Reviews in Clinical Gerontology 2014 24; 239–254 First published online 27 August 2014
© Cambridge University Press 2014 doi:10.1017/S0959259814000124

Frailty in relation to sedentary behaviours and moderate-vigorous intensity physical activity

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Summary

As the mean life expectancy of the population continues to increase, the challenge for individuals is to remain healthy and fit throughout their life span. This review examines the relationships between moderate-vigorous physical activity and sedentary behaviour in relation to the fitness-frailty continuum. The association between increased physical activity and decreased adverse health outcomes is firmly established. A direct association between frailty and moderate-vigorous physical activity has been established to a lesser degree. What has some potential to undermine even these gains is the increasingly recognized relationship between sedentary behaviour and poor health. It now seems likely that sedentary behaviour can have a negative impact on an individual's health, over and above that of meeting the recommendations of moderate-vigorous physical activity. Individuals must consider both increasing their level of moderate-vigorous physical activity and minimizing their level of sedentary behaviour during all aspects of daily life.

Key words: frailty, ageing, sedentary behavior, moderate-vigorous physical activity

Introduction

As the baby boomers begin to reach 65 years of age, the demographic distribution of the world's population is changing. The World Health Organization[1] estimated that adults over the age of 65 would triple, to nearly 1.5 billion or 16% of the total world population by 2050. This increase is expected to be particularly strong in developing countries such as China and India, with projections of 330 million and 227 million over the age of 65, respectively. Whereas some seniors age successfully and meet or exceed life expectancy, many others experience a lower quality of life and a higher proportion of chronic diseases,[2–5] which inhibit their ability to function independently. For many countries, the management of these chronic diseases places a heavy burden on their healthcare systems. Another World Health Organization report concludes that chronic disease is the leading global cause of death.[6] The high incidence of chronic diseases and inability to function independently in seniors often arise in settings of high levels of frailty.[2,3,5] Frailty is long recognized as representing increased vulnerability to adverse health outcomes[7,8] and has been associated with falls, fractures and disability,[9] and poor health status;[10] as such, frailty has been established as a clear risk factor for morbidity and mortality.[11–13]

Reducing or eliminating risks, and increasing protective factors, offer some potential to reduce frailty. Levers *et al.*[14] identified age, sex, disease, social factors, economic factors, malnutrition and poor physical functioning as risk factors in frailty, with physical inactivity also being identified as the fourth leading risk factor for global mortality.[6] The association between frailty or adverse health outcomes and physical activity has focused mostly on moderate-vigorous intensity activity (e.g. exercise). Even so, there is increasing evidence of an association between high levels of sedentary behaviour (e.g. watching TV, driving) and increased frailty or adverse outcomes such as cardiovascular problems, metabolism, depression and obesity,[15–18] even in individuals who meet the recommended level of moderate-vigorous physical activity.[19]

The purpose of this paper is to review the association between frailty, moderate-vigorous physical activity (MVPA) and sedentary behaviour. We will first examine and compare how frailty has been theoretically and operationally defined, followed by recognized definitions of physical

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https://doi.org/10.1017/S0959259814000124 Published online by Cambridge University Press

activity and sedentary behaviour. We will then review the association between physical activity and frailty. While increasing moderate-vigorous physical activity appears to reduce frailty in some individuals, the novel association between increased sedentary behaviour and greater levels of frailty also merits discussion. The patterns of inactivity of older adults will be explored and preferred methods to measure both moderate-vigorous physical activity and sedentary behaviour will be summarized. Finally, we will discuss the potential implications of this association, and what future research is needed.

Search methods

For this review we utilized PubMed and MEDLINE as the primary search bases, although World of Science database, the World Health Organization website and a few other reliable websites and books were consulted as well. The initial search terms included a combination of the following terms: 'frailty', 'ageing', 'physical activity', 'MVPA', and 'sedentary behaviour.' Given the novelty of the topic to be reviewed, we did not limit the initial searches by article type, publication date or species type.

