Are steps per day enough? Quality versus quantity of ambulatory behavior after a light-intensity physical activity intervention for older cancer survivors.

Elizabeth Michaela Harding

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Are steps per day enough? Quality versus quantity of ambulatory behavior after light-intensity physical activity intervention for older cancer survivors.

BY

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DISSERTATION

Submitted in Partial Fulfillment of the

Requirements for the Degree of

Doctor of Philosophy

Physical Education, Sports, and Exercise Science

Department of Health, Exercise, and Sport Sciences

The University of New Mexico

Albuquerque, New Mexico

July, 2019
DEDICATION

This dissertation is dedicated in loving memory to my father R. Michael Harding, whose love and generosity have provided me with the opportunity to further my education - in academia and in life.
I would like to extend my sincerest gratitude to the members of my dissertation committee, Drs. Ann Gibson, Micah Zuhl, Huining Kang and Cindy Blair for their guidance and support during this dissertation process. I would like to thank Dr. Ann Gibson for guiding me throughout my entire PhD journey and for demonstrating unwavering support in my academic endeavors. I would also like to thank Dr. Micah Zuhl for his reassurance and keen insights that have only served to further ignite my passion for exercise science. I would also like to express my sincerest appreciation to Dr. Huining Kang - a fantastic teacher, who has taught me many valuable lessons in statistics, including, “If a simple test will work, use a simple test”. I especially want to thank Dr. Cindy Blair for her time, patience, encouragement and mentorship throughout this endeavor.

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This dissertation would not have been possible without the love and support from my friends and family. I would like to extend a special thanks to my dearest friend and mentor, Dr. Kimberly Page, for the valuable lessons in work-life balance and for
listening, offering me advice, and supporting me throughout each step of this process. I would like to thank my mother whose unending love and support has proved constant throughout all of my life-adventures. And lastly, to my partner John, who makes every day better.
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By

Elizabeth M. Harding
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ABSTRACT OF DISSERTATION

Physical activity and exercise are powerful means by which to preserve physical function, and stave off mobility loss, morbidity and mortality. Historically, physical activity (PA) interventions have been structured around the national guidelines for PA and exercise. However, some populations such as older adults and those with chronic disease and mobility limitations may find these recommendations too rigorous or daunting. Consequently, they tend to spend more time engaged in sedentary behaviors that further exacerbate the already detrimental effects of age and chronic disease. PA interventions that serve to bridge the gap between sedentary behavior and exercise are needed as our population ages and more individuals are suffering the effects of, and living longer with, diseases that can potentially reduce their quality of life and affect their ability to live independently. The MY Health Study was a randomized controlled trial targeting sedentary behavior (SB) among older cancer survivors and was designed to break up SB with light intensity physical activity such as standing and light stepping. The goals of the MY Health study were to 1) increase average daily steps by 3000 above baseline and 2) break up sedentary behavior approximately 1-2 times per hour during
most waking hours. There were no specific recommendations as to the intensity or duration for which participants were to achieve these goals. This was a secondary analyses, the purpose of which was to evaluate the effectiveness of the intervention on improving free-living walking cadence and time spent engaged in ambulatory activities associated with purposeful movement and higher intensity walking. Despite results suggesting that the majority of participants within the Intervention group did not increase their average daily steps above 3000 (median increase: 976; IQR: -388-3532), there is evidence suggesting that, compared with controls, participants within the Intervention group self-selected to walk faster, thereby increasing their intensity of ambulation. These findings may have important clinical implications as both duration (quantity of physical activity) and intensity (quality of ambulation) have shown to offer cardioprotective and other health-related benefits.
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%: percent
Δ: change
±: plus or minus
 <: less than
>: greater than
~: approximately
≤: less than or equal to
≥: greater than or equal to
ACSM: American College of Sports Medicine
ADL: Activities of daily living
BMI: Body mass index
FACIT: Functional Assessment of Chronic Illness Therapy
FHS: Framingham Heart Study
GPS: Global Positioning System
HLPA: High-light intensity physical activity
Hz: Hertz
IC: Intermittent claudication
IQR: Interquartile range
LLPA: Low-light intensity physical activity
LPA: Light-intensity physical activity
m/s: Meters per second
METs: Metabolic equivalents (≈ 3.5 ml O₂/kg/min)

MPA: Moderate-intensity physical activity

MVPA: Moderate-to-vigorous intensity physical activity

NMTR: New Mexico Tumor Registry

PA: Physical activity

PF: Physical function

QoL: Quality of life

SB: Sedentary behavior

REE: Resting energy expenditure

RMR: Resting metabolic rate

SF-36: Short form 36

SF-36-PF: Short form 36, physical function sub-scale

STS: Sit-to-stand transitions

SPPB: Short physical performance battery

VPA: Vigorous-intensity physical activity

Yrs: Years
Chapter 1

Introduction

Overview

As of 2018, there were over 15 million cancer survivors in the United States, a number projected to reach close to 20 million over the next ten years (Bluethmann, Mariotto, & Rowland, 2016). Cancer is highly associated with aging as 62% of cancer survivors are 65 years and older (Bluethmann et al., 2016). Early detection and improved treatment have led to an increase in cancer survivorship, but older cancer survivors are faced with a special set of challenges as many are living with multiple comorbidities in addition to age related health factors such as deficits in physical function (PF) (Deimling, Arendt, Kypriotakis, & Bowman, 2009; Weaver et al., 2016). This may exacerbate the already detrimental effects of cancer and cancer treatments and can have a negative impact on their health-related quality of life (QoL) (Sogaard, Thomsen, Bossen, Sorensen, & Norgaard, 2013). Furthermore, older adults who attain low levels of daily physical activity (PA) and high levels of sedentary behavior (SB) are more likely to experience mobility deficits and functional limitations than their active counterparts, the consequences of which increase the risk of long-term disability, morbidity and mortality (den Ouden, Schuermans, Arts, & van der Schouw, 2011; Dunlop et al., 2015; Onder et al., 2005; Sweeney et al., 2006).

Older cancer survivors and sedentary behavior

The physiological mechanisms responsible for the negative effects of SB are distinct from too little PA, and older adults and older cancer survivors spend more time
engaged in sedentary activity than their younger and healthier counterparts. The average older American adult (≥ 60 years) spends approximately 60% of their waking hours engaged in SB (Matthews et al., 2008). Analyses from the National Health and Nutrition Survey (NHANES) from 2003 showed that the proportion of daily inactivity is even greater in breast and prostate cancer survivors amounting to approximately 68% and 68.5% of waking hours, respectively (Lynch, 2010). SB refers to activities spent in a seated or lying position with an energy expenditure ≤ 1.5 METs (Mansoubi et al., 2015; Tremblay, Colley, Saunders, Healy, & Owen, 2010). A metabolic equivalent is a multiple of resting energy expenditure (REE) and is roughly equivalent to the energy cost of sitting quietly (~3.5 mLO₂/kg/min). The Compendium of Physical Activities published in 1993 and updated in 2000 and 2011 by Ainsworth et al. lists MET values associated with activities and activities of daily living (ADL) (Ainsworth et al., 2011; Ainsworth et al., 1993; Ainsworth et al., 2000). The Compendium of Physical Activity was designed as a coding structure for observational research, a way to catalog and compare self-report physical activity data from participant logs and surveys (Ainsworth et al., 2011). The Compendium was never intended to be a guide for physical activity or exercise prescription. One concern is that resting metabolic rate (RMR) declines with age and can be lower in overweight or obese individuals which could lead to an overestimation of MET values for some activities (Ainsworth et al., 2011; Kozey, Lyden, Staudenmayer, & Freedson, 2010). This highlights the importance of customizing PA and exercise prescription to an individual’s characteristics and abilities. It also stresses the importance of more tailored research investigating the average daily energy expenditure of activities and ADL performed by older populations and populations with deficits in physical
function; as certain activities classified in the Compendium may not accurately reflect the relatively lower intensities at which older populations ambulate. Hekler et al. addressed this issue through reevaluation of the Community Healthy Activities Model Program for Seniors (CHAMPS) questionnaire that measures self-reported physical activities appropriate for and common to older adults. The authors suggested several changes in the classification of certain activities. For example, instead of a MET value of 8.0 for singles tennis, as reported in the 2000 Compendium of Physical Activities (Ainsworth et al., 2000), the authors recommend a MET value of 6.0 to reflect a lower physical exertion exhibited by older populations (Hekler et al., 2012). Table 1 outlines the estimated metabolic equivalent values (METs) associated with intensities of physical activity and inactivity for older adults in line with the recommendations by Hekler et al. For reference, a sedentary activity (i.e. watching television) has a MET value equal to 1.0 METs whereas a moderate-to-vigorous intensity physical activity (MVPA) such as brisk walking is defined as ≥ 3 METs. In general, older adults are less physically active than their younger counterparts, and those who do spend a comparable amount of time engaged in PA and leisure-time pursuits tend to participate in recreational activities of a lower intensity (≤ 2.9 METs) such as golf, slow-walking, or gardening. This is in contrast to younger adults who may tend to participate in higher intensity activities (≥ 3.0 METs) such as high intensity aerobic activities, or running.

Current physical activity recommendations

It is the current position stand of the American College of Sports Medicine (ACSM) that all adults can gain some benefit from any amount of PA and that “some physical activity is better than none” (Chodzko-Zajko et al., 2009).
Table 1. MET values for commonly used physical activity intensity classifications.

<table>
<thead>
<tr>
<th>Intensity</th>
<th>MET Values a</th>
<th>Examples of common physical activities (associated MET values)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quiet Inactivity</td>
<td>1.0</td>
<td>Lying or sitting quietly watching television (1.0)</td>
</tr>
<tr>
<td>Sedentary</td>
<td>&lt; 1.5</td>
<td>Sitting or quiet lying activities such as listening to music or watching a movie in a theater; reclining while talking on the phone (1.0)</td>
</tr>
<tr>
<td><strong>Light</strong></td>
<td>1.5-2.9</td>
<td></td>
</tr>
<tr>
<td>Low-Light</td>
<td>1.5-2.0</td>
<td>Arts &amp; crafts, playing cards (1.5); sitting, talking or talking on the phone (1.5); typing on a computer (1.5); standing, talking on phone (1.8) ; walking slowly around home, store or office (2.0)</td>
</tr>
<tr>
<td>High-Light</td>
<td>2.1-2.9</td>
<td>Volunteer work (2.3); light house-work (2.5); light gardening (2.3); leisurely walking (2.5); yoga or Tai Chi (2.5)</td>
</tr>
<tr>
<td>Moderate</td>
<td>≥3.0 - 5.9</td>
<td>Heavy housework (3.0); brisk walking (3.5); heavy yard work (4.0)</td>
</tr>
<tr>
<td>Vigorous</td>
<td>≥ 6.0</td>
<td>Walking or hiking up-hill (6.0); singles tennis (6.0); stair-step machine (7.0)</td>
</tr>
</tbody>
</table>
Historically, programs addressing the needs of an older adult population have incorporated structured PA at a moderate-to-vigorous intensity. These include walking programs and facility-based exercise regimens that incorporate multiple exercise modalities in line with the World Health Organization and the ACSM guidelines (Beauchamp et al., 2015; Kruger, Buchner, & Prohaska, 2009; Rejeski et al., 2013; Rejeski et al., 2005; Santanasto et al., 2017). The ACSM recommends 150 minutes per week of moderate-intensity PA (MPA), or 75 minutes of vigorous-intensity PA (VPA), or a combination of both for healthy adults of all ages (2018). In addition to exercise prescriptions for cardiorespiratory fitness, current recommendations include guidelines to encourage musculoskeletal and neuromotor fitness (e.g. balance) (Garber et al., 2011). Cancer survivors are encouraged to adhere to these same guidelines with the caveat that although exercise during and after cancer treatment has been deemed safe, limitations associated with certain types of cancers should be taken into consideration (Wolin, Schwartz, Matthews, Courneya, & Schmitz, 2012).

Interventions targeting physical activity in older populations and older cancer survivors have centered on structured moderate-to-vigorous physical activity (MVPA). This is likely due to the strong evidence supporting the relationship between MVPA and improvements in health-related outcomes (Daum, Cochrane, Fitzgerald, Johnson, & Buford, 2016; Fielding et al., 2017; Rejeski et al., 2005; Tudor-Locke et al., 2014). For those individuals with time or health constraints, the ACSM suggests three 10-minute bouts of MVPA spread throughout the day, most days of the week, in lieu of a single 30-minute bout of MVPA. However, it has been demonstrated that even shorter bouts (i.e.
seven 30s intervals) of high-intensity physical activity (≥ 85% maximal heart rate) performed three times per week can lead to improvements in cardiorespiratory fitness, lower body strength and waist circumference in sedentary cancer survivors (mean age of 51 ± 12 years) (Toohey et al., 2018). However, what has yet to be determined is whether or not frequent, short bouts of LPA or MPA performed throughout the day can result in similar benefits, especially in populations with reduced physical capacity. Although there are numerous benefits associated with MVPA, structured exercise at a moderate-to-vigorous intensity may be too daunting or rigorous for certain populations. It is possible that interventions promoting a reduction in SB and replacement of SB with LPA may bridge the gap between sedentarism and structured exercise programs. Simply instructing participants to “move more throughout the day, every day”, could possibly prove an effective solution at attenuating functional decline and mobility loss in older cancer survivors.

There have been few interventions investigating the effects of breaking up SB with bouts of LPA in older individuals (Gardiner, Eakin, Healy, & Owen, 2011) and there is limited evidence as to the health benefits of LPA with regards to reducing or reversing the physiologic decline observed in aging, disuse and disease. However, a relationship between LPA and QoL, cognitive and emotional well-being, and maintenance of mobility throughout later life has been observed in cross-sectional and longitudinal studies (Johnson et al., 2016; Stubbs, Chen, Chang, Sun, & Ku, 2017; Van Roekel et al., 2015). Furthermore, time substitution (isotemporal) statistical models in which reallocation of SB to LPA suggest health benefits (Grgic et al., 2018). For example, in a longitudinal study of 851 Swedish adults ≥ 50 years, reallocation of 30 minutes of SB with 30 minutes
of LPA suggested a reduction in all-cause mortality risk of 11%. This same analysis also suggested a 24% and 14% reduction in risk for cardiovascular disease and cancer mortality, respectively (Dohrn, Kwak, Oja, Sjostrom, & Hagstromer, 2018). Isotemporal substitution methods applied to cross-sectional data have also suggested a positive influence on frailty status by replacing 30 minutes of SB with LPA in individuals ≥ 65 years with a comorbidity. Interestingly, these results were not observed in individuals without comorbidities, suggesting that lower intensity activity may only benefit those starting at a relatively low level of physical fitness (Manas et al., 2018). A recent review by Daum, et al. examined the relationship between structured PA interventions and physical function in middle- and older-aged cancer survivors. While the authors noted that few of the 38 studies examined these outcomes in cancer survivors 65 years and older, there is promising evidence that structured PA at light intensity is capable of staving off age-associated declines in mobility and physical function (Daum et al., 2016). Still, more randomized controlled trials are needed in older and special populations to confirm the utility of LPA on major health outcomes and to determine an appropriate dose-response relationship between LPA and physical function/morbidity.

Capturing ambulatory behavior in a free-living environment

Prior to the advent of wearable movement sensors (accelerometers, pedometers, etc.), the study of human movement and physical activity was limited to lab-based, direct observation, and/or self-report methods that failed to accurately and thoroughly capture day-to-day, habitual ambulatory behavior. There are variations in walking gait with changing terrain and environment that cannot be measured on a treadmill or in a lab-based setting (Patterson et al., 2014; Rispens et al., 2016). Gait characteristics measured
in a free-living environment may expose compensation strategies masked by patients in laboratory settings (Najafi, Khan, & Wrobel, 2011), as well as predict fall risk in older populations (Weiss et al., 2013). Comparison of self-report and objectively measured PA has shown that older adults tend to over-report PA (Kowalski, Rhodes, Naylor, Tuokko, & MacDonald, 2012). The use of accelerometers has become an efficient and cost-effective tool to objectively measure SB and PA in large-scale interventions and longitudinal observational studies with a high degree of accuracy (Berendsen et al., 2014). The use of accelerometers allows for dissemination of interventions by reducing the travel time and lab costs associated with PA assessment, in addition to providing an unbiased measure of PA. Single accelerometers and accompanying proprietary software can be used to obtain activity counts or steps per day in addition to time spent sitting or lying, standing, and stepping. PA classifications (activity count cutpoints) have been derived from raw accelerometer data and validated using indirect calorimetry to establish corresponding MET values (Freedson, Melanson, & Sirard, 1998) that may be different for healthy-older populations (Copeland & Esliger, 2009). The time-stamp feature of most modern accelerometers allows for the calculation of step rate or cadence, which can be used to gauge intensity and can also provide more detailed information as to an individual’s daily patterns of PA - such as the speed at which one is capable of ambulating and time spent ambulating at higher-intensities or at intensities indicative of purposeful movement.

The average number of steps achieved per day is directly associated with cardiometabolic health (Tudor-Locke et al., 2017), QoL (Dohrn, Hagstromer, Hellenius, & Stahle, 2016; Rowlands, Schuna, Stiles, & Tudor-Locke, 2014; Withall et al., 2014),
bone density (Rowlands et al., 2014), and BMI (Tudor-Locke, Brashear, Katzmarzyk, & Johnson, 2012; Withall et al., 2014). Healthy older-adults should aim to achieve 7,000-10,000 steps/day (Tudor-Locke, Craig, Brown, et al., 2011). However, an increase of 2,000 steps/day over baseline for very sedentary (< 5,000 steps/day) or functionally limited individuals has resulted in favorable changes in cardiometabolic health and physical function (Tudor-Locke et al., 2017). However, while steps/day is a measure of volume of activity, measures of cadence can provide greater detail as to the quality of PA (i.e. intensity) and provide a richer and more detailed picture of free-living ambulatory behavior. In healthy adults, a walking cadence of $\geq 100$ steps/min, measured by accelerometry in free-living and laboratory settings, has been deemed a reasonable estimate of “brisk walking” equating to $\geq 3.0$ METs, the threshold for MPA (Tudor-Locke, Sisson, Collova, Lee, & Swan, 2005). While leg length contributes to only modest variations, the threshold for MPA can be affected by age and/or disability/disease (Tudor-Locke, Craig, Aoyagi, et al., 2011; Tudor-Locke et al., 2018). Work is currently underway to find a reasonable target value for MPA in older populations, as the relative intensity to achieve MPA may be less compared to younger/healthier counterparts (ClinicalTrials.gov: NCT02650258).

Current physical activity guidelines from the ACSM and World Health Organization (WHO) recommend at least 30 minutes of MVPA or three, 10-minute bouts of MVPA most days of the week for minimal attainment of cardiometabolic benefit and attenuation of age-related decline (ACSM 2018; WHO 2018). However, it is currently unclear as to whether or not changes in the number of steps accumulated throughout an average day can result in similar benefits as the addition of 30 (or three times 10)
consecutive minutes of MVPA, especially in those subjects who attain a greater volume of daily ambulatory activity in the high-light PA (HLPA) range of 2.1-2.9 METS, or in participants starting out with a high level of SB or deficits in PF. This would be in comparison to healthier subjects, or those achieving 30 or more minutes of structured and continuous MVPA but spending the remainder of the day in SB or low-light PA (LLPA). Also, while home-base interventions prescribing structured PA in accordance with current PA guidelines have been successful at increasing walking cadence in older populations (Maruya et al., 2016; Pahor et al., 2014; Santanasto et al., 2017; Talbot, Gaines, Huynh, & Metter, 2003), it has yet to be determined if individuals participating in a home-based intervention to increase PA and decrease SB would self-select to walk at cadences associated with more purposeful movements (≥ 40 steps/min). It also has yet to be determined whether peak walking speed and measures of endurance in a free-living setting can be positively influenced by an increase in breaks in sedentary time. There have been few interventions using changes in walking cadence as outcome measures in older and/or special populations. While steps/day is a useful metric to evaluate overall changes in PA, measures of cadence can provide a more detailed depiction of ambulatory behavior in order to better tailor PA prescriptions in older and special populations.

**Study purpose and hypotheses**

We conducted an intervention among older cancer survivors (≥ 60 years; any type of cancer) to reduce and break-up sedentary time with LPA (standing and stepping). This intervention, aptly named the Move for Your Health (MY Health) Study, was a randomized controlled trial that utilized a wrist-worn activity monitor and corresponding smartphone application, in addition to over-the-phone health coaching and technical
support with a trained investigator to encourage reductions in SB. Participants were recruited from Albuquerque and surrounding communities via the New Mexico Tumor Registry (NMTR) and flyers placed throughout the communities. Primary outcomes of the MY Health Study were feasibility and acceptability of the intervention, change in total volume of SB (hours/day), change in number of breaks in SB and secondary outcomes included changes in LPA, steps/day, physical performance, physical functioning, QoL, and cardiometabolic biomarkers. Steps per day, breaks in sedentary time, and time spent sitting/lying were measured using an ActivPAL3 activity monitor that the participant wore for the first and last weeks of the study - weeks 1 and 16, respectively. Participants in the intervention group were encouraged to break up sitting time and “move more throughout the day” with the help of the ‘reminder to move’ feature of the activity monitor; however, they were not given specific instructions as to an intensity or duration of physical activity. Exploration into self-selected amount, quality and duration of LPA is novel and could potentially inform future interventions targeting this population.

The proposed secondary analysis seeks to evaluate the effectiveness of this intervention on improving cadence and time spent in ambulatory activities. Data from the MY Health Study will be used to address the following issues related to cadence and markers of PF.

**Purposes of the study**

There are three purposes of this study. The first purpose is to evaluate whether a 16-week, LPA intervention targeted at disrupting sedentary time with bouts of stepping, results in an increase in time spent and number of steps in cadence bands indicative of at
least purposeful stepping (≥ 40 steps/minute). Second, we will evaluate whether a 16-week, LPA intervention targeted at disrupting sedentary time with bouts of stepping, results in an increase in peak and average walking cadence. And third, we will examine the influence of baseline PA and baseline physical function on the intervention change in cadence variables. For example, we will determine if the change in peak cadence is different for those who are less physically active at baseline (pre-intervention).

**Hypotheses**

There are two sets of hypotheses being tested in this analysis. The first will examine change in time and number of steps spent in cadence bands of varying intensities between the Intervention and Control groups. Cadence bands associated with walking/ambulatory intensities are outlined in Table 2. The second set of hypotheses will examine changes in peak- and average-cadence between the Intervention and Control groups.

Table 2. Cadence bands associated with varying levels of physical activity intensity.

<table>
<thead>
<tr>
<th>Cadence Bands (steps/min)</th>
<th>Intensity of ambulatory activity(^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Non-movement</td>
</tr>
<tr>
<td>1-19</td>
<td>Incidental movement</td>
</tr>
<tr>
<td>20-39</td>
<td>Sporadic movement</td>
</tr>
<tr>
<td>40-59</td>
<td>Purposeful steps</td>
</tr>
<tr>
<td>60-79</td>
<td>Slow walking</td>
</tr>
<tr>
<td>80-99</td>
<td>Medium walking</td>
</tr>
<tr>
<td>100-119</td>
<td>Brisk walking</td>
</tr>
<tr>
<td>≥120</td>
<td>Fast locomotor movements</td>
</tr>
</tbody>
</table>

\(^b\) In accordance with: Tudor-Locke et al. (2018); Tudor-Locke and Rowe (2012)

**Hypothesis 1a.** There will be a significant increase in the number of steps per day and time spent in cadence bands indicative of purposeful stepping (≥ 40 steps/minute) in the Intervention group compared to the Control group.
**Rationale.** Older adults and adults with chronic diseases spend more time engaged in sedentary behaviors and exhibit slower walking speeds (Dohrn et al., 2016). There is a well-established relationship between SB and walking speed in older adults, in that the more time spent sedentary, the slower the walking speed (Del Pozo-Cruz et al., 2017; Dohrn et al., 2016; Song et al., 2015; Willey et al., 2017). The current intervention encourages a reduction in sedentary time via reminders to move (mild vibration of the monitor indicating a specified time of inactivity, e.g. 30 minutes). By heeding reminders to move, hence decreasing sedentary behavior, it is likely that participants will engage in purposeful walking behavior in addition to standing during these regular breaks from sitting. This change in behavior may further increase leg strength which may lead to more stepping or walking, thereby increasing leg strength even more and potentially leading to faster walking cadence. Time spent at faster walking cadence may serve to increase overall fitness, improve health outcomes and motivate participants to engage in more, and more frequent PA throughout the day. Figure 1 summarizes this rationale.
Figure 1. Rationale for reminders to move. Reminders to move could lead to increased walking and faster walking behaviors in older cancer survivors.

**Hypothesis 1b.** There will be a significant increase in the number of steps per day and time spent in cadence bands indicative of medium-intensity walking ($\geq 80$ steps/minute) in the Intervention group compared to the Control group.

**Rationale.** The MY Health intervention encouraged participants to increase their number of steps per day by 3,000 steps above their individual baseline level. Although not explicitly stated, participants who chose to achieve this goal in blocks of time rather than spread out throughout the day may have engaged in purposeful walking at medium to higher intensities. Results from studies evaluating the effectiveness of home-based PA interventions at a self-selected intensity are lacking. Furthermore, few studies have used
cadence or time spent and steps taken in cadence bands of increasing value in older adult populations. This may be the first analysis of its kind.

A secondary analysis by Barreira et al. found increased time spent and steps accumulated in cadence bands associated with moderate and higher intensity walking after a PA intervention targeting MVPA in obese and overweight, low-active individuals (2016). The intervention was successful at decreasing participants’ weight and increasing the daily amount of MVPA. However, the steps per day did not increase in the intervention group. But looking beyond the overall volume of PA (steps/day), the authors noted changes in the patterns, or rather intensity, of ambulatory behavior and discovered that although participants maintained their daily step average, they walked faster (Barreira et al., 2016). This suggests that by only evaluating change in steps per day, important improvements associated with health benefits may go undetected. We will be conducting a similar analysis using data from the MY Health intervention. Although while not specifically targeting MVPA, it is possible that the intention of increasing steps per day coupled with environmental context leads to a faster stepping rate. If the intention changes from typical ‘activities of daily living’ to bouts of ‘purposeful physical activity’ or ‘exercise’, step cadence is likely to increase.

**Hypothesis 1c.** There will be a significant redistribution of steps taken from lower cadence bands to higher cadence bands over the 16-week intervention among the Intervention compared to the Control group.

**Rationale.** The MY Health intervention encouraged participants to increase their number of steps per day by 3,000 steps above their individual baseline level. Although not
explicitly stated, participants who chose to achieve this goal in blocks of time rather than spread out throughout the day may have engaged in purposeful walking at medium to higher intensities. Sorting cadence into ‘bands’ allows for analyses of patterns of ambulatory behavior from pre- to post-intervention.

**Hypothesis 1d.** There will be a significant redistribution of time spent from lower cadence bands to higher cadence bands over the 16-week study period among the Intervention compared to the Control group.

**Rationale.** Patterns of ambulatory behavior can provide additional information as to the success of an intervention. Barreira et al. found that steps per day did not increase after a physical activity intervention but the intensity (cadence) at which the participants ambulated increased (Barreira, Katzmarzyk, Johnson, & Tudor-Locke, 2012). These results could be viewed as a marker of success that may have otherwise been overlooked by only evaluating steps per day.

**Hypothesis 2a.** There will be a significant increase in peak 1-minute cadence over the 16-week trial among the Intervention compared to the Control group.

**Rationale.** Peak 1-minute cadence represents the highest intensity achieved during typical daily ambulatory activity in a free-living environment (Tudor-Locke et al., 2012) and has been associated with reduced central pulse pressure in older adults (Gonzales, 2016). Mean peak 1-minute cadence for a total sample of 3522 adults (20-70+ years old) is ≥ 100 steps/minute - which is a reasonable threshold of moderate-intensity activity (3
METs) (Tudor-Locke et al., 2018; Tudor-Locke, Sisson, et al., 2005). However, this value decreases with increased age and BMI. The average peak 1-minute cadence for 1196 adults 60 years and older is ~ 88 steps/min (Tudor-Locke, Sisson, et al., 2005). There is a strong relationship between average daily step count and habitual walking cadence. Individuals with low average daily step count of < 2500 or 2500-4999 steps per day present with slower peak 1-minute cadence equating to 68.9 steps/minute and 95.3 steps/minute, respectively, compared to more active adults achieving 5000-7499 steps/day with a peak 1-minute cadence of 105.4 steps/minute (Tudor-Locke et al., 2012). Based on these cross-sectional findings, we propose that our intervention, aimed at increasing the average steps per day, will also result in faster peak 1-minute cadence.

**Hypothesis 2b.** There will be a significant increase in peak 30-minute cadence over the 16-week trial among the Intervention compared to the Control group.

**Rationale.** Gardner et al. (2007) compared the peak activity index of individuals with intermittent claudication, a complication from peripheral arterial disease, to those without using the StepWatch activity monitor and found that individuals with intermittent claudication had lower peak activity indices than healthy controls. These results indicate that individuals with intermittent claudication have a slower rate of daily ambulatory behavior. Peak activity index is output directly from the StepWatch activity monitor and represents the highest number of steps per minute for 30 (not necessarily consecutive) minutes. Tudor-Locke et al. applied this concept to NHANES Actigraph accelerometry data resulting in peak 30-minute and peak 60-minute cadence indices. Peak effort
indicators such as peak 30- and 60-minute cadence are considered a depiction of habitual ambulatory behavior and persistence of effort (Tudor-Locke et al., 2012). Barreira et al. found improvements in peak 30- and 60-minute cadence in overweight or obese individuals after a PA and health education intervention. The authors suggested that peak 30- and 60-minute cadence may be more representative of behavior change versus peak 1-minute cadence, which may be subject to variations in day-to-day activity and may not fully exemplify change in ambulatory behavior (Barreira et al., 2016). The authors also suggested that more studies are needed to determine if these variables are relevant to health outcomes Barreira et al. (2016). Participants in the aforementioned study did not significantly improve the number of overall steps per day but did increase peak cadence indices. Although we did not specifically request walking at a higher cadence, participants in the MY Health study may have self-selected a higher walking speed resulting from the intention to move to meet their goal of increasing their steps/day.

**Hypothesis 2c.** There will be a significant increase in average 30-minute cadence over the 16-week trial among the Intervention group compared to the Control group.

**Rationale.** A 30-minute sliding window will be used to find the highest bout of 30 consecutive minutes of daily ambulatory behavior. Reductions in average walking cadence have been observed in some clinical populations (Allet et al., 2009; Bindawas, 2016; Bindawas & Vennu, 2015; Clermont & Barden, 2016; Gardner et al., 2007; Ko, Stenholm, & Ferrucci, 2010; McDermott et al., 2016; Wert, Brach, Perera, & VanSwearingen, 2010). The ACSM recommends at least 30 minutes of MPA most days.
of the week and asserts that some activity, regardless of time or intensity, is better than none. The MY Health study did not specifically prescribe walking for a specific time or intensity. However, we intend to explore the possibility that as the intervention progressed, individuals in the intervention group may have inadvertently increased their lower extremity strength and endurance by increasing their daily physical activity (standing, stepping) and could ambulate at higher intensities for longer periods.

**Hypothesis 2d.** There will be a significant increase in average 10-minute cadence over the 16-week trial among the Intervention group compared to the Control group.

**Rationale.** According to the ACSM, the recommended 30 minutes of MVPA most days of the week (150 min/week) can be divided into bouts of 10 or more minutes. For individuals with time or health constraints, three 10-minute bouts of MPA may be more achievable than 30 continuous minutes of physical activity. However, according to NHANES data, less than 10% of Americans are meeting the recommended guidelines for MVPA (Tucker, Welk, & Beyler, 2011) and only 2.5% of individuals 60 years and older are meeting those guidelines in 10-minute bouts (Tucker et al., 2011). The goals of the MY Health Study were to 1) increase overall steps per day by at least 3,000 steps over the course of the intervention and 2) to break up sedentary time by moving more frequently throughout the day. It is possible that those in the intervention group self-selected shorter durations at higher intensities which could be reflected in their average 10-minute cadence.
Scope of study

This is a secondary analysis of data collected during the MY Health study, a randomized controlled trial designed to break up sedentary time with standing, stepping or other LPA in a population of older (≥ 60 yrs) cancer survivors. PA was measured for one week at baseline and following the 16-week intervention using an ActivPAL3 activity monitor (PAL Technologies Ltd., Glasgow, UK). The ActivPAL3 is the gold standard in SB research and has excellent validity and reliability (Chastin et al., 2018; Gennuso, Thraen-Borowski, Gangnon, & Colbert, 2016). Data collected from the ActivPAL3 was downloaded using the manufacturer’s proprietary software and processed in SAS (Version 9.4, Copyright 2002-2012 by SAS Institute Inc., Cary, NC, USA). Peak-cadence, average-cadence, and time spent and steps taken within cadence bands were quantified and analyzed. Analyses included data from 41 older cancer survivors with complete pre- and post- intervention ActivPAL3 data. Participants had to have completed primary treatment (surgery, chemotherapy, radiation) at least six months prior to enrolling in the study. For analyses of ActivPAL data pre- and post- intervention, a valid wear-day was defined as ≥ 10 hours per day for a minimum of 4 days, consistent with other studies (Colley, Connor Gorber, & Tremblay, 2010; Troiano et al., 2008). Data analyses were generated using SAS software and differences between Intervention and Control groups regarding cadence and patterns of cadence were evaluated. Statistical analyses were conducted to determine if baseline physical function and physical activity influenced the results of the intervention.
Chapter 2

Review of related literature

Analyses of walking gait have revealed that usual gait speeds slower than 0.8 m/s are indicative of mobility limitations, disability, mortality and increased fall risk (Studenski et al., 2011). Analysis of gait speed is a powerful diagnostic regarding frailty in older adults and has been shown superior over other tests of physical function such as step length and rising from a chair (Schoon, Bongers, Van Kempen, Melis, & Olde Rikkert, 2014). Simple gait assessments including the 6-minute walk, the 8-foot walk, and timed-up-and-go tests can easily be achieved in a clinic or lab-based setting but may pose some limitations regarding reliability of results. Participants tend to walk faster in lab-based settings compared with their habitual walking speed in a free-living environment (Tudor-Locke, Barreira, Brouillette, Foil, & Keller, 2013). Precise measures of gait analysis often require an individual to travel to labs outfitted with expensive and highly-involved motion capture systems. More affordable, portable and smaller systems such as Gait Rite® have been used successfully in clinical and research settings (Bilney, Morris, & Webster, 2003; K. E. Webster, Wittwer, & Feller, 2005). However, the use of such systems does not negate the issue of heightened participant performance observed in the presence of an investigator or clinician. Therefore, analysis of gait in a clinical or laboratory setting may not provide a complete picture of one’s physical capabilities in performing activities of daily living (ADL) in their typical environment.

Wearable motion sensors are capable of accurately capturing gait parameters in a free-living setting. Research grade wearable sensor technology has become accessible in terms of size and cost, potentially reducing researcher and participant burden. However,
in order to mimic the same rich data provided by lab-based motion capture systems, multiple sensors are required, thereby making precise measurement of gait parameters in a free-living environment cumbersome, expensive and requiring highly motivated and committed participants (Geraedts et al., 2017; McCarthy & Grey, 2015). Although true gait speed and other gait parameters are difficult to measure in a free-living environment due to these limitations and cost of technology, Tudor-Locke and colleagues have developed methods to assess cadence in a free-living environment using statistical analyses of accelerometry data (Tudor-Locke et al., 2013; Tudor-Locke, Bittman, Merom, & Bauman, 2005; Tudor-Locke et al., 2012; Tudor-Locke & Rowe, 2012).

Measurement of cadence in a free-living environment has been used to gauge intensity, with ≥ 100 steps/minute equating to walking at a brisk pace and the threshold for MPA (≥ 3.0 METs) (Tudor-Locke, Sisson, et al., 2005). It should be noted that cadence, or rather steps per minute, is not the same as gait speed per se, which is comprised of both stride (step length) and cadence (Tudor Locke et al., 2013). Also, it has yet to be determined if cadence measures capture the similar prognostic and diagnostic utility of gait speed. However, Brown et al. found little difference between the discriminative characteristics of walking speed and gait in individuals 60 years and older regarding 5- and 10-year mortality risk (J. C. Brown, Harhay, & Harhay, 2014). Investigators also determined that the ability to walk ≥ 100 steps per minute was associated with a 21% reduction in all-cause mortality J. C. Brown et al. (2014). Slow walking speeds have been linked to increased cardiovascular risk factors in children (Barreira, Katzmarzyk, Johnson, & Tudor-Locke, 2013) and adults (median age = 44.8 years) (Tudor-Locke et al., 2017) and reduced vascular compliance in young adults (18-
31 years) (Gonzales, Shephard, & Dubey, 2015). While there does appear to be strong, positive associations between physical activity and physical function, in that more daily physical activity correlates with retention of ADL and quality of life (QoL) (Pahor et al., 2006; Sardinha et al., 2015) there have been few interventions and little research investigating the potential for free-living cadence to identify potential adverse outcomes in older individuals (Tudor-Locke, 2013). Further investigations into the relationship of free-living cadence and physical function may help inform interventions designed at promoting physical activity and staving off functional decline. In this regard, assessment of cadence in a free-living environment may be a practical alternative to the more cumbersome clinic- and lab-based gait analysis.

**Cadence-based metrics**

*Peak Cadence*

Peak cadence represents ‘best natural effort’ or the highest intensity achieved for a specified number of minutes during typical daily ambulatory activity in a free-living environment (Tudor-Locke et al., 2012). Peak 1-minute cadence, or maximum 1-minute cadence, represents maximal daily effort for short bursts of ambulatory activity. Peak 1-minute cadence for a typical adult is ≥ 100 steps/minute (Tudor-Locke, Sisson, et al., 2005). While most adults are capable of achieving such intensities, they seldom do during habitual ambulation (Tudor-Locke et al., 2013). While this is a reasonable target for most healthy individuals and public health recommendations, the threshold for MPA in older and clinical populations is less clear (Peacock, Hewitt, Rowe, & Sutherland, 2014; Serrano, Slaght, Senechal, Duhamel, & Bouchard, 2017; Tudor-Locke et al., 2018). Cadence is inversely associated with age and body mass index (BMI), and some older (≥
60 years) and clinical populations present with much lower values for peak 1-minute cadence (70-90 steps/min) than their age-matched, healthier counterparts (Tudor-Locke et al., 2018). However, without sufficient longitudinal or controlled studies, it is difficult to determine whether slow-walking speed contributes to increased BMI or certain mobility disabilities, or if it is simply the result.

Peak 30-minute cadence values are calculated by rank ordering daily steps/minute (not necessarily consecutive minutes) from highest to lowest and taking the average of the first 30 minutes. Peak 30-minute cadence, first described as peak activity index, has been used to compare inter-individual differences between healthy and clinical populations (Busse, Pearson, Van Deursen, & Wiles, 2004; Gardner et al., 2007) and intra-individual changes post-intervention (Brown & Simnad 2016; Webber, Strachan, & Pachu, 2017). It has been suggested that peak 30-minute cadence, used as a marker or characteristic of the intensity of habitual ambulatory behavior, may be more strongly associated with age and BMI than volume of PA (steps/day). However, in a population of 143 older (58-92 years) adults, Schuna et al. found steps/day and peak 30-minute cadence to be strongly correlated in men (r = .81, p < .01) and women (r = .88, p < .01) and concluded that peak 30-minute cadence was not independent of the volume of PA associated with age or BMI (Schuna et al., 2013). However, based on the premise that intensity of physical activity may be more important than volume, Gonzales et al. used linear regression to tease apart the effects of peak 30-minute cadence and steps/day on functional capacity in 43 healthy older (60-78 years) adults. They found that peak 30-minute cadence was more strongly associated with functional capacity than steps/day in women, but not in men (Gonzales et al., 2015). The average number of steps/day in both
studies was greater than 5,000 and considered ‘low-active’ (Tudor-Locke, Craig, Brown, et al., 2011). However, the distinction between intensity and volume of ambulatory behavior may prove more substantial in older and special populations achieving less than 5,000 steps/day. For example, short but frequent (1-2 times/hour) bouts of moderate or high-intensity activity such as rising quickly from a chair or walking briskly for 30-60 seconds, may provide enough of a stimulus that could translate to better functional status, independent of total volume of physical activity.

**Average Cadence**

Average cadence is a measure of sustained endurance activity and is calculated as the highest average walking speed obtained in a specified number of continuous minutes. Gardner et al. reported average 5-, 20-, 30- and 60-minute cadence values for individuals with intermittent claudication, a complication due to peripheral arterial disease, in which subjects experience cramping leg pain that is often exacerbated with exercise (Gardner et al., 2007). Average 5- 20-, 30- and 60-minute cadence values were lower in individuals with intermittent claudication and could represent a compensation strategy to stay below pain thresholds during longer periods of ambulatory activity (Gardner et al., 2007). In another study by Gardner et al., a home-based walking program resulted in improvements in average cadence in individuals with intermittent claudication compared to those randomized to supervised-treadmill or usual care groups. However, both exercise groups increased time to onset of claudication and peak walking time (Gardner, Parker, Montgomery, Scott, & Blevins, 2011). It is of interest to note that the participants in the home-based and treadmill programs had similar volumes of physical activity, but the home-based group chose to walk longer at a slower, self-selected pace than the
supervised-treadmill group (Gardner et al., 2011). These results suggest that in certain compromised populations, a higher volume of lower intensity activity can improve self-selected walking speed. While walking faster is associated with higher-intensity of PA, and higher-intensity PA is linked to better functional outcomes, more research is needed to determine the clinical significance of improved cadence in clinical populations.

**Cadence bands and patterns of free-living ambulatory behavior**

Daily step accumulation represents the volume of daily physical activity while cadence is related to intensity of movement and can provide additional information as to the daily patterns of physical activity. In order to investigate the daily step-accumulation patterns of 3744 adults ≥ 20 years of age from the National Health and Nutrition Examination Survey (NHANES), Tudor-Locke et al., grouped cadence data into bands of 20 steps/min corresponding with non- (0 steps/min) and incidental-movement (1-19 steps/min) up to brisk-walking (100 steps/min) and fast locomotor movements (≥ 120 steps/min) (2011). Table 2 in Chapter 1 outlines cadence bands associated with increasing levels of physical activity and ambulatory behavior. Cross-sectional analyses of accelerometry data has shown that older adults and special populations spend more time at 0 cadence and cadence bands associated with incidental and sporadic movement and less time ambulating above cadence bands indicative of purposeful movement (≥ 40 steps/min) compared to their younger and healthier counterparts (Ayabe et al., 2009; Cavanaugh, Coleman, Gaines, Laing, & Morey, 2007; Tudor-Locke et al., 2013). How or at what intensity one ambulates throughout their waking day is of particular importance in SB research due to the distinct physiological mechanisms associated with increased SB and reduced PA. Analyses of time spent in cadence bands of varying intensities may
provide some insight as to participant compliance or strategies used to increase PA and decrease SB. The association between patterns or combinations of walking-speeds and positive health outcomes has yet to be fully elucidated. It would be helpful to know of effective strategies, or intermediate and achievable goals for those low-active or health-compromised individuals starting out at less than 5,000 steps per day as certain recommendations (i.e. 10,000 steps per day) may be daunting or excessive (Choi, Pak, Choi, & Choi, 2007; Hall & McAuley, 2010; Tudor-Locke, Craig, Aoyagi, et al., 2011).

Identifying patterns of free-living ambulatory behavior is useful for informing future interventions as the inability to ambulate at higher intensities may further exacerbate the already detrimental effects of too little PA and too much SB in some populations (Tudor-Locke et al., 2018). Most data regarding self-selected cadence and patterns of cadence in a free-living environment come from cross-sectional analyses (J. C. Brown et al., 2014; Fortune, Mundell, Amin, & Kaufman, 2017; Kang, Kim, & Rowe, 2016; Tudor-Locke et al., 2013). The prognostic value of cadence and patterns of cadence in a free-living environment has yet to be fully investigated and few interventions have used free-living cadence as an outcome measure. Additional studies are needed to determine the influence of self-selected typical ambulatory cadence on health outcomes.
Chapter 3

Methods

The work presented here is a secondary analysis of physical activity data collected during the first and last weeks of the Move for Your Health (MY Health) Study, a 16-week intervention targeting reductions in sedentary behavior (SB) in older (≥ 60 years) cancer survivors. The MY Health Study was a home-based intervention that consisted of two clinic visits: pre- and post-intervention. Clinic visits took place in the Clinical and Translational Sciences Center (CTSC) on the Health Science Campus of the University of New Mexico in Albuquerque, New Mexico, USA.

Potential participants were identified by the New Mexico Tumor Registry (NMTR) and sent an information letter about the study. The letter was followed-up by a telephone call from a member of the study team to determine interest and eligibility. If interested and eligible, the participant’s first clinic visit was scheduled and they were mailed a study packet that included questionnaires to be completed before or during their clinic visit. Participants were eligible if they were 60 years of age or older, diagnosed with cancer and had completed primary treatment, owned a smartphone or tablet capable of running the Jawbone UP2 application, were able to read and understand English, lived independently, able to walk three blocks (~ 0.25mi) without the aid of an assistive device and resided within 50 miles of the CTSC. Potential participants were excluded if they were participating in another study or program to decrease SB or increase physical activity (PA), worked or volunteered more than 20 hours per week or had any severe impairments or pre-existing medical conditions.
Participants

Fifty-four participants were recruited to the MY Health Study. Seven participants dropped out prior to their follow-up visit and six participants had incomplete data from their physical activity monitor. Forty-one participants with complete data from their ActivPAL3 activity monitor for baseline and follow-up time periods were included in these analyses. Participants were randomized to one of three groups: Health Coaching (HC), Tech Support (TS) and Waitlist Control (WC). A 1:1:1 randomization was performed, stratified based on a body mass index (BMI) of < or ≥ 30 kg/m². Participant flow through the 16-week study is illustrated in Figure 2. Participants attended baseline and follow-up clinic visits at weeks 1 and 16, respectively. For the sake of simplicity, only those methods relative to the current analyses are fully described. A more detailed outline of all methods and outcomes from the MY Health Study can be found at https://clinicaltrials.gov/ct2/show/NCT03632694. In summary, each clinic visit was comprised of routine clinical measurements including: resting blood pressure, resting heart rate, height, weight and hematological biomarkers of metabolic function and inflammation. Data regarding cancer diagnosis (type of cancer and age at time of diagnosis) were obtained from the NMTR.

Prior to their clinic visits, participants completed questionnaires concerning self-perceived quality of life (QoL), physical function (PF), sedentary behavior (SB), physical activity (PA), pain and fatigue. Self-reported PF is one of eight subdomains included in the Medical Outcomes Study Short Form-36 (SF-36) which assesses general health-related QoL. The SF-36 has been used extensively in cancer and non-cancer patients and
Figure 2. Participant flow through the 16-week MY Health Study. The study began with a baseline clinic visit. During the clinic visit, participants were outfitted with activity monitors which they were instructed to wear for at least seven days. At the conclusion of their wear days, participants mailed the monitors and logs back in the pre-paid (postage) package. Participants were then contacted by a member of the study team and randomized to one of three groups: HC, TS, WC. One week prior to their follow-up clinic visit (week 15), monitors, wear-logs and instructions were mailed to participants. Participants wore the monitors for at least seven days; monitors were collected by the study staff at the follow-up clinic visit.

is used by Medicare for routine monitoring of adult patients (Baker, Haffer, & Denniston, 2003). Proprietary software is required to score the SF-36 and compare individual results with normative values from the U.S. population. Summary score and individual scores for all subdomains are out of a possible 100 points with a mean score of 50 being the national average, where higher scores indicate better QoL or PF. The Functional
Assessment of Chronic Illness Therapy (FACIT) Fatigue Scale (Version 4) was used to assess perception of fatigue by study participants. This 13-item survey attempts to identify the intensity of participants’ fatigue experienced over the previous seven days (K. Webster, Cella, & Yost, 2003). Scores for each item range from zero (not at all) to four (very much) with a highest possible score of 52. Scores greater than 30 are indicative of severe fatigue (Piper & Cella, 2010).

Participants completed the Short Physical Performance Battery (SPPB) at both baseline and follow-up clinic visits. The SPPB is an objective assessment tool used to evaluate lower extremity function in older individuals and has been found to be predictive of fall-risk, loss of independence and mortality (Guralnik et al., 2000; Guralnik, Ferrucci, Simonsick, Salive, & Wallace, 1995; Onder et al., 2005; Pavrasini et al., 2016). The three areas of assessment are balance, mobility and gait speed over a distance of 8 feet. The highest score attainable on the SPPB is 12 points, with each assessment having a possible score of 4 points. Higher scores indicate better performance. For purposes of these analyses, usual walking speed was determined as participants’ individual 8-foot walk times converted to meters per second.

Procedures

Instrumentation

The data for the primary outcomes used in these analyses were collected from the ActivPAL3 micro monitor (PAL Technologies Ltd., Glasgow, UK). The ActivPAL3 micro is a small, thin monitor that affixes to the midline of the mid-right thigh with a Tegaderm™ adhesive dressing. The ActivPAL3 uses proprietary algorithms to distinguish sitting or lying, standing, and stepping behaviors (Grant, Ryan, Tigbe, &
Granat, 2006; Kozey-Keadle, Libertine, Lyden, Staudenmayer, & Freedson, 2011; Lyden, Keadle, Staudenmayer, & Freedson, 2014). The device has excellent correlation (r = .96) with direct observation and accurately distinguishes between sitting/lying, standing and stepping behaviors (Grant et al., 2006). Because of these features, the use of ActivPAL technology in SB research has drastically increased over the past decade making it the gold standard for objectively measured SB (Chastin et al., 2018). Participants were asked to wear the ActivPAL3 micro for one week (seven consecutive days) after their initial clinic visit and during the week leading up to their follow-up clinic visit. Investigators demonstrated the monitor application procedure and helped apply the activity monitor to the participant during the first clinic visit. Participants were mailed the ActivPAL3 monitor and an instruction packet outlining how to apply the monitor prior to their follow-up clinic visit. On both occasions, participants were provided with monitor logs to track their self-reported sleep and wake times and monitor removal during each week’s worth of wear. Participants were instructed to only remove the monitor if swimming, bathing or any other activity that would require the monitor to be submerged in water or in the event of skin irritation under or surrounding the Tegaderm™ dressing occurred.

Data were collected pre- and post-intervention at the default sampling rate of 20Hz and downloaded using the manufacturer’s software. ActivPAL3 summary events files were processed using customized script in SAS (Version 9.4, Copyright 2002-2012 by SAS Institute Inc., Cary, NC, USA) in order to assess movement behaviors occurring in 1-minute epochs. Participants were included in the analyses if they met the valid wear-time threshold of ≥ 10 hours of wear time for ≥ 4 days. Sleep and wear time were visually confirmed using ActivPAL proprietary image files and compared against wear-logs from
participants. Methods similar to those of Tudor-Locke et al. and Barreira et al. were used to quantify daily time (minutes) and steps accumulated in the following cadence bands: 20-39 (sporadic movement), 40-59 (purposeful steps), 60-79 (slow speed walking), 80-99 (medium speed walking), 100-119 (brisk walking), and > 120 steps/min (fast locomotor movements) (Barreira et al., 2016; Tudor-Locke, Camhi, et al., 2011). Additionally, daily peak 1- and 30-minute cadence values were calculated according to the methods outlined by Tudor-Locke and Gardner (Gardner et al., 2007; Tudor-Locke, Camhi, et al., 2011). Briefly, peak 1-minute cadence represents the highest daily 1-minute cadence value. Peak 30-minute cadence was determined by sorting daily cadence values from highest to lowest and taking an average of the first, not necessarily consecutive, 30 minutes. Thirty- and 10-minute average cadence values were calculated using a 30- and 10-minute sliding window to find the average of the highest 30 and 10 consecutive minutes. Determination of peak and average cadence variables was carried out in SAS.

**Intervention**

Participants randomized to the TS and HC groups received a Jawbone UP2 activity monitor (Jawbone, San Francisco, CA), educational materials about the negative effects of SB and suggestions for breaking up sedentary time, and an individual project schedule to use during their HC/TS calls. As can be seen in Figure 2, both HC and TS groups received five phone calls from a trained staff member that provided technical assistance in setting up their device and corresponding smartphone application (app). Throughout the intervention, the technical support specialist helped TS participants change settings and update their goals through the Jawbone UP2 smartphone app. In addition to technical support, as of July 2017, the brand and company identifying as Jawbone was no longer in business.
assistance, participants in the HC group were provided encouragement and suggestions to help motivate them in modifying their sedentary behavior. Individuals randomized to WC received instructions to continue their typical daily physical activity levels for 16-weeks, at which time, they received an abbreviated form of the intervention during their follow-up clinic visit.

Participants’ initial daily step goal was determined at week four by adding 1,000 steps to their previous week’s step count as determined by the Jawbone UP2 activity monitor. Daily step goals were increased by 500 steps/day every two weeks until a goal of 3,000 steps/day above baseline was achieved at week 12. Participants were instructed to maintain this new step goal for the next four weeks until conclusion of the intervention. The Jawbone Idle Alert was initially set to 1 hour at which time a slight vibration of the wrist-worn monitor would inform the participant that they had been sedentary for 60 minutes. The idle alert setting was reduced to every 45 minutes from weeks six thru nine, and every 30 minutes thereafter until conclusion of the intervention. Table 3 outlines the support call and goal setting schedule for participants in the HC and TS groups.

Outcome Measures

Outcome measures included changes in peak 1- and peak 30-minute cadence, average 10- and 30-minute cadence, and change in time and steps accumulated in cadence bands of increasing intensities. Time and steps accumulated at cadences associated with incidental (≥ 40 steps/min) and purposeful (≥ 80 steps/min) movement were also evaluated.
Table 3. Support call and goal setting schedule.

<table>
<thead>
<tr>
<th>Week</th>
<th>Health Coaching/ Tech Support</th>
<th>Steps/Day Goal</th>
<th>Idle Alert Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Jawbone Set-up Call</td>
<td>Begin wear; establish baseline steps/day</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Call</td>
<td>1,000 + baseline</td>
<td>60-minutes</td>
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<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>6</td>
<td>Call</td>
<td>1,500 + baseline</td>
<td>45-minutes</td>
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<td>7</td>
<td></td>
<td></td>
<td></td>
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<td>8</td>
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<td>2,000 + baseline</td>
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<td>9</td>
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<tr>
<td>10</td>
<td>Call</td>
<td>2,500 + baseline</td>
<td>30-minutes</td>
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<td>11</td>
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</tr>
<tr>
<td>12</td>
<td>Call</td>
<td>3,000 + baseline</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td></td>
<td>3,000 + baseline</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td></td>
<td>3,000 + baseline</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td></td>
<td>3,000 + baseline</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td></td>
<td>3,000 + baseline</td>
<td></td>
</tr>
</tbody>
</table>

Initial step goal was determined by average daily steps obtained during the first week of Jawbone wear. For some participants, the suggested increase in steps per day or hourly idle alert was not rigidly adhered to due to physical limitations, scheduling constraints or the desire of the participant to keep their goal attainable.

**Summarization of data**

Results from this study were examined using per-protocol analyses, in that only participants with complete pre- and post-intervention ActivPAL3 data have been included in these analyses. Steps per day and cadence values were averaged across valid wear days for pre- and post-intervention time points. Time spent stepping and steps taken within six cadence bands indicative of ambulatory behavior were evaluated. Cadence bands associated with ambulatory behavior (specifically stepping) began at 20 steps/min (sporadic movement) and increased in increments of 20 steps/min, up to a cadence band of greater than or equal to 120 steps/min. At cadence bands < 20 steps/min, step counts are not registered. This is a limitation in the technology and processing software; therefore, the average daily number of steps and the total time spent engaged in
ambulatory behavior was determined as the sum of all time spent ambulating at $\geq 20$ steps/min averaged across valid wear days.

**Statistical Analyses**

Randomization resulted in similar baseline characteristics between groups. Preliminary analyses suggested no difference in outcomes between HC and TS groups. Based on these findings, HC and TS groups were combined to form a single Intervention group, resulting in 24 and 17 participants in the Intervention and Control groups, respectively. Two sample independent and paired $t$ tests were used for comparisons of continuous variables between and within groups, respectively. Fisher’s exact tests were used to compare the proportions of categorical data between two independent groups. Graphical methods (qq-plots and histograms) and the Shapiro-Wilk test for normality ($p \geq .05$, normal) were used to identify potential outliers and deviations from normality. In the event that assumptions of normality were violated, Wilcoxon rank-sum- (independent samples) and Wilcoxon signed-rank- (paired samples) tests were employed. Repeated measures analysis of variance (ANOVA) was used to evaluate group differences regarding number of steps and time spent in cadence bands of increasing intensity.

We sought to determine if changes in average or peak cadence values from pre- to post-intervention (outcome) within the Intervention group (exposure) were influenced by participants’ lower-extremity physical function (i.e. SPPB score). It is possible, due to a ceiling effect, that significant improvement in peak- or average-cadence may not be realized in those participants who were already exhibiting high levels of physical function. Alternatively, those who scored low on the SPPB may have had greater room for improvement and, therefore, may have experienced greater benefits from the
intervention. These benefits could manifest as a significant increase in peak- or average-
cadence in those participants with lower levels of physical functioning at baseline.
Therefore, analyses of peak- and average-cadence variables were conducted in those
participants with greater room for improvement, identified as having an SPPB score of 10
or lower out of a possible 12 points. Additionally, Spearman’s rank correlations were
conducted between baseline measures of physical function (PF) and baseline PA with
regards to change (pre- to post-intervention) in peak and average cadence variables to
gather insight as to whether baseline PF and PA may have influenced the outcomes of the
intervention. All statistical analyses were performed in SAS 9.4 (SAS Institute, Cary
NC). Significance was considered at $p < 0.05$. 
Participant baseline characteristics

Characteristics of the 41 MY Health study participants used in these analyses are presented in Table 4. Continuous variables are summarized as mean and standard deviation (SD) and categorical variables are summarized by frequency (n) and percentage (%). Analyses of participant characteristics indicated that there were no significant differences at baseline between the Intervention and Control groups. Over one-half (56.1%) of study participants were female and the mean age of all participants at baseline was 70.1 (±4.4) years. The mean age of study participants at cancer diagnosis was 65.6 (±4.3 years) with breast and prostate cancer most frequent, affecting 34.2% and 29.3% of the study population, respectively. Of the participants included in these analyses, 53.7% self-reported to be in “very good to excellent” health, yet 61% of participants had greater than or equal to three co-existing medical conditions at baseline as evidenced by the comorbidities questionnaire. Eighty percent of study participants were classified as overweight to obese (BMI of ≥ 25.00 kg/m²). Only six of the 41 participants (14.6%) reported extreme fatigue as indicated by a FACIT score of greater than 30 out of 52 possible points. Analyses of demographic characteristics indicate that 22% of participants identified as Hispanic, 75.6% were married or living in marriage-like relationships, and 61.0% had an average household income ≥ $50,000 per year. Fifty-eight percent of study participants had earned a college degree or higher.
Table 4. Baseline participant characteristics.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Intervention $n = 24$</th>
<th>Control $n = 17$</th>
<th>$p$ value(^a)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Female n (%)</strong></td>
<td>14 (58.3)</td>
<td>9 (52.9)</td>
<td>.73</td>
</tr>
<tr>
<td><strong>Age (years)</strong></td>
<td>69.58 (3.43)</td>
<td>70.8 (5.4)</td>
<td>.41</td>
</tr>
<tr>
<td><strong>Height (cm)</strong></td>
<td>164.90 (11.39)</td>
<td>168.3 (11.0)</td>
<td>.34</td>
</tr>
<tr>
<td><strong>Weight (kg)</strong></td>
<td>78.95 (16.24)</td>
<td>83.6 (16.8)</td>
<td>.38</td>
</tr>
<tr>
<td><strong>BMI (kg/m(^2))</strong></td>
<td>29.0 (4.68)</td>
<td>29.5 (5.3)</td>
<td>.75</td>
</tr>
<tr>
<td><strong>BMI Classification n (%)</strong></td>
<td>20 (83.3)</td>
<td>13 (76.5)</td>
<td>.58</td>
</tr>
<tr>
<td><em>(Overweight/Obese: ≥ 25.00 kg/m(^2))</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cancer type</strong></td>
<td></td>
<td></td>
<td>.48</td>
</tr>
<tr>
<td>Breast</td>
<td>10 (41.7)</td>
<td>4 (23.5)</td>
<td></td>
</tr>
<tr>
<td>Prostate</td>
<td>6 (25.0)</td>
<td>6 (35.3)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>8 (33.3)</td>
<td>7 (41.2)</td>
<td></td>
</tr>
<tr>
<td><strong>Age at diagnosis</strong></td>
<td>65.2 (3.7)</td>
<td>66.2 (5.1)</td>
<td>.46</td>
</tr>
<tr>
<td><strong>Smoking status</strong></td>
<td></td>
<td></td>
<td>.48</td>
</tr>
<tr>
<td>Never smoked n (%)</td>
<td>14 (58.3)</td>
<td>8 (47.1)</td>
<td></td>
</tr>
<tr>
<td>Have smoked n (%)</td>
<td>10 (41.7)</td>
<td>9 (52.9)</td>
<td></td>
</tr>
<tr>
<td><strong>Health status (self-report)</strong></td>
<td></td>
<td></td>
<td>.94</td>
</tr>
<tr>
<td>Very good/excellent n (%)</td>
<td>13 (54.2)</td>
<td>9 (52.9)</td>
<td></td>
</tr>
<tr>
<td>Good n (%)</td>
<td>9 (37.5)</td>
<td>7 (41.2)</td>
<td></td>
</tr>
<tr>
<td>Fair/poor n (%)</td>
<td>2 (8.3)</td>
<td>1 (5.9)</td>
<td></td>
</tr>
<tr>
<td><strong>Number chronic conditions ≥ 3</strong></td>
<td>8 (33.3)</td>
<td>7 (41.2)</td>
<td>.61</td>
</tr>
<tr>
<td><strong>FACIT Fatigue (score 0-52)</strong></td>
<td>37.8 (10.2)</td>
<td>36.5 (8.3)</td>
<td>.67</td>
</tr>
<tr>
<td>Severe fatigue(^b) n (%)</td>
<td>4 (16.7)</td>
<td>2 (11.8)</td>
<td>.67</td>
</tr>
<tr>
<td><strong>Average steps/day</strong></td>
<td>6790 (2790)</td>
<td>7946 (2916)</td>
<td>.21</td>
</tr>
<tr>
<td><strong>Race/ethnicity</strong></td>
<td></td>
<td></td>
<td>.84</td>
</tr>
<tr>
<td>White (Non-Hispanic) n (%)</td>
<td>19 (79.2)</td>
<td>13 (76.5)</td>
<td></td>
</tr>
<tr>
<td>Hispanic n (%)</td>
<td>17 (20.8)</td>
<td>4 (23.5)</td>
<td></td>
</tr>
<tr>
<td><strong>Marital Status</strong></td>
<td></td>
<td></td>
<td>.40</td>
</tr>
<tr>
<td>Married or living in marriage-like relationship n (%)</td>
<td>17 (70.8)</td>
<td>14 (82.4)</td>
<td></td>
</tr>
<tr>
<td>Not Married (single, divorced, widowed) n (%)</td>
<td>7 (29.2)</td>
<td>3 (17.7)</td>
<td></td>
</tr>
</tbody>
</table>
### Characteristics

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Intervention n=24</th>
<th>Control n=17</th>
<th>p-value*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Education</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than high school or high school graduate n (%)</td>
<td>3 (12.5)</td>
<td>3 (17.6)</td>
<td>.82</td>
</tr>
<tr>
<td>Post high-school training or some college n (%)</td>
<td>6 (25.0)</td>
<td>5 (29.4)</td>
<td></td>
</tr>
<tr>
<td>College degree or higher n (%)</td>
<td>15 (62.5)</td>
<td>9 (53.0)</td>
<td></td>
</tr>
<tr>
<td><strong>Annual household income</strong></td>
<td></td>
<td></td>
<td>.17</td>
</tr>
<tr>
<td>≥ 50,000/yr. n (%)</td>
<td>12 (50.0)</td>
<td>13 (76.5)</td>
<td></td>
</tr>
<tr>
<td>&lt; 50,000/yr. n (%)</td>
<td>10 (41.7)</td>
<td>4 (23.5)</td>
<td></td>
</tr>
<tr>
<td>Declined response n (%)</td>
<td>2 (8.3)</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Continuous variables presented as mean (SD); categorical variables presented as n (%).  
*p values of Fisher exact test (for categorical characteristics) or t test (for continuous characteristics) for the difference between the two groups at baseline.

Severe fatigue defined as a score of < 30 out of 52 possible points on FACIT questionnaire.

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### Physical Function & Walking Speed

Self-report and objective measures of physical function are presented in Table 6.

There were no significant differences observed in physical function between the Intervention and Control groups at baseline (*p* values ≥ .05). Physical function (PF) measured using the SF-36 PF subscale suggested that 75.6% of study participants included in these analyses fare the “same or better” than the general population (Score of 70-100 out of 100 possible). Of the participants included in these analyses, 36.6% exhibited walking speeds slower than 0.8 m/s, an indicator of physical frailty (Studenski et al., 2011). On average, five (29.4%) participants in the Control group and 10 (41.7%) participants in the Intervention group walked slower than 0.8 m/s during the baseline SPPB gait assessment. Both Intervention and Control groups attained a median score of 11.0 (IQR: 10.0-12.0) out of a possible 12 on the SPPB test of lower extremity physical function at baseline. There was no indication that either group’s self-reported PF (SF-36)
or lower-extremity PF (SPPB) scores increased significantly from pre- to post-intervention ($p \geq .05$). However, a median increase of 0.10 (IQR: -0.05-0.25) m/s in walking speed was observed within the Intervention group ($p = 0.04$) from pre- to post-intervention. Individual changes in walking speed at pre- and post-intervention time points are depicted in Figure 3. Positive values represent increased walking speed (i.e. participants walked faster at follow-up compared to baseline visit). Negative values represent a reduction in walking speed (i.e. participants walked slower from pre- to post-intervention).

**Physical Activity**

*Step-based physical activity categories*

According to Tudor-Locke, et al., a value of less than 5000 steps per day is considered *sedentary* (limited activity) (Tudor-Locke, 2010). Categories of physical activity determined by steps per day are outlined in Table 5. There were no significant differences between groups at baseline regarding physical activity level ($p > .05$). Approximately 38% of Intervention group participants took less than 5000 steps pre-intervention compared to 12% ($n = 2$) of Control group participants. Eighteen percent of participants in the Control group ($n = 3$) were classified as *highly active* at baseline. Data suggest that over one-half of participants (51%) were somewhat active, taking between 7500 to 9000 steps/day prior to the start of the intervention. The number of Intervention group participants that were categorized as ‘sedentary’ decreased from nine (38%) to five (21%) suggesting that four participants increased their PA status by the end of the intervention. The number of participants in the Intervention group classified as *highly active* increased from zero participants at baseline to six participants post-intervention.
Further investigation indicates that four of these six participants moved from *active* status at baseline to *highly active* at follow-up. A total of eight participants in the Intervention group increased in PA status by one level and four participants increased by two or more levels. One-half of the participants in the Intervention group either decreased by one physical activity level ($n = 5$) or stayed within the same category ($n = 7$).

Table 5. Hierarchy of physical activity pre- and post-intervention defined by total number of steps/day.

<table>
<thead>
<tr>
<th>Step defined physical activity$^b$</th>
<th>Baseline (pre-intervention)</th>
<th>Follow-up (post-intervention)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
<td>C</td>
</tr>
<tr>
<td>Sedentary ($&lt; 5000$ steps/day)</td>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td>Low Active ($5000 - 7499$ steps/day)</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Somewhat Active ($7500 - 9999$ steps/day)</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>Active ($10000 - 12499$ steps/day)</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Highly Active ($\geq 12000$ steps/day)</td>
<td>0</td>
<td>3</td>
</tr>
</tbody>
</table>

Data presented are frequency (%). $^b$: Table adapted from Tudor -Locke et al., (2010). $P$ values for between group comparisons determined using Fisher’s exact tests (alpha = .05). I: Intervention; C: Control.
Table 6. Self-report and objective measures of physical function.

<table>
<thead>
<tr>
<th>Measure of Physical Function</th>
<th>Intervention n = 24</th>
<th>Control n = 17</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>SF-36 Physical function</td>
<td>75.0 (67.5-90.0)</td>
<td>77.5 (67.5-95.0)</td>
</tr>
<tr>
<td>SPPB Total</td>
<td>11.0 (10.0-12.0)</td>
<td>12.0 (11.0-12.0)</td>
</tr>
<tr>
<td>Balance</td>
<td>4.0 (4.0-4.0)</td>
<td>4.0 (4.0-4.0)</td>
</tr>
<tr>
<td>Chair</td>
<td>3.5 (3.0-4.0)</td>
<td>4.0 (3.0-4.0)</td>
</tr>
<tr>
<td>Gait</td>
<td>4.0 (3.0-4.0)</td>
<td>4.0 (3.0-4.0)</td>
</tr>
<tr>
<td>Walking Speed (m/s)β</td>
<td>0.82 (0.76-0.93)</td>
<td>0.90 (0.81-1.06)</td>
</tr>
</tbody>
</table>

Values presented are medians (IQR) unless otherwise noted. P values are from the Wilcoxon signed rank test (within group analyses) and the Wilcoxon rank-sum test (between group analyses). β: p values determined using independent samples t tests for between group differences and paired-samples t tests to evaluate within group differences. p₁: p values calculated for measures within Intervention group; pₑ: p values calculated for measures within Control group; pₑc: p values calculated for change (Δ) variables between groups. SPPB: Short physical performance battery; SF-36-PF: Short-form 36 physical function subscale; m/s: meters/second. *Denotes significance.
Figure 3. Individual changes in walking speed from pre- to post-intervention. Box and whiskers plots: boxes represent median (IQR); whiskers represent minimum and maximum values. Intervention group median: 0.10 (IQR: -0.05-0.25); Control group median: -0.14 (IQR: -0.14-0.05). Differences within the Intervention group from pre- to post-intervention were significant (paired-samples \( t \) test, \( p = .04 \)).

**Quantity of ambulatory behavior**

*Steps per day*

A summary of the average number of steps per day measured at pre- and post-intervention time points is presented in Table 7. Increases in average daily steps from pre- to post-intervention were significant within the Intervention group (\( p = .02 \)). The median increase in steps per day was 976 (IQR: -388-3532) suggesting a 14% increase in average daily steps within the Intervention group compared to a 2% increase (Median = 354; IQR: -658-1300 steps) observed in the Control group. However, differences between groups did not reach significance (Wilcoxon rank-sum: \( p = .19 \)).
Table 7. Average steps/day of participants before and after the 16-week intervention.

<table>
<thead>
<tr>
<th></th>
<th>Intervention (n=24)</th>
<th>Control (n=17)</th>
<th>^aP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7378 (4368-8586)</td>
<td>7732 (5747.7-10022)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>8423 (6001-11063)</td>
<td>7890 (6159-9627)</td>
<td></td>
</tr>
<tr>
<td>Δ</td>
<td>976 (-388-3532)</td>
<td>354 (-658-1300)</td>
<td>^aP_{ic} = .19</td>
</tr>
<tr>
<td>^aP</td>
<td>^aP_{i} = .02*</td>
<td>^aP_{c} = .61</td>
<td></td>
</tr>
</tbody>
</table>

Data presented are median (IQR). ^aP values obtained using Wilcoxon signed-rank tests for within group comparisons (P_i = intervention and P_c = control). Change (Δ) in step counts between groups (P_{ic}) was assessed using Wilcoxon rank-sum test. * Denotes significance (alpha = .05).

Individual differences in average steps per day from pre- to post-intervention are depicted in Figure 4 with upward sloping lines indicating an increase in average daily steps and horizontal or downward sloping lines representing no change or a decrease, respectively. As can be seen in Figure 4, the pre- to post-intervention change was highly variable, especially within the Intervention group.
Figure 4. Individual changes in average daily steps from pre- to post-intervention. Upward sloping lines represent increases in steps per day from pre- to post-intervention. Downward sloping lines represent decreases in average steps/day. * Denotes significance between pre- and post-intervention time points (Wilcoxon signed-rank, $p = .02$).

**Quality of ambulatory behavior**

*Walking cadence in a free-living environment*

Audit of ambulatory behavior was evaluated using peak and average cadence. Pre- and post-intervention values associated with quality of ambulatory behavior are displayed in Table 8. There was a modest increase of 3.8 steps/min (IQR: -5.8-7.7) in peak 1-minute cadence noted in the Intervention group compared to a decrease of 0.87 (IQR: -5.8-7.7) steps/min in the Control group. Between- or within-group comparisons did not reach significance ($p > .05$). Peak 30-minute cadence, defined as the average of the 30 highest peak 1-minute cadence values per day, increased in the intervention group.
by 4.3 steps/minute compared to an increase of 1.9 steps/min in the control group \((p = .03)\). The median increase of 4.3 (IQR: -0.96-16.8) steps/min suggests a persistence of effort, and is roughly equivalent to an additional 130 steps within a 30-minute time period. Differences in the change in average 30- and 10-minute cadence values were observed between Intervention and Control groups \((p < .05)\). Over the highest 30 consecutive minutes of stepping per day (average 30-minute cadence), the Intervention group increased their stepping rate by 5.7 steps/min; suggesting an increase of approximately 171 steps over 30 minutes compared to a decrease of 25 steps observed in the Control group \((p = .03)\). Results also suggest that the Intervention group increased average 10-minute cadence by 4.1 steps/min suggesting an average increase of 41 steps over 10 minutes versus a decrease of 66 steps observed in the control group \((p = .04)\).

The average increase in steps per day was 976 and 354 among the Intervention and Control groups, respectively. The changes in the number of steps taken at cadences of 40 steps/min or above (954 vs. 327 for Intervention vs. Control groups) indicate that the majority (92 – 98%) of the additional steps per day were performed at a purposeful or higher cadence. The changes in the number of steps taken at a medium-intensity walking cadence or higher (≥ 80 steps/min) increased by 71% in the intervention group \((p < 0.01)\) compared to 18% in the Control group. However, there was not enough evidence supporting a between-group difference \((p = .08)\). The amount of time spent engaged in ambulatory behavior (cadence ≥ 20 steps/min) is outlined in Table 9. The median increase of time spent engaged in purposeful or higher intensity movement was 8.48 (IQR: -5.87-8.19) and 6.84 (IQR: -12.00-8.20) minutes per day for the Intervention and Control groups, respectively.
Table 8. Outcomes related to quality of ambulatory behavior.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Intervention (n=24)</th>
<th>Control (n=17)</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Δ</td>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Δ</td>
<td></td>
</tr>
<tr>
<td>Peak 1-min (s/m)</td>
<td>100.8</td>
<td>108.2</td>
<td>3.8</td>
<td>.06</td>
<td>103.0</td>
<td>99.7</td>
<td>-0.87</td>
<td>.86</td>
</tr>
<tr>
<td></td>
<td>(90.3-113.0)</td>
<td>(100.5-115.7)</td>
<td>(-1.9-10.9)</td>
<td></td>
<td>(89.7-110.7)</td>
<td>(96.7-110.8)</td>
<td>(-5.8-7.7)</td>
<td></td>
</tr>
<tr>
<td>Peak 30-minute (s/m)</td>
<td>61.7</td>
<td>78.5</td>
<td>4.3</td>
<td>.03*</td>
<td>63.7</td>
<td>65.6</td>
<td>1.92</td>
<td>.82</td>
</tr>
<tr>
<td></td>
<td>(54.2-85.2)</td>
<td>(61.9-103.2)</td>
<td>(-0.96-16.8)</td>
<td></td>
<td>(59.3-87.9)</td>
<td>(61.3-83.9)</td>
<td>(-4.4-3.9)</td>
<td></td>
</tr>
<tr>
<td>Average 30-minute (s/m)</td>
<td>30.6</td>
<td>60.9</td>
<td>5.7</td>
<td>.01*</td>
<td>41.9</td>
<td>41.7</td>
<td>-0.82</td>
<td>.61</td>
</tr>
<tr>
<td></td>
<td>(25.2-62.3)</td>
<td>(31.4-93.7)</td>
<td>(0.8-30.7)</td>
<td></td>
<td>(30.5-74.6)</td>
<td>(29.7-69.7)</td>
<td>(-6.9-5.0)</td>
<td></td>
</tr>
<tr>
<td>Average 10-minute (s/m)</td>
<td>50.3</td>
<td>73.7</td>
<td>4.14</td>
<td>.02*</td>
<td>61.9</td>
<td>57.9</td>
<td>-6.6</td>
<td>.38</td>
</tr>
<tr>
<td></td>
<td>(42.5-81.7)</td>
<td>(50.6-106.0)</td>
<td>(-1.25-21.8)</td>
<td></td>
<td>(51.0-87.1)</td>
<td>(48.0-82.6)</td>
<td>(-10.0-5.4)</td>
<td></td>
</tr>
<tr>
<td>Steps ≥ 40 s/m (steps)</td>
<td>6860</td>
<td>8104</td>
<td>954</td>
<td>.01*</td>
<td>7141</td>
<td>7411</td>
<td>327</td>
<td>.71</td>
</tr>
<tr>
<td></td>
<td>(4128.3-8183.2)</td>
<td>(5668.6-10647.2)</td>
<td>(-324.8-3355.6)</td>
<td></td>
<td>(5439.7-9437.0)</td>
<td>(5861.0-9217.2)</td>
<td>(-558.33-1230.3)</td>
<td></td>
</tr>
<tr>
<td>Steps ≥ 80 s/m (steps)</td>
<td>4125</td>
<td>6123</td>
<td>679</td>
<td>&lt;.01*</td>
<td>4651</td>
<td>4706</td>
<td>59.1</td>
<td>.89</td>
</tr>
<tr>
<td></td>
<td>(2815.3-6461.2)</td>
<td>(3479.7-8116.5)</td>
<td>(-333.3-2767.0)</td>
<td></td>
<td>(3512.3-6580.7)</td>
<td>(4203.7-7078.8)</td>
<td>(-368.3-764.3)</td>
<td></td>
</tr>
<tr>
<td>Time spent ≥ 40 s/m (min)</td>
<td>90.2</td>
<td>102.3</td>
<td>8.39</td>
<td>.04*</td>
<td>97.4</td>
<td>99.3</td>
<td>6.38</td>
<td>.60</td>
</tr>
<tr>
<td></td>
<td>(54.9-113.0)</td>
<td>(69.7-131.1)</td>
<td>(-5.97-27.8)</td>
<td></td>
<td>(72.6-121.2)</td>
<td>(76.1-117.9)</td>
<td>(-10.3-17.2)</td>
<td></td>
</tr>
<tr>
<td>Time spent ≥ 80 s/m (min)</td>
<td>60.5</td>
<td>74.3</td>
<td>7.8</td>
<td>.02*</td>
<td>66.5</td>
<td>67.1</td>
<td>1.2</td>
<td>.70</td>
</tr>
<tr>
<td></td>
<td>(37.8-77.8)</td>
<td>(50.8-100.3)</td>
<td>(-4.0-24.6)</td>
<td></td>
<td>(49.2-89.5)</td>
<td>(54.5-90.4)</td>
<td>(-7.21-10.7)</td>
<td></td>
</tr>
</tbody>
</table>

Data presented are median (IQR). Wilcoxon rank-sum test used for between-group comparisons and Wilcoxon signed-rank test used for within-group comparisons. \( P_i \): \( p \) values obtained for within Intervention group comparisons; \( P_c \): \( p \) values obtained for Control group comparisons; \( P_{ic} \): \( p \) values obtained for between group comparisons of change (\( \Delta \)) variables. Pre: pre-intervention; post: post-intervention; s/m: steps per minute; IQR: Interquartile range. * Denotes significance (alpha = .05).
Referring to Table 8, the time spent and steps taken in cadence bands indicative of purposeful movement (≥ 40 steps/min) and medium intensity walking (≥ 80 steps/min) increased in both Intervention and Control groups from pre- to post-intervention. Within the Intervention group, the time spent at cadences ≥ 40 steps/min increased from 90.2 to 102.3 minutes per day. However, the proportion of time spent at cadences ≥ 40 steps/min relative to the total time spent in ambulatory activity was 94% for both pre- and post-intervention time points (95.6 to 108.7 minutes total ambulation time pre- to post-intervention), indicating no change within the Intervention group. The Control group also increased time spent in cadences ≥ 40 steps/min from 97.4 to 99.3 minutes per day, suggesting an increase of 4% when considered relative to total time spent engaged in ambulatory activity (109.0 to 106.3 minutes total ambulation time pre- to post-intervention). When evaluating time spent engaged in medium intensity or higher walking (≥80 steps/min) relative to the total time spent ambulating, the Intervention group exhibited an 8% increase from pre- to post-intervention versus a 3% increase observed in the Control group. However, within- (pre- to post-intervention) and between-group differences were not significant when time spent at cadences ≥ 40 and ≥ 80 steps/min were evaluated as respective proportions of total time spent ambulating (p > .05).
Table 9. Time spent engaged in ambulatory behavior.

<table>
<thead>
<tr>
<th></th>
<th>Minutes per day of ambulatory behavior (cadence ≥ 20 steps/min)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Intervention (n=24)</td>
<td>Control (n=17)</td>
</tr>
<tr>
<td>Pre</td>
<td>95.60 (58.20-120.45)</td>
<td>109.00 (77.60-124.80)</td>
</tr>
<tr>
<td>Post</td>
<td>108.72 (72.35-136.30)</td>
<td>106.30 (81.40-127.80)</td>
</tr>
<tr>
<td>Δ</td>
<td>8.48 (-5.87-28.19)</td>
<td>6.84 (-12.0-18.2)</td>
</tr>
</tbody>
</table>

* Denotes significance (alpha = .05).

Data presented are median (IQR). *P: p values obtained using Wilcoxon rank sum for between group comparisons. Wilcoxon signed-rank used for within group comparisons (Pi = intervention and Pc = control). Δ: change.

Cadence bands as patterns of ambulatory behavior

Individual patterns of change in the number of steps and time spent within cadence bands associated with increasing intensities of ambulatory behavior are depicted in Figures 5 and 6, respectively. As can be seen in both figures, the Intervention group appears to have increased both steps and time spent in the cadence bands associated with medium-intensity walking (80-99 steps/min) and moderate-intensity physical activity (100-119 steps/min). This is in contrast to the Control group who appears to have increased the time spent engaged in medium-intensity walking, but decreased steps and time spent at cadences between 100-119 steps/min. However, it should be noted that both groups increased time spent engaged in more vigorous activities (≥ 120 steps/min). It should also be noted that variability among participants appears to have increased with increasing intensity.
Figure 5. Individual changes in average daily steps within cadence bands associated with intensity of ambulatory behavior. * Denotes significant difference between Intervention and Control groups at cadences between 100-119 steps/min (Wilcoxon rank-sum, $p < .01$). Magenta bars represent median differences for each cadence band across groups.
Figure 6. Individual changes in time spent within cadence bands associated with intensity of ambulatory behavior. * Denotes significant difference between Intervention and Control groups at cadences between 100-119 steps/min (Wilcoxon rank-sum, p = .02). Magenta bars represent median differences for each cadence band across groups.

Steps taken and time spent within cadence bands associated with increasing intensities of ambulatory behavior are highlighted in Tables 10 and 11, respectively.
Results from the repeated measures ANOVA with six cadence bands suggested a significant interaction of the intervention on cadence bands for both steps and time ($p < .001$). As can be seen in Tables 10 and 11, the Intervention group decreased time spent and steps taken at cadence bands $< 100$ steps/min, with one exception being a nominal increase of 4 steps taken within the cadence band associated with slow walking (60-79 steps/min). The Control group appears to have increased time spent and steps taken in all cadence bands except for the cadence band associated with brisk walking and moderate physical activity (100-119 steps/min). Post-hoc tests determined a significant difference between groups for cadences between 100-119 steps/min for steps (Wilcoxon rank-sum, $p < .01$) and time (Wilcoxon rank-sum, $p = .02$). No other between-group differences were noted regarding changes in time spent and steps taken within cadence bands.

Additional inquiry into time spent at cadences between 100-119 steps/min suggests that on average, nine participants in the intervention group (~38%) increased the time spent engaged in moderate intensity PA by 10 minutes or more compared to zero participants in the Control group (Fisher’s exact, $p = .01$).
Table 10. Number of steps taken within cadence bands.

<table>
<thead>
<tr>
<th>Steps/min</th>
<th>Sporadic Movement</th>
<th>Purposeful Steps</th>
<th>Slow Walking</th>
<th>Medium Walking</th>
<th>Brisk Walking</th>
<th>Fast Locomotion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20-39</td>
<td>40-59</td>
<td>60-79</td>
<td>80-99</td>
<td>100-119*</td>
<td>≥ 120</td>
</tr>
<tr>
<td>Pre</td>
<td>327 (266.5-516.8)</td>
<td>677 (541.2-980.8)</td>
<td>1030 (791.2-1364.3)</td>
<td>1826 (1447.5-2341.6)</td>
<td>1488 (827.7-2912.3)</td>
<td>103 (44.8-782.2)</td>
</tr>
<tr>
<td>I</td>
<td>346 (231.2-498.2)</td>
<td>711 (479.8-1102.5)</td>
<td>1021 (775.5-1601.2)</td>
<td>1925 (1479.3-3201.0)</td>
<td>3013 (1424.0-4190.0)</td>
<td>245 (45.9-1018.0)</td>
</tr>
<tr>
<td>Post</td>
<td>346 (231.2-498.2)</td>
<td>711 (479.8-1102.5)</td>
<td>1021 (775.5-1601.2)</td>
<td>1925 (1479.3-3201.0)</td>
<td>3013 (1424.0-4190.0)</td>
<td>245 (45.9-1018.0)</td>
</tr>
<tr>
<td>∆</td>
<td>-12 (-52.5-31.2)</td>
<td>-8 (-100.3-76.7)</td>
<td>4 (-160.8-238.1)</td>
<td>-29 (-269.8-469.8)</td>
<td>478 (-121.3-1843.7)</td>
<td>15 (-20.4-362.3)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Steps/min</th>
<th>Sporadic Movement</th>
<th>Purposeful Steps</th>
<th>Slow Walking</th>
<th>Medium Walking</th>
<th>Brisk Walking</th>
<th>Fast Locomotion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20-39</td>
<td>40-59</td>
<td>60-79</td>
<td>80-99</td>
<td>100-119*</td>
<td>≥ 120</td>
</tr>
<tr>
<td>Pre</td>
<td>351 (293.0-584.7)</td>
<td>771 (657.3-1139.7)</td>
<td>1185 (995.7-1580.3)</td>
<td>2286 (2089.0-3099.3)</td>
<td>2088 (1657.7-2967.7)</td>
<td>106 (71.3-193.7)</td>
</tr>
<tr>
<td>C</td>
<td>425 (346.7-556.8)</td>
<td>915 (747.0-1023.2)</td>
<td>1249 (1039.3-1629.7)</td>
<td>2462 (1949.7-3758.7)</td>
<td>1996 (1165.3-2316.9)</td>
<td>121 (78.7-205.3)</td>
</tr>
<tr>
<td>Post</td>
<td>425 (346.7-556.8)</td>
<td>915 (747.0-1023.2)</td>
<td>1249 (1039.3-1629.7)</td>
<td>2462 (1949.7-3758.7)</td>
<td>1996 (1165.3-2316.9)</td>
<td>121 (78.7-205.3)</td>
</tr>
<tr>
<td>∆</td>
<td>-100.0-113.0</td>
<td>-149.3-226.0</td>
<td>-176.0-305.1</td>
<td>-139.3-867.9</td>
<td>-509.5-180.8</td>
<td>-27.0-79.0</td>
</tr>
</tbody>
</table>

Data presented are median (IQR). ∆: represents change from pre- to post-intervention. Repeated measures ANOVA suggested a significant interaction of group and cadence bands (p < .001). *: Post-hoc tests indicate a significant difference between group for steps taken between 100-119 steps/min (Wilcoxon rank-sum, p < .01). ANOVA: Analysis of variance.
Table 11. Time spent in cadence bands indicative of ambulatory behavior.

<table>
<thead>
<tr>
<th>Steps/min</th>
<th>Sporadic Movement 20-39</th>
<th>Purposeful Steps 40-59</th>
<th>Slow Walking 60-79</th>
<th>Medium Walking 80-99</th>
<th>Brisk Walking 100-119</th>
<th>Fast Locomotion ≥ 120</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pre</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(min)</td>
<td>4.3</td>
<td>8.5</td>
<td>12.7</td>
<td>23.7</td>
<td>20.1</td>
<td>1.4</td>
</tr>
<tr>
<td></td>
<td>(3.4-7.1)</td>
<td>(7.2-13.6)</td>
<td>(10.9-18.8)</td>
<td>(18.7-30.3)</td>
<td>(11.5-36.5)</td>
<td>(0.6-9.3)</td>
</tr>
<tr>
<td><strong>Post</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(min)</td>
<td>4.3</td>
<td>8.9</td>
<td>12.9</td>
<td>22.0</td>
<td>37.7</td>
<td>3.2</td>
</tr>
<tr>
<td></td>
<td>(2.8-6.5)</td>
<td>(6.0-14.1)</td>
<td>(9.4-20.6)</td>
<td>(19.7-42.7)</td>
<td>(19.0-47.6)</td>
<td>(0.7-12.3)</td>
</tr>
<tr>
<td><strong>Δ</strong></td>
<td>-0.4</td>
<td>-0.7</td>
<td>-0.3</td>
<td>-1.5</td>
<td>3.6</td>
<td>0.1</td>
</tr>
<tr>
<td>(min)</td>
<td>(-1.0-0.4)</td>
<td>(-1.9-0.8)</td>
<td>(-2.6-2.5)</td>
<td>(-5.3-5.9)</td>
<td>(-1.9-21.9)</td>
<td>(-0.3-4.2)</td>
</tr>
<tr>
<td><strong>C</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pre</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(min)</td>
<td>5.0</td>
<td>10.1</td>
<td>14.7</td>
<td>33.0</td>
<td>26.4</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>(3.6-8.0)</td>
<td>(8.0-16.9)</td>
<td>(14.1-21.7)</td>
<td>(25.7-43.9)</td>
<td>(21.3-37.7)</td>
<td>(1.1-2.5)</td>
</tr>
<tr>
<td><strong>Post</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(min)</td>
<td>5.3</td>
<td>11.1</td>
<td>17.5</td>
<td>34.8</td>
<td>26.3</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>(4.7-7.1)</td>
<td>(10.8-14.3)</td>
<td>(14.7-20.2)</td>
<td>(25.6-51.6)</td>
<td>(15.9-29.5)</td>
<td>(1.0-2.6)</td>
</tr>
<tr>
<td><strong>Δ</strong></td>
<td>0.9</td>
<td>1.0</td>
<td>3.0</td>
<td>4.3</td>
<td>-0.9</td>
<td>0.3</td>
</tr>
<tr>
<td>(min)</td>
<td>(-1.5-1.7)</td>
<td>(-2.5-3.3)</td>
<td>(-3.1-5.1)</td>
<td>(-1.8-12.8)</td>
<td>(-7.1-3.5)</td>
<td>(-0.3-4.0)</td>
</tr>
</tbody>
</table>

Data presented are median (IQR). Δ: represents change from pre- to post-intervention. ß: Repeated measures ANOVA suggested a significant interaction of group and cadence bands (p <.001). Unlike steps taken, between-group comparisons for time spent stepping between 100-119 steps/min were not significant (Wilcoxon rank-sum, p=.02). ANOVA: Analysis of variance.
Spearman’s rank correlations were conducted to determine the degree to which baseline physical activity (PA) and physical function (PF) may have influenced changes in cadence variables within the Intervention group. These results are presented in Table 12. There were negligible associations ($r_s \leq \pm 0.30$) between baseline physical function (PF score), physical performance (SPPB score), and walking speed with change in cadence variables. However, there were moderate inverse correlations ($r_s = -0.43$ to $-0.60$) between average daily steps at baseline and changes in peak and average cadence values.

Associations between baseline physical activity (average daily steps) and change in cadence are presented in Figure 7. As can be seen in Figure 7, individuals with the lowest average daily steps at baseline had the largest improvement in peak and average cadence.

Table 12. Correlations between baseline PF values and change in cadence outcomes.

<table>
<thead>
<tr>
<th>Cadence Variables (s/m)</th>
<th>Baseline Variables</th>
<th>PF (score)</th>
<th>SPPB (score)</th>
<th>Walking Speed (m/s)</th>
<th>Daily Steps (steps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Δ Peak 1-min</td>
<td></td>
<td>.09</td>
<td>-.06</td>
<td>-.11</td>
<td>-.60</td>
</tr>
<tr>
<td>Δ Peak 30-min</td>
<td></td>
<td>.11</td>
<td>-.01</td>
<td>.01</td>
<td>-.54</td>
</tr>
<tr>
<td>Δ 10-min&lt;sub&gt;ave&lt;/sub&gt;</td>
<td></td>
<td>.21</td>
<td>.01</td>
<td>-.03</td>
<td>-.45</td>
</tr>
<tr>
<td>Δ 30-min&lt;sub&gt;ave&lt;/sub&gt;</td>
<td></td>
<td>.18</td>
<td>-.04</td>
<td>.00</td>
<td>-.43</td>
</tr>
<tr>
<td>Δ 80+</td>
<td></td>
<td>.13</td>
<td>.06</td>
<td>.05</td>
<td>-.24</td>
</tr>
</tbody>
</table>

Data presented are Spearman’s rank correlation values. Correlations were conducted to examine the associations between baseline physical function and baseline physical activity on change (Δ) in cadence variables. PF: Physical function (SF-36-PF); SPPB: Short Physical Performance Battery; s/m: steps per minute; 80+: Steps taken at a cadence greater than or equal to 80 steps/min; ave: average. Moderate $\pm$ (0.4 to 0.6) correlations in bold.
Figure 7. Correlations between baseline steps and changes in cadence variables. $r_s$:
Spearman’s rank correlation defined as: Weak $r_s: \pm (0.00$ to $< 0.40$); Moderate $r_s: \pm (0.4$ to $< 0.6$); Strong $r_s: \pm (0.6$ to $< 0.8)$. 
Room for improvement - potential ceiling effect

It is possible that some participants within the Intervention group experienced a ceiling effect, in that those characterized as having high PF or PA at baseline did not demonstrate an appreciable change in peak and average cadence. Likewise, those who scored low on the SPPB test of lower-extremity PF may have had more to gain from a light-intensity PA intervention and therefore responded with greater increases in walking cadence. The influence of the intervention on the change in peak- and average-cadence variables were reevaluated between participants with room for improvement (SPPB ≤ 10) and those with little-to-no room for improvement (SPPB > 10). Eight of the 24 participants in the Intervention group were found to have SPPB scores ≤ 10 and have been classified as having ‘room for improvement’ versus the remaining 16 participants with ‘less room for improvement’. Median (IQR) values for peak- and average-cadence variables are presented in Table 13, and individual changes in cadence variables are depicted in Figure 8. Median peak- and average-cadence values increased in both subsets of the Intervention group, and appear to be greater among those with room for improvement. However, while p-values for within- and between-groups are reported, results should be interpreted with caution as there is insufficient data to detect any but the largest differences. Also, as can be seen in Figure 8, there appears to be greater variability among the eight participants with room for improvement, further obscuring any notable trends.
Table 13. Change in peak and average cadence in participants with or without much room for improvement.

<table>
<thead>
<tr>
<th>Cadence Variable</th>
<th>Room for improvement ((n=8))</th>
<th>Less room for improvement ((n=16))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(\Delta) pre-to post-</td>
<td>(\Delta) pre-to post-</td>
</tr>
<tr>
<td>peak 1-min (s/m)</td>
<td>8.57 (8.17-18.83)</td>
<td>3.10 (-1.17-7.93)</td>
</tr>
<tr>
<td>peak 30-min (s/m)</td>
<td>9.57 (-8.83-41.03)</td>
<td>4.29 (-0.74-11.37)</td>
</tr>
<tr>
<td>ave-10 (s/m)</td>
<td>13.83 (-9.19-51.87)</td>
<td>4.14 (0.35-11.96)</td>
</tr>
<tr>
<td>ave-30 (s/m)</td>
<td>19.26 (-7.01-50.44)</td>
<td>5.72 (1.89-9.64)</td>
</tr>
</tbody>
</table>

Participants were classified as having room for improvement based on SPPB score \(\leq 10\). Data presented are median (IQR). \(^a\)\(P\): \(p\) values obtained using Wilcoxon signed-rank tests for within group comparisons and \(^\beta\)\(P\) for between group comparisons. \(P_{ri}\): \(p\)-values for within the group with room for improvement; \(P_{nori}\): \(p\)-values for within group with less room for improvement; \(P_{bg}\): \(p\)-values for between groups with and without room for improvement. \(\Delta\): change. * Denotes significance (alpha = .05).

Figure 8. Changes in cadence values based on those with or without room for improvement. Magenta bars represent median (IQR). Open circles represent individuals with room for improvement as determined by SPPB score of \(\leq 10\). Solid circles represent individuals with less room for improvement based on SPPB score of \(>10\). \(\Delta\): change.
Influence of change in average daily steps on change in peak and average cadence

In healthy adults, peak 1- and 30-minute cadence values tend to increase as steps/day defined physical activity categories increase (Tudor-Locke et al., 2012). There was a median change of 976 (-388-3532) steps noted within the Intervention group, a value below the 2000 to 2500 step increase observed in pedometer based interventions (Kang, Marshall, Barreira, & Lee, 2009), however, not unlike Barreira, et al., who observed a mean increase of just 1063 steps in a population of overweight adults taking part in a physical activity, diet, and behavior change intervention (Barreira et al., 2016). Given the relationship between steps per day and walking cadence, we sought to evaluate whether changes in average daily steps influenced changes in peak and average cadence. The associations between the change in average daily steps and peak- and average-cadence for the Intervention group are presented in Figure 9. There was a moderate correlation (Spearman’s rank correlation: $r_s = .46$) between the change in average daily steps and change in peak 1-minute cadence. However, there were strong correlations ($r_s = .63$ to $.69$) between change in average daily steps and changes in peak-30 minute and average 10- and 30-minute cadence values, suggesting that individuals who had a greater change in average daily steps also increased their free-living walking speed.
Figure 9. Associations between change in average daily steps and change in cadence values. Solid circles represent Intervention group participants. $r_s$: Spearman’s rank correlation defined as: Weak $r_s: \pm (0.00$ to $< 0.40)$; Moderate $r_s = \pm (0.4$ to $< 0.6)$; Strong $r_s = \pm (0.6$ to $< 0.8)$.

**Changes in cadence without appreciable change in steps**

Even without an appreciable change in average daily steps, participants could increase their intensity thereby contributing to an overall increase in daily volume of physical activity. To investigate this further, data for change in average daily steps from the Intervention group participants were rank-ordered and subdivided by quintiles (Figure 10). Participants without an appreciable change in steps were determined as having a
change in average daily steps within 1000 steps from their baseline values, representing
the second and third quintiles ($n = 10$). The numbers of participants and change in
average daily steps associated with each quintile are presented in Table 14. Time spent
and steps taken within cadence bands associated with intensity of human locomotion
were then re-evaluated to determine if individuals without an appreciable change in steps
increased their intensity of ambulatory behavior despite not having increased their
average daily steps from baseline. These data are presented in Table 15. There was a
median decrease of 90 (IQR: -412-493) steps per day in addition to decreases in the
number of steps taken within cadence bands representing sporadic movement (20-39
steps/min) through medium-intensity walking (80-99 steps/min). In general, the number
of steps taken at a moderate-intensity (100-119 steps/min) increased by 223 (IQR: -188-
497) steps. Similar trends were observed regarding time spent engaged in ambulatory
behavior which decreased by 2.53 (IQR: -7.20-1.84) minutes. There appears to be a
displacement of time spent and steps taken in cadence bands associated with lower
intensity physical activity. However, the amount of time engaged in moderate-intensity
PA appears to have only increased by 1 minute (IQR: -2.63-7.47). Also, there does not
appear to be a substantial change in the amount of time spent and steps taken at a more
vigorous intensity (≥ 120 steps/min).
Figure 10. Assessment of Intervention group participants without an appreciable change in steps. Labels 1-5 refer to quintiles; values reported are participants’ change in average daily steps from pre- to post-intervention.

Table 14. Distribution of Intervention group’s change in average daily steps arranged by quintile.

<table>
<thead>
<tr>
<th>Quintile</th>
<th>1 (Min)</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Δ Steps</td>
<td>-2654</td>
<td>-901</td>
<td>69</td>
<td>1048</td>
<td>3356</td>
<td>11770</td>
</tr>
<tr>
<td>Participants per quintile</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

Values represented are lowest values within range for each quintile. Min: minimum value; Max: maximum value. Δ: change.
Table 15. Change in average daily steps within cadence bands.

<table>
<thead>
<tr>
<th></th>
<th>Total Δ</th>
<th>20-39 s/m</th>
<th>40-59 s/m</th>
<th>60-79 s/m</th>
<th>80-99 s/m</th>
<th>100-119 s/m</th>
<th>120 s/m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Δ Steps</td>
<td>-90</td>
<td>-43</td>
<td>-68</td>
<td>-64</td>
<td>-117</td>
<td>223</td>
<td>1</td>
</tr>
<tr>
<td>Δ Time (min)</td>
<td>-2.53</td>
<td>-0.73</td>
<td>-1.21</td>
<td>-0.67</td>
<td>-2.07</td>
<td>1.12</td>
<td>0.00</td>
</tr>
</tbody>
</table>
|                  | (-7.20-1.84) | (-1.03-0.06) | (-2.17-0.61) | (-2.30-1.77) | (-5.52-0.04) | (-2.63-7.47) | (-0.56-1.45) |}

Data presented are for Intervention group participants without a discernable change in average daily steps as defined as a change in steps within 1000 steps of baseline value. Data presented are median (IQR). Δ: represents change from pre- to post-intervention. s/m: steps/min
Chapter 5

Discussion

The purpose of this investigation was to evaluate whether a 16-week, light-intensity physical activity (LPA) intervention targeted at disrupting sedentary time with bouts of LPA such as standing and light stepping, resulted in increased walking cadence. We also sought to determine whether or not baseline physical activity (PA) and physical function (PF) influenced the study outcomes. There were two sets of hypotheses tested. The first was to evaluate changes in cadence patterns associated with varying levels of movement (walking) intensity, including time spent and steps taken in cadences associated with purposeful movement (≥ 40 steps/min) and medium intensity walking (≥ 80 steps/min). The second was to evaluate changes in peak- and average-cadence indices. A summary of hypotheses statements and outcomes is presented in Table 16. These hypotheses were highly dependent on the assumption that the Intervention group increased their steps more than the Control group.

When considering the relative change in time spent and steps taken at cadences associated with purposeful movement (≥ 40 steps/min) and medium intensity walking (≥ 80 steps/min) between-group differences were not significant. Consequently, our hypotheses (Hypotheses 1a-b) were not supported. Investigations on sedentary behavior (SB) and physical activity indicate that most adults spend a large portion of the day engaged in SB or ambulating at very low cadences (≤ 40 steps/min) (Tudor-Locke, Camhi, et al., 2011; Tudor-Locke, Craig, Aoyagi, et al., 2011). Given the nature of the intervention (i.e. increase in daily step goal and reminder to move feature of the Jawbone
activity monitor) we had speculated that participants in the Intervention group would spend more time engaged in more purposeful movement (≥ 40 steps/min).
<table>
<thead>
<tr>
<th>HYPOTHESIS STATEMENT</th>
<th>SUPPORTED?</th>
<th>P-VALUE</th>
<th>FINDING</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a There will be a significant increase in the number of steps per day and time spent in cadence bands indicative of purposeful stepping (≥ 40 steps/minute) in the Intervention group compared to the Control group.</td>
<td>No</td>
<td>0.15 (steps)</td>
<td>0.35 (time)</td>
</tr>
<tr>
<td>1b There will be a significant increase in the number of steps per day and time spent in cadence bands indicative of medium-intensity walking (≥ 80 steps/minute) in the Intervention group compared to the Control group.</td>
<td>No</td>
<td>0.08 (steps)</td>
<td>0.15 (time)</td>
</tr>
<tr>
<td>1c There will be a significant redistribution of steps from lower cadence bands to higher cadence bands over the 16-week intervention among the Intervention compared to the Control group.</td>
<td>Yes*</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>1d There will be a significant redistribution of time spent from lower cadence bands to higher cadence bands over the 16-week intervention among the intervention compared to the Control group.</td>
<td>Yes*</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td>HYPOTHESIS STATEMENT</td>
<td>SUPPORTED?</td>
<td>P-VALUE</td>
<td>FINDING</td>
</tr>
<tr>
<td>----------------------</td>
<td>------------</td>
<td>---------</td>
<td>---------</td>
</tr>
<tr>
<td>2a There will be a significant increase in peak 1-minute cadence over the 16-week trial among the Intervention compared to the Control group.</td>
<td>No</td>
<td>0.18</td>
<td>There was not enough evidence to support that the Intervention group had a greater increase in peak 1-minute cadence compared to the Control group.</td>
</tr>
<tr>
<td>2b There will be a significant increase in peak 30-minute cadence over the 16-week trial among the Intervention compared to the Control group.</td>
<td>Yes</td>
<td>0.03</td>
<td>Results suggest that peak 30-minute cadence increased in the intervention compared to the control group. Median increase within Intervention group was 4.3 (IQR: -0.96 - 16.8) steps/min compared to 1.92 (IQR:-4.4 - 3.9) steps/min in Control.</td>
</tr>
<tr>
<td>2c There will be a significant increase in average 30-minute cadence over the 16-week trial among the Intervention group compared to the Control group.</td>
<td>Yes</td>
<td>0.03</td>
<td>Results suggest that average 30-minute cadence increased in the Intervention compared to the control Group. Median increase in Intervention group was 5.7 (IQR: 0.8-30.7) steps/min compared to -0.82 (IQR-6.9-5.0) steps/min in Control.</td>
</tr>
<tr>
<td>2d There will be a significant increase in average 10-minute cadence over the 16-week intervention among the intervention group compared to the Control group.</td>
<td>Yes</td>
<td>0.04</td>
<td>Results suggest that average 10-minute cadence increased in the Intervention compared to the control group. Median increase in Intervention group was 4.14 (IQR: -1.25-21.8) steps/min compared to -6.6 (IQR-10.0-5.4) steps/min in Control.</td>
</tr>
</tbody>
</table>

* Although results from the repeated measures analysis of variance suggested the influence of group on cadence bands for both steps and time (p < .001), there is not enough evidence to support the displacement of time spent or number of steps taken in cadence bands of lower intensity to those of higher intensity.
While participants in the Intervention group did show a significant increase in the number of steps or time spent stepping at cadences ≥ 40 steps/min, participants in the Control group also increased in steps and time. Thus, differences between groups were not statistically significant. It is possible that any differences between groups were obfuscated by a wide range of activities that could occur at cadences upwards of 40 steps/minute, including several different intensities of walking that may not be influenced by the intervention. We had anticipated that although participants were not given explicit instructions on how they should achieve their daily step goal, they may have chosen to ambulate at an intensity at least coincident with medium-intensity walking. The change in steps and time taken at cadences ≥ 80 steps/min was significant within the Intervention group, but with a positive change in the Control group, we did not find a significant difference between groups.

We had hypothesized that there would be a displacement of time spent and steps taken from cadence bands associated with lower to those of higher intensities (Hypotheses 1c-d). While there was an indication of a significant interaction between groups and cadence bands, the only significant between group difference was noted in the cadence band associated with MPA (100-119 steps/min), in which the Intervention group increased by 478 steps (3.6 minutes) and the Control group decreased by 92 steps (~ 0.9 minutes). However, results as outlined in chapter 4, Tables 10 and 11 are suggestive of a reduction in steps taken and time spent at cadences < 80 steps/min within the Intervention group; one exception being for steps taken at 60-79 steps/min where the Intervention group showed a nominal increase of 4 steps. The only decrease noted in the Control group was for steps taken at 100-119 steps/min. However, there was an increase in both
time and steps taken at slow (60-79 steps/min) and medium (80-99) walking. One possible explanation for these findings is that the increase in slow and medium walking noted in the Control group came at the expense of brisk walking (100-119 steps/min). This could be due to seasonal effects occurring over the 16-week intervention that may have less of an impact in the Intervention group due to certain motivational factors, such as a feeling of obligation as a study participant, or the additional motivation and support provided by the Intervention team. However, at this time and without sufficient evidence, it would be presumptuous to state that individuals in the Control group were less motivated to ambulate at a higher intensity, or rather that due to seasonal affects (i.e. warmer weather), participants were not participating in typical walking pursuits. Further investigation as to the influence of seasonal changes and influential factors from the Intervention such as motivation and support are warranted.

Peak 1-minute cadence represents the highest number of steps per minute in a single day and may represent one’s ‘best natural effort’, or rather the free-living walking cadence for which an individual is capable. We had hypothesized that there would be a significant difference in change in peak 1-minute cadence due to the intervention, and that participants within the Intervention group would significantly increase their peak 1-minute cadence (Hypothesis 2a). Peak 1-minute cadence is highly dependent on age, physical activity level (i.e. steps/day), physical function and body mass index (BMI) (Tudor-Locke & Rowe, 2012; Tudor-Locke et al., 2017). Analyses of cross-sectional data have indicated that, on average, peak 1-minute cadence in healthy adults (< 60 years of age) is approximately 100 steps/min and can be lower (94.2 to 81.5 steps/min) in older (>70 years), or relatively unhealthy adults (Tudor-Locke et al., 2018). While eighty
percent of MY Health Study participants included in these analyses were classified as overweight to obese (BMI \( \geq 25.00 \text{ kg/m}^2 \)), both self-report and objective measures of physical function indicated an above average to high level of physical functioning. Slow-to very-slow walking cadences of 68 to 88 steps per minute have been found among sedentary (<5000 steps/day) to very sedentary (\( \leq 2500 \text{ steps/day} \)) individuals, often concomitant with advanced age and chronic illness (Schuna et al., 2013; Slaght, Senechal, Hrubeniuk, Mayo, & Bouchard, 2017; Tudor-Locke & Rowe, 2012). However, over 70% of MY Health Study participants were classified as low-active (5000 – 7499 steps/day) to highly active (\( \geq 12000 \text{ steps/day} \)) pre-intervention. Therefore, it was not surprising that median peak cadence values for both groups were greater than 100 steps/min at baseline. Consequently, our hypothesis was not supported, and while changes in peak 1-minute cadence approached significance within the Intervention group, there were no significant differences between groups after the intervention. This may be attributed to the already high peak 1-minute cadence exhibited amongst participants at baseline, potentially leaving very little room to increase step accumulation within such a brief (1-minute) period.

In contrast to the peak 1-minute cadence, peak 30-minute cadence is considered a metric of ‘persistence of effort’ and defined as the average of the highest 30 peak 1-minute cadence values per day. It has been suggested that peak 30-minute cadence may be more characteristic of true behavior change compared to peak 1-minute cadence, which can vary greatly within an individual from day-to-day (Barreira et al., 2016). Our hypothesis that change in peak 30-minute cadence would be significant between groups was supported (Hypothesis 2b), a finding coincident with interventions using walking
behavior (or increased steps/day) as a means to increase physical activity (Barreira et al., 2016; Gardner et al., 2011). Although there were no specific guidelines regarding intensity or duration of physical activity, we had speculated that MY Health Study participants might self-select to move at a faster cadence as their intention to move (i.e. increase their daily steps) increased. Follow-up interviews with study participants are currently underway to gain insight as to motivating factors and/or strategies used by participants throughout the intervention to accomplish their daily PA goals.

Significant increases between groups were noted for average 10- and 30-minute cadence variables. We had hypothesized that average 30-minute cadence values would increase (Hypotheses 2c), the rationale being that as participants replaced sedentary time with standing or light stepping, and/or took more steps throughout the day, leg strength may increase leading to more stepping and a subsequent increase in endurance. We did not suggest to participants that they achieve their daily step goal in 30 consecutive minutes, but we did suggest that they increase their daily steps by 3000 above baseline over the course of the intervention. The motivation to achieve 3000 steps above baseline coupled with our initial findings that suggest participants self-selected a walking cadence between 100-119 steps/min could mean that at least some participants within the Intervention group achieved 30 minutes of MPA most days of the week (100 steps/min times 30 minutes = 3000 steps) without being explicitly coached to do so. However, if this were the case for the majority of Intervention participants, we would expect their average 30-minute cadence post-intervention to approach 100 steps/min. While average 30-minute cadence did not approach 100 steps/min within the Intervention group, it nearly doubled from pre- to post-intervention (from median = 30.6; IQR: 25.2-62.3 to
median = 60.9; IQR 31.4-93.7 steps/min). The overall change in average cadence among the Intervention group is an exciting finding as it may suggest an increase in endurance, especially in those participants with lower physical function at baseline. However, we did not fully investigate as to whether this increase in endurance was due to an increase in leg strength. Interventions utilizing accelerometers to measure changes in cadence variables are still quite novel and future investigations should further explore potential causes of increases in free-living cadence metrics.

Given that some clinical populations or those with reduced physical capacity may find long bouts of continuous walking difficult or unfeasible, we speculated that participants may choose to achieve their daily step goals in shorter bouts, and that average 10-minute cadence would increase among the Intervention group compared to the Control group (Hypothesis 2d). Our hypothesis was supported, and according to our results, the participants in the Intervention group increased average 10-minute cadence by a little more than 4 steps/min. Ten minutes was selected as it is the recommendation of the American College of Sports Medicine to achieve one’s weekly dose of MVPA (150 minutes/week or 30 minutes most days of the week) in bouts of 10 or more consecutive minutes. However, cross-sectional analyses of PA measured objectively (Actical accelerometer) from the Framingham Heart Study (FHS) suggest that shorter bouts (< 10 minutes) may still offer cardio protective benefits and have a positive impact on BMI, waist circumference, triglycerides, and cholesterol so long as the recommended minimum of ≥ 150 minutes/week is met (Glazer et al., 2013). However, these findings may not be representative of all populations as the mean age of participants in the third generation of the FHS were approximately 47 years old (55% women) and mostly white. The authors
did express that other lifestyle factors such as physical fitness, and dietary habits were not considered in their analyses. More longitudinal and randomized controlled trials are needed to more fully examine the effects of shorter bouts (< 10 minutes) of PA on health outcomes.

**Influence of baseline physical activity and physical function on cadence outcomes**

We found negligible associations between baseline PF and change in peak and average cadence variables. This is likely due to the already high physical function status of participants as determined by the SF-36 self-report physical function questionnaire and short physical performance battery (SPPB). However, closer examination of those participants with room for improvement (Chapter 3, Figure 9 and Table 12) suggests a relatively large improvement in cadence variables for those individuals scoring ≤ 10 points on the SPPB. Ceiling effects may occur in higher functioning older adults suggesting that the scoring mechanism used in the SPPB may lack the precision to detect subtle differences in physical function (Balasubramanian, 2015; Sayers, Guralnik, Newman, Brach, & Fielding, 2006). However, our results suggest that even without substantial room for improvement, several participants did experience an increase in peak- and average-walking cadence.

There were moderate inverse correlations between baseline physical activity (steps/day) and changes in peak and average cadence variables, suggesting that individuals with fewer steps at baseline may have benefited more from the intervention than their more physically active counterparts. These findings (highlighted in Chapter 3, Figure 8) point to a potential ceiling effect, where individuals who have a high number of steps at baseline were unable to show substantial increases in peak and average cadence.
One possible reason for these findings is that these individuals are likely habitually physically active and are more likely to partake in walking for leisure/fitness than their more sedentary counterparts. Without having given any particular instructions as to increasing their intensity of ambulation throughout the intervention, it is probable that these already active individuals were ambulating at their comfortable pace. However, the increases in peak- and average-cadence among those with reduced PA at baseline highlight the potential for interventions like the MY Health Study to be a valuable prescription for those individuals classified as sedentary (<5000 steps/day).

Additional findings

In addition to the aforementioned conclusions, we found that participants within the Intervention group who did not show an appreciable change in steps from pre- to post-intervention (within 1000 steps/day from baseline measurement) did increase their time spent (Median: 1.2; IQR: -2.62-7.47 minutes) and steps taken (Median: 223; IQR: -188-497 steps) between 100-119 steps/min, the intensity associated with moderate physical activity. The advantage to conducting an analyses of patterns of daily ambulatory behavior (i.e. intensity) in addition to evaluating changes in quantity (i.e. number of steps per day) is that even without an appreciable change in average daily steps, individuals could increase their intensity thereby contributing to an overall increase in daily volume of physical activity. This has important implications for physical activity interventions where the primary outcome is an increase of daily steps. As we and others have shown, relying on quantity of PA alone excludes valuable details about an intervention, potentially leading to erroneous conclusions and misinforming future interventions (Barreira et al., 2016).
We separated the Intervention group into those with *room for improvement* and those with *little to no room for improvement* based on an SPPB score of $\leq 10$ (room for improvement). Although not statistically powered to see all but the largest changes, the *room for improvement* group showed relatively large increases in median peak- and average-cadence variables compared to the *little to no room for improvement* group. As can be seen in Figure 9 from Chapter 4, there was a large amount of variability amongst the participants within the Intervention group, especially the eight participants with room for improvement. This could certainly obscure any within group differences but as noted in the results, there was a two- to three-fold increase in peak- and average-cadence values observed in those individuals with baseline SPPB $\leq 10$. While this could indicate a potentially meaningful improvement in cadence variables, further investigation is warranted. It would also be interesting to know more about the individuals within the Intervention group that failed to demonstrate increases in peak- and average-cadence despite having room for improvement. It is possible that a participant had a substantial change in health status over the course of the 16-week intervention, or perhaps non-compliance was a factor. These factors could certainly influence our findings and if possible should be examined further, if for no reason other than to inform future interventions.

We further evaluated the associations between change in average daily steps and changes in peak- and average-cadence variables. There were moderate to strong correlations suggesting that those who increased their daily steps took those steps at a faster cadence. Cross-sectional analyses and interventions targeting clinical populations have demonstrated a strong relationship between average daily step count and habitual
cadence. Therefore our results are not surprising. However, further investigation as to motivational factors could provide additