of light activity during waking hours
dur_day_total_MOD_min_pla	Plain average of total minutes of moderate activity during waking hours
dur_day_total_VIG_min_pla	Plain average of total minutes of vigorous activity during waking hours

☆IMPORTANT☆

values are averages

→ numbers under these columns are the AVERAGE of all recording days.

i.e. If there are 7 days of data, the values in these columns x 7 = the sum of days from the DaySummary file

69

Base Code Results Interpretation:

- https://cran.r-project.org/web/packages/GGIR/vignettes/GGIR.html#4_Inspecting_the_results

This link takes you to where they explain what each variable means in the output .csv summary files

Also look at data dictionary

70

Sleep Regularity Index (SRI)
sleepreg package
https://github.com/dpwindred/sleepreg

71

Installation of sleepreg package

- This package currently works using GGIR version 2.0-0. If you have a different version of GGIR installed, remove and install 2.0-0:

```
remove.packages("GGIR")
```

- Delete the 'GGIR' folder on your local machine (e.g., R/win-library directory) and restart R
- Download 'GGIR_2.0-0.tar.gz' from https://cran.r-project.org/src/contrib/Archive/GGIR/
- Install GGIR 2.0-0 (replace [your directory] with directory of the downloaded tar.gz file)

```
install.packages("[your directory]/GGIR_2.0-0.tar.gz", repos = NULL, type="source")
```

- Install 'sleepreg' package' (note: during installation R will ask if you want to update GGIR - say no)

```
install.packages("devtools")
devtools::install_github("dpwindred/sleepreg")
library(sleepreg)
```

72

Appendix 4: WARM Hearts Frailty Index

Number	Domain	Tool used in WARM Hearts	Variable	Cut Offs	References	Comments
1	Physical	Hand Dynamometer	Grip Strength	[BMI ≤ 23, 1=≤ 17 kg, 0=>17 kg], [BMI 23.1-26, 1=≤ 17.3 kg, 0=>17.3 kg], [BMI 26.1-29, 1=≤ 18 kg, 0=>18 kg], BMI >29, 1=≤21 kg, 0=>21 kg]	Fried (2001)	Stratified by BMI
2	Physical	Seniors Fitness Test	Chair Stand	[Age 50-64: 1=<12, 0=≥12], [Age 65-69: 1=<11, 0=≥11], [Age 70-74: 1=<10, 0=≥10], [Age 75-79: 1=<10, 0=≥10], [Age 80-84: 1=<9, 0=≥9], [Age 85-89: 1=<8, 0=≥8], [Age 90-94: 1=< 4, 0=≥ 4]	Rikli & Jones (2002)	Stratified by Age
3	Physical	5 M Gait Speed Test	Gait Speed	[Height ≤ 159 cm - 1=≤ 0.76 m/s, 0=>0.76 m/s], [Height >159 cm - 1=≤ 0.65 m/s, 0=>0.65 m/s]	Fried (2001)	Stratified by Height
4	Physical	Seniors Fitness Test	Arm Curls	[Age 50-64: 1=<13, 0=≥13], [Age 65-69: 1=<12, 0=≥12], [Age 70-74: 1=<12, 0=≥12], [Age 75-79: 1=<11, 0=≥11], [Age 80-84: 1=<10, 0=≥10], [Age 85-89: 1=<10, 0=≥10], [Age 90-94: 1=<8, 0=≥8]	Rikli & Jones (2002)	Stratified by Age
5	Physical	Seniors Fitness Test	Back Scratch	[Age 50-64: 1=<-3, 0=≥-3], [Age 65-69: 1=<-3.5, 0=≥-3.5], [Age 70-74: 1=<-4.0, 0=≥-4.0], [Age 75-79: 1=<-5, 0=≥-5], [Age 80-84: 1=<-5.5, 0=≥-5.5], [Age 85-89: 1=<-7, 0=≥-7], [Age 90-94: 1=<-8, 0=≥-8]	Rikli & Jones (2002)	Stratified by Age
6	Physical	Seniors Fitness Test	Sit and Reach	[Age 50-64: 1=<-0.5, 0=≥-0.5], [Age 65-69: 1=<-0.5, 0=≥-0.5], [Age 70-74: 1=<-1, 0=≥-1], [Age 75-79: 1=<-1.5, 0=≥-1.5], [Age 80-84: 1=<-2, 0=≥-2], [Age 85-89: 1=<-2.5, 0=≥-2.5], [Age 90-94: 1=<-4.5, 0=≥-4.5]	Rikli & Jones (2002)	Stratified by Age
7	Physical	Seniors Fitness Test	8Ft Up and Go	[Age 50-64: 1=>6.0, 0=≤6.0], [Age 65-69: 1=>6.4, 0=≤6.4], [Age 70-74: 1=>7.1, 0=≤7.1], [Age 75-79: 1=>7.4, 0=≤7.4], [Age 80-84: 1=>8.7, 0=≤8.7], [Age 85-89: 1=>9.6, 0=≤9.6], [Age 90-94: 1=>11.5, 0=≤11.5]	Rikli & Jones (2002)	Stratified by Age
8	Physical	Seniors Fitness Test	6 Min Walk Test	[Age 50-64: 1=<498.35, 0=≥498.35], [Age 65-69: 1=<457.20, 0=≥457.20], [Age 70-74: 1=<438.91, 0=≥438.91], [Age 75-79: 1=<397.76,	Rikli & Jones (2002)	Stratified by Age