Defining and measuring frailty

Frailty is a term that has seen increasing use over the past two decades. Frail people have an increased vulnerability to adverse health outcomes, which is the result of an age-associated decline in multiple physiological systems.[7,8,20,21] The two most commonly used approaches to frailty differ in that Fried *et al.*[8] view frailty as a syndrome, while Rockwood and colleagues[20–22] see it as a state.

Fried *et al.*[8] propose a continuous cycle of frailty arising with chronic malnutrition, sarcopaenia (the loss of muscle mass and strength), poor resting metabolic rate and poor total energy expenditure. Fried *et al.*[8] suggest that there is no single cause, but instead that many different factors play a role in the emergence of each other, so that frailty can arise from any point in the cycle. The accumulation of deficits approach[22] sees frailty as a state that arises when damage (either environmental or intrinsic, the latter largely arising as by-products of metabolism) goes either unrepaired or unremoved, resulting in deficits that affect the ability to repair damage.[20,23] Frailty is thus seen as a dynamic process of deficit accumulation; these deficits arise first at a subcellular level before consequently affecting tissues, organs and function.[24,25] A wide variety of deficits are associated with frailty, so that many different stochastic pathways lead to the multiply determined state of increased vulnerability. The deficit accumulation approach likewise recognizes grades of frailty.

Both approaches recognize that frail individuals are at greater risk of adverse health outcomes such as death, disability and increased healthcare utilization, including both hospitalization and institutionalization.[8,26,27] Being able to identify who is at increased risk of adverse outcomes can be very beneficial; consequently a lot of research has focused on the operational definitions of frailty.[2,28–31] The frailty phenotype and the frailty index are the two that have generated the most consideration,[32] and are based on the syndrome *versus* state models, respectively. Other operational definitions of frailty include the Groningen Frailty Indicator,[33] the Tilburg Frailty Indicator,[34] the Clinical Frailty Scale,[35] the Edmonton Frailty Scale[36] and the FRAIL scale.[37]

The most commonly used working definition of frailty was created by Fried *et al.*[8] by evaluating the prevalence, correlation and validity of their operational definition in relation to its ability to predict adverse outcomes including worsening mobility, increased disability, increased falls, hospitalization and death. They identified five features that correspond with frailty: unintentional weight loss, low energy, slow gait, reduced grip strength and reduced physical activity. Frailty was defined as being present when any three of the five criteria were met, whereas meeting only one or two of the criteria suggested that the individual was at a higher risk of becoming frail, and was labelled as 'pre-frail'.[8] The Fried frailty phenotype, though widely cited, has also been subject to criticism, mainly on grounds of poor generalizability and limited clinical utility.[38–41] The phenotype does not include any consideration of cognition, despite a known association with functional decline.[42] An important but somewhat overlooked criticism is that the frailty phenotype may not be applicable to all individuals at increased risk. In the cohort in which the phenotype was determined, Fried *et al.*[8] excluded individuals with moderate to severe cognitive impairment, those

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with a history of Parkinson's disease or stroke as well as those taking anti-depressants; thus there is some uncertainty surrounding the generalizability of the frailty phenotype to those individuals.[43] Although the phenotype can identify those who are at high risk of becoming frail, it discriminates less well between those who are fit and those who are at lower or moderate risk of becoming frail[44,45] and excludes many people who cannot participate in performance testing, but who remain at higher risk.[46,47]

In the frailty index, proposed by Rockwood and Mitnitski,[20,22,48] health deficits are counted, so that the higher the number of deficits relative to all deficits considered, the more frail the individual.[49,50] Since its introduction in 2001, multiple groups around the world have used frailty indexes, constructed with a variety of different deficits[11,51–55] that are counted (and variably include disability items). Notably, the original frailty index meets a number of properties that appear independent of its construction. For example, as long as key criteria are met (see below) the frailty index has a characteristic distribution in community-dwelling samples (skewed, with a long right tail)[56] and in clinical samples (closer to a normal distribution).[57] Similarly, at any age, the mean values of the frailty index are higher in women than in men, whereas for any given level of the frailty index, mortality is higher in women.[58] The reproducibility of frailty across different frailty indexes suggests that the number of deficits present, perhaps even more than their nature, is key, at least at the group level. While one study considers 40 variables for a frailty index, a separate study can consider 60 different variables and would yield similar frailty index findings. The frailty index is considered to be both a sensitive measure of frailty as well as a reliable predictor of poor health outcomes.[59,60] The graded frailty index allows for dose–response relationships to be evaluated.[61,62] The greatest strengths of the frailty index are its ability to be created for nearly any dataset and the mathematical properties. Note that the frailty index has also been used to quantify the health of younger populations as early as 20 years of age.[56]

Searle *et al*.[50] outlined a standard protocol for creating a frailty index for any dataset. The frailty index is calculated as a ratio of deficits present out of the total number of possible deficits, giving a continuous score from total fitness to total frailty. For example, if 50 deficits are considered in a given frailty index and a patient has 10, the person will have a frailty score of 0.2. Five criteria should be satisfied for a deficit to be included in a frailty index: the deficit should be related with health status, the deficit should become more prevalent with increasing age, the deficit should not saturate too early, the deficits should cover a range of systems and finally if a frailty index is to be compared for the same individual, the deficits used should be the same.

Ideally, a minimum of 30 to 40 variables should be included in the frailty index;[5,27,50] the more variables included, the more precise the score will be.[50] It is not yet known if there is an upper limit or an optimal number of variables to be included. The overall validity and reliability of the frailty index is shown in its ability to predict death, health status, chronic disease outcomes, health decline and healthcare utilization.[20,27,63,64]

Defining physical activity and sedentary behaviour

As frailty is often associated with a loss of physical resiliency,[29] this is an avenue relevant to prevention that warrants pursuit. Before pursuing this, it is important to define the constructs. *Physical activity* is defined as 'any bodily movement produced by skeletal muscles that requires energy expenditure',[6] and can be differentiated by both type and intensity. Exercise, leisure activity and occupational activity are all examples of types of physical activity. *Exercise* is physical activity that is planned or structured with the objective of increasing or maintaining physical fitness.[65] Energy expenditure is often measured in METs or metabolic equivalents, as a measure of how hard the body is working. The more strenuous the activity is, the more oxygen the body must use for energy and thus the higher the MET level. A MET level of 1.0 is considered to be the reference level of an individual at rest.[66] Vigorous intensity activity refers to physical activity in which the individual exerts 6 METs or more. *Vigorous intensity* activities include running, swimming, bicycling >10 km/h, and hiking uphill among others.[67,68] *Moderate intensity* activity refers to physical activities in which the individual exerts between 3 and 6 METs, such as brisk walking, water aerobics, bicycling <10 km/h or gardening.[67,68] Finally, *light intensity* activity refers to physical activities in which the individual exerts between

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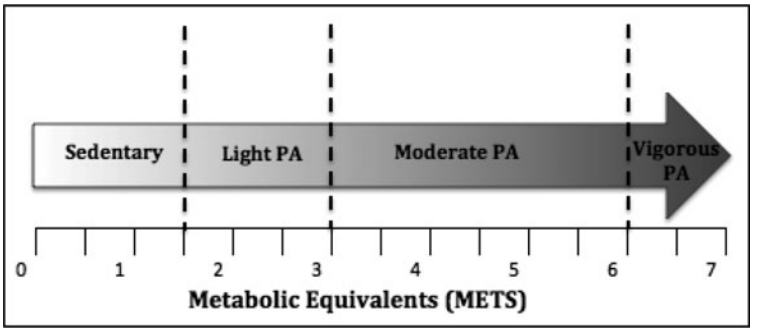


Figure 1. The energy expenditure continuum

1.5 and 3 METs; examples of this are light walking, stretching, fishing or leisurely sports such as table tennis or playing catch.[67,68] Please refer to Figure 1.

The definition of *sedentary behaviour* has been contradictory in the literature and as a result, measurement of sedentary behaviour has been inconsistent. Operationally, sedentary behaviour has been defined as any waking activity characterized by an energy expenditure of less than 1.5 METs in a sitting or reclining position.[68–72] Common sedentary behaviours include watching TV, driving, screen time (video games, computers), and reading; essentially, anything done awake while sitting or lying down.[68] In the past, a number of studies have misconstrued sedentary behaviour – mostly defining it as a mere lack of moderate to vigorous activity.[73,74] For example, past research has defined sedentary behaviour as levels of activity that fail to achieve the levels of moderate or vigorous physical activity,[75] or those spending less than 2000 kcal/week through walking, climbing stairs and playing sports.[76]

Associations between physical activity and frailty

Physical inactivity was identified by the World Health Organization as the fourth leading risk factor for global mortality, after high blood pressure, tobacco use and high blood glucose.[6] There has also been a great deal of evidence surrounding its protective health benefits in the maintenance of physical resiliency.[4,77–79] Whereas lack of physical activity is known to be one of the major sources that lead to disability,[2,5,80,81] there is also evidence of an inverse association between physical activity and frailty. Cruz-Jentoft *et al.*[82] demonstrated that physical activity could help slow down the age-related decline of muscle strength and muscle mass associated with frailty. Physical activity was also found to be inversely associated with other components of frailty including physical disability,[83–88] cognitive impairment,[89,90] and depression.[91,92] Peterson *et al.*[93] examined the longitudinal relationship between physical activity and frailty, suggesting that physical activity had an independent, preventative effect against frailty as a whole; this effect held true for both sexes and all ages. Despite this evidence on the positive impact of physical activity interventions on frailty, causality has yet to reliably established.[94–96]

The recommendation that physical activity is beneficial for one's health is not novel; it has been repeatedly suggested for decades.[87,97–101] The Canadian Physical Activity Guidelines (CPAG) report that health benefits can be achieved by adults, aged 18 and older if they accumulate at least 2.5 hours of moderate to vigorous physical activity each week, in bouts of 10 minutes or more.[102] A study by Hubbard *et al.*[103] found that at 5-year follow-up, older adults who exercised were more likely to improve their health status than those who did not. Hubbard *et al.*[103] also found that the more frail one was at baseline, the more likely they were to yield greater benefits. This relationship remained across all levels of frailty, suggesting the potential impact of exercise at the population level. Although it has been reported that greater health benefits can be obtained if the physical activity is of longer duration or more vigorous intensity,[86,88,97] other studies have demonstrated that benefits can still be elicited with low to moderate activities.[88] The benefits of engaging in moderate-vigorous physical activity during daily

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life are well established, whereas the evidence on the importance of light activities and the harm of sedentary behaviours is limited.

Associations between sedentary behaviour and health

Research studies have examined the effect of sedentary behaviour on a wide range of health domains such as body mass composition, cardiovascular disease, cancer and psychological disorders. Sedentary behaviour is recognized as a risk factor for poor health, morbidity and mortality.[15,17,18,104] The odds of weight gain was higher in people whose daily sitting time was 8 hours or more per day compared with those who sat for less than 3 hours.[105] Similarly, a cross-sectional study demonstrated that the odds of being obese increased as weekly hours of TV viewing time increased.[106] TV viewing time and objectively measured sedentary behaviour with physical activity monitors were both found to be associated with abnormal glucose tolerance,[18,107] increased cardio-metabolic risk,[108,109] metabolic syndrome[107] and an increased risk of type 2 diabetes.[110,111] Increased risk of endometrial cancer in women and colon cancer in men were associated with high levels of TV watching,[112,113] increased daily sitting time[113] and self-reported levels of sedentary behavior.[114] Finally, a linear relationship was found between a sedentary index and the risk of developing a mental disorder.[115]

The relationship between sedentary behaviour and poor health outcomes persists even after controlling for moderate-vigorous activity. Camhi *et al.*[116] suggested that higher levels of sedentary behaviour were associated with increased cardio-metabolic risk factors. Similarly, Healy *et al.*[19,117] found an association between high levels of sedentary behaviour and increased waist circumference, metabolic risks and risk for type II diabetes. Sedentary behaviour and all-cause mortality, independent of moderate-vigorous activity, have been found to be significantly associated in a population of men and women aged 45 to 75 years.[118] One study proposed the 'Active Couch Potato' phenomenon in which there was a strong, significant dose–response association between TV watching time and waist circumference, systolic blood pressure and diabetes risk in a sample of men and women who reported at least 150 min a week of moderate-to-vigorous intensity physical activity – meeting the suggested guidelines.[19]

Despite an abundance of research evaluating the effect of sedentary behaviour on an array of health outcomes, there is considerably less research on the effect of sedentary behaviour on ageing and especially on frailty. Sedentary behaviours are particularly common in older adults, with evidence that older adults are the most sedentary age group.[119,120] In the 2003–2004 iteration of NHANES, the number of waking hours spent daily in sedentary behaviour increased in each 10-year age group from 7.24 hours at age 30–39, eventually reaching 9.28 hours at age 70–85.[119] Dogra and Stathokostas[121] suggested that amongst 45- to 64-year-old adults, those who were least sedentary were 43% more likely to age successfully than those who were most sedentary. This association was found to have a dose–response relationship in older adults, aged 65 and above; those who were moderately sedentary were 38% more likely to age successfully and those who were least sedentary were 43% more likely. A short-term association between decreasing sedentary activity and decreasing frailty has been proposed,[122] with moderate evidence suggesting that exercise interventions and reduced sedentary behaviour can be used to either improve or maintain physical function and independence in frail, older adults.[94–96,123,124] The American College of Sports Medicine (ACSM) suggest that increasing physical activity may be more beneficial for frail people than any other intervention;[94,96,125,126] however, no recommendation currently exists about decreasing sedentary behaviour.

There is little information about the temporal relationship between sedentary behaviour and frailty. The Health, Aging and Body Composition study followed the physical activity of an older cohort for 5 years.[93] Exercise activities were independently associated with delaying the onset and progression of frailty. Even so, there was no association between differing amounts or intensities of physical activity and the odds of transitioning to frailty,[93] suggesting that any level of activity and thus reduction of sedentary behaviour could decrease the odds of becoming frail. This finding is particularly important for older and frailer individuals, who might not necessarily be able to participate in vigorous physical activities. Of note, however, the study relied on self-reports of physical activity, which

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has been criticized.[127–129] Furthermore, the use of a phenotypic definition of frailty does not allow the degree of frailty to be graded, and thus there was no observation of a dose–response relationship.

Patterns of physical activity

The positive relationship between physical activity and health has resulted in increases in physical activity-related consumerism.[130–132] In 2012, the global health and fitness club industry alone generated nearly 76 billion US dollars.[132] Global health and wellness sales are expected to reach a record high of US $1 trillion by 2017.[131] The number of fitness and health clubs in the United States increased from 26,830 in 2005 to 30,500 in 2012. These numbers are expected to rise further as shown by the increase in the number of fitness memberships from 41.3 million in 2005 to 50.2 million in 2012.[132]

Even so, the relationship between fitness club membership and population physical activity is not clear: the latter appears to have decreased.[133] The reduction in overall physical activity has been associated with an increased number of health problems and the obesity epidemic.[104] For many reasons, the decrease in many types of physical activity has been associated with an increase in sedentary behaviours.[104,134,135] This combination is thought to be due to the transition from work-related physical labour to more sedentary, desk-bound jobs,[134] the conversion from physical domestic chores to labour-saving technology in the home,[135] the availability of motorized travel as opposed to previous non-motorized travel[134] and finally the shift from physical leisure activities to passive entertainment such as TV, computers or other electronic devices.[104] The rate of physical activity in Americans has decreased by approximately 8.5% from 1955 to 2005.[105] A UK National Travel Survey reported that the average person now walks 304 km each year; this is 106 km less than the average 25 years ago.[136] This decrease in walking probably parallels an increase in sedentary behaviour. James et al.[137] reported that urbanization in China has reduced daily energy expenditure by up to 600 calories over the past 40 years.

Whereas some individuals participate in very little physical activity overall, others demonstrate both high levels of moderate-vigorous physical activity and high levels of sedentary behavior.[138] Many individuals engage in 30–60 minutes of vigorous physical activity once a day while remaining largely sedentary otherwise.[18,139] Figure 2A demonstrates a typical daily pattern of sedentary behaviour in which the individual engages in purposeful exercise upon waking before participating in more than 15 hours of sedentary behaviour. This includes sitting for meals, transportation to and from work, sitting at a desk at work and watching TV or some other form of evening relaxation.[69] Figure 2B demonstrates a typical daily pattern of an active individual, one who does not participate in moderate-vigorous activity, yet remains active throughout the course of the day by walking to and from work, working an active job such as groundskeeper, nurse or carpenter and through active relaxation-playing with children or going for a light walk.

Measuring physical activity and sedentary behaviour

Studies have differed in their measurement of physical activity and sedentary behavior – both objective and subjective measures have been used and there are differences within these two categories as well. Studies that used subjective questionnaires to examine the benefits of physical activity asked individuals to report on their engagement in various activities – mainly higher intensity activities. These questionnaires did not include questions about light activities such as cooking or washing dishes or questions about sedentary behaviours such as watching TV and reading.[66] This approach to the measurement of sedentary behaviour and physical activity could lead to misclassification bias. For example, one person could engage in sedentary behaviours for 20% of the day and in light activities for the other 80% (similar to the pattern described in Fig. 2B); whereas another person could engage in sedentary behaviour for 75% of the day, in light activities for 20% of the day and finally in moderate-vigorous physical activity for the remaining 5% (similar to the pattern described in Fig. 2A). A questionnaire that only includes moderate-vigorous activities could wrongly classify the first individual as sedentary and the second as active. Further, if the total METs of these people

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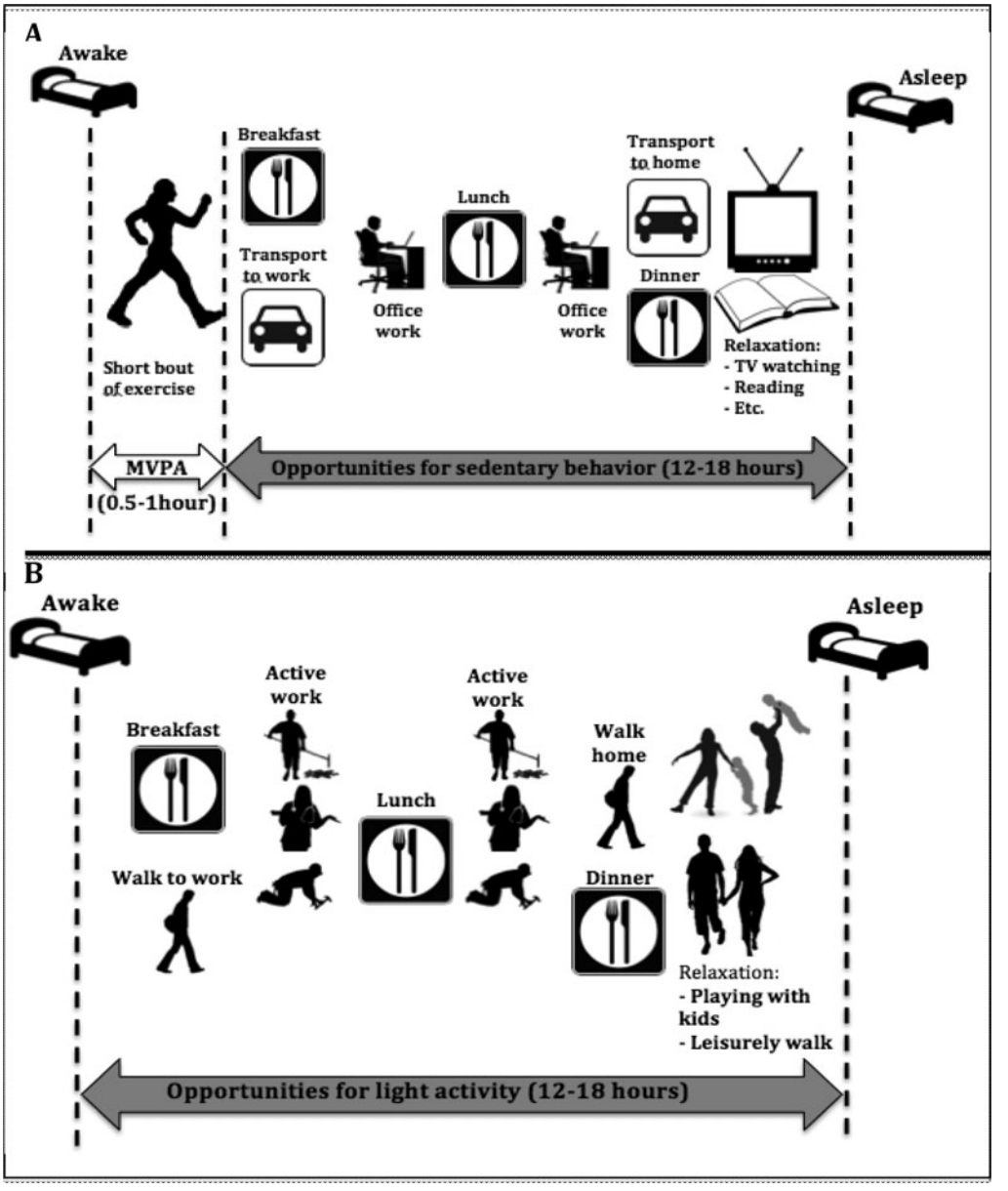


Figure 2. A, daily pattern of sedentary behaviour opportunities and their distribution over the day; B, daily pattern of light behaviour opportunities and their distribution over the day.

were calculated, the first person would be likely to have the higher daily energy expenditure.[66]

To avoid misclassification in the exposure, sedentary behaviour needs to be defined and measured.[18,70,73,139] As detailed above, an individual who is sedentary is not to be confused with an individual who does not meet the physical activity guidelines or more specifically, who performs insufficient amounts of moderate to vigorous activity.[68] Self-report of sedentary behaviour has been widely used to measure sedentary behaviour, due to its feasibility and low

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cost. Some studies simply ask subjects to report the duration of a sedentary behaviour such as watching TV,[19,75,108,140] whereas other studies have used questionnaires developed to estimate levels of sedentary behaviours such as the 7-day Sedentary and Light Intensity Physical Activity Log[141] or the Sedentary Behaviour Questionnaire.[142] Levels of one specific type of sedentary behaviour such as TV watching, talking on the phone, lying on the couch or driving to work are often generalized to represent sedentary behaviour as a whole.[18,19,105–108,110,111,113,140,143–146] Although sedentary behaviour does encompass these activities, one behavioural measure alone does not comprehensively assess sedentary behaviour throughout the day. Technology-related sedentary behaviours such as TV watching or computer use are the most commonly used measures of sedentary behaviour. Although TV viewing is the most prevalent sedentary behaviour, with the average American watching 2.8 hours per day, this constitutes less than 50%[147] of the time spent in a sedentary state. In consequence, more than 50% of sedentary behaviour would not be accurately captured if TV watching were used as a proxy measure for sedentary behaviour.[148] Measures like reading, lying on the couch, driving to work, etc. contribute to total sedentary behaviour even less than TV watching and thus may be even less reliable than TV watching as a proxy for sedentary behaviour.

Using questionnaires to measure physical activity and sedentary behaviours has proven limitations. Klesges *et al.*[149] discovered that subjects specifically tended to underestimate their level of sedentary behaviour and overestimate their aerobic activities by nearly 300%. In addition, there is not always coherence between self-reported and objectively measured sedentary behaviour using physical activity monitors such as accelerometers. Self-reports of physical activity in the NHANES dataset indicated that 60–63% of US adults between the age of 60 and 69 met the minimum US recommendations of physical activity.[150,151] However, objectively measured physical activity, using accelerometers, in the same dataset, indicated that only 9–26% of the designated population met the recommendations.[151,152] In short, self-report data may overestimate levels of physical activity; many factors could play a role in this. Self-report bias is thought to contribute,[153,154] as subjects may intentionally provide false reports. There has also been evidence that sex[155] and weight can impact self-reporting of physical activity.[156] Difficulty recalling activities, cultural differences in interpretation and human error can influence self-reporting as well.[129]

Accelerometers have emerged as useful instruments to measure levels of physical activity and sedentary behaviours. They provide an objective, reliable and accurate measure that overcomes many of the limitations of self-reported data.[157–161] Accelerometers measure the acceleration of an individual in specified planes[151] and can be used to describe how often and how long someone is sedentary in addition to the intensity, duration, frequency and patterns of movement.[102,162] Accelerometers have been used to measure physical activity and sedentary behaviours in both young[163] and older adults[164,165] and have consistently demonstrated a high degree of reliability in their measurement of physical activity, with very little variation over time.[163,166] Gardner and Poehlman[167] compared physical activity assessed by an accelerometer with doubly labelled water, the reference standard measurement of physical activity; the two measurements were highly correlated with an R of 0.83 and a P-value of less than 0.001. Doubly labelled water involves the ingestion of water labelled with isotopes of hydrogen and oxygen; as the body consumes energy, carbon dioxide and water are produced. Measuring these levels allows the exact total energy expenditure to be calculated.[168]

Compared with other measures of physical activity such as self-report[169,170] and heart rate measurements,[171,172] accelerometers have been found to be more sensitive to the actual level of physical activity of the individual. The ongoing development of accelerometers has resulted in increased battery life and decreased cost leading to increased feasibility for use in epidemiological studies.[117,119] Accelerometers can be worn around the wrist,[173] thigh[174] or preferably the waist.[102,173] A 7-day accelerometer wear period is recommended in order to obtain reliable estimates of average behavior,[175] although others have suggested that a 5-day wear period is sufficient in older adults to obtain an accurate measure of average daily sedentary time.[176] While accelerometers can capture so many different aspects of physical activity, they remain limited by their inability to capture the full energy expenditure

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of activities such as walking, lifting weights or walking on an incline, as acceleration does not change under these conditions.

Conclusions and future perspectives

Research on sedentary behaviour and adverse health outcomes is growing, and understanding how these relate to frailty is an emerging area of investigation. The association between frailty and sedentary behaviour needs to be confirmed, and the direction(s) of any temporal relationship should be evaluated. To demonstrate the association between sedentary behaviour and frailty requires first that reliable measures of the two constructs must be used. Measurement of sedentary behaviour is diverse and has not always been reliable, ranging from self-reports of TV watching and physical activities to accelerometer data. Studies that have examined the effect of physical activity or sedentary behaviour on frailty state have yet to use a consistent and reliable measure of frailty; many studies have used non-validated frailty definitions,[96,125,177–179] while others have employed operational definitions of uncertain measurement properties.[180–184]

Additional research to confirm the effect of sedentary behaviour on frailty, independent of moderate-vigorous physical activity, has the potential for important public health implications. Healthcare professionals, national recommendations and society in general should not just be emphasizing the benefits of exercise (moderate-vigorous physical activity); rather the benefits of light activity should be considered as well. This is of particular importance in the technological age as more and more individuals spend increasing portions of their day and life in a sedentary state. Although the increase in sedentary desk jobs appears to be inevitable, modifications in workplaces and office spaces have the potential to help counter the problem of sedentary behaviour. Despite the dangers of bed rest being long recognized,[185] elderly patients are often inadequately mobilized in hospital and long-term care settings. Furthermore, societies should consider various ways in which the environment can support and promote physical activity. Decreasing sedentary behaviour and increasing moderate-vigorous physical activity has the potential to be an easy, cost-effective, feasible lifestyle change that would encourage healthy ageing, decrease frailty, decrease chronic disease and decrease healthcare utilization.

Financial support

KR is supported by an operating grant from the Canadian Institutes of Health Research and receives funding from the Dalhousie Medical Research Foundation as Kathryn Allen Weldon Professor of Alzheimer Research. OT is supported by a Banting Postdoctoral Fellowship.

Conflict of interest

KR is investigating possible avenues to commercialize a version of the Frailty Index based on a Comprehensive Geriatric Assessment.

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