				0=≥397.76], [Age 80-84: 1=<352.04, 0=≥352.04], [Age 85-89: 1=<310.90, 0=≥310.90], [Age 90-94: 1=<251.46, 0=≥251.46]		
9	Body Comp	InBody	Fat Mass (kg)	1=<18.2 or ≥36.1, 0=18.2-36.099	Kehler (2020)	
10	Body Comp	InBody	Fat-Free Mass (kg)	1=<40.9, 0.75=40,9-<43.3, 0.50=43.3-<45.8, 0.25=45.8-<49.3, 0=≥49.30	Kehler (2020)	
11	Mood/Depression	PHQ-9	PHQ-9 Score	1=20-27 (severe), 0.80=15-19 (moderately severe), 0.60=10-14 (moderate), 0.40=5-9 (mild), 0.20=1-4 (minimal), 0=0 (none)	Kroenke (2001)	
12	Mood/Depression	"Medical Conditions"	Clinical Diagnosis of Depression/Anxiety	1=yes, 0=no		
13	Cognition	MoCA	MoCA	1= ≤ 25, 0= ≥ 26	Nasreddine (2006)	
14	Nutrition	Self Report Questionnaire	Unintentional Weight Loss	1=yes, 0=no	Fried (2001)	
15	Nutrition	Self Report Questionnaire	Decline in Food intake	1=yes, 0=no	Reber (2019)	
16	Nutrition/QOL	SCREEN II	Is biting or chewing food difficut for you?	1=Often or always, .6666=Sometimes, .3333=Rarely, 0=Never		
17	Nutrition/QOL	SCREEN II	Do you have any problems getting your groceries?	1=Always, .6666=Often, .3333= Sometimes, 0=Never or Rarely		
18	Exhaustion	CES-D	Feel everything was an effort	1=Most (3), .6666=Moderate (2), .3333=Sometimes (1), 0=Rarely (0)	Fried (2001)	
19	Exhaustion	CES-D	Could not "get going"	1=Most (3), .6666=Moderate (2), .3333=Sometimes (1), 0=Rarely (0)	Fried (2001)	
20	Quality of Life	EQ-5D-5L	Mobility	1=Extreme, 0.75=Severe, 0.50=Moderate, 0.25=Slight, 0=None	Janssen (2008)	
21	Quality of Life	EQ-5D-5L	Self Care	1=Extreme, 0.75=Severe, 0.50=Moderate, 0.25=Slight, 0=None	Janssen (2008)	`
22	Quality of Life	EQ-5D-5L	Usual Activities	1=Extreme, 0.75=Severe, 0.50=Moderate, 0.25=Slight, 0=None	Janssen (2008)	

23	Quality of Life	EQ-5D-5L	Pain/Discomfort	1=Extreme, 0.75=Severe, 0.50=Moderate, 0.25=Slight, 0=None	Janssen (2008)	
24	Quality of Life	EQ VAS	Rate Health today	1-(EQ-VAS score/100)	Janssen (2008)	
25	Comorbidities	"Medical History"	Arthritis	1=yes, 0=no	Kehler (2017)	
26	Comorbidities	"Medical History"	Sleep Apnea	1=yes, 0=no	Kehler (2017), Kehler (2020)	
27	Comorbidities	"Medical History"	Cancer	1=yes, 0=no	Kehler (2017)	
28	Comorbidities	"Medical History"	IBD	1=yes, 0=no		
29	Comorbidities	"Medical History"	Asthma	1=yes, 0=no	Kehler (2020)	
30	Lab Values	Blood Pressure	Pulse Pressure	1= <30 or >60 mmHg, 0= 30-60 mmHg	Kehler (2020)	
31	Lab Values	Heart Rate Monitor	Resting HR	1= <60 or >99 bpm, 0= 60-99 mmHg	Kehler (2017), Kehler (2020)	
32	Lab Values	Blood Draw	Glucose (Fasting)	1=<3.9 or >6.1 mmol/L, 0=3.9-6.1 mmol/L	Kehler (2017), Kehler (2020)	
33	Lab Values	Blood Draw	LDL Cholesterol	1= <0.98 or >3.36 mmol/L, 0= 0.98-3.36 mmol/L	Kehler (2020)	
34	Medications	# of Medications	# of Medications	1=≥5, 0=0-4		

BMI, *body mass index;* ***PA,*** *physical activity;* ***PHQ-9,*** *Patient Health Questionnaire-9;* ***QOL,*** *quality of life;* ***MoCA,*** *Montreal Cognitive Assessment;* ***SCREEN II****, Seniors in the Community: Risk evaluation for eating and nutrition Version II*; ***CES-D,*** *Center for Epidemiologic Studies Depression Scale;* ***EQ-5D-5L,*** *EuroQol 5-Dimension 5-Level;* ***EQ VAS,*** *EuroQol Visual Analogue Scale;* ***IBD,*** *inflammatory bowel disorder;* ***BP****, blood pressure;* ***HR,*** *heart rate;* ***HDL,*** *high-density lipoprotein;* ***LDL,*** *low-density lipoprotein;* ***PSQI,*** *Pittsburgh Sleep Quality Index.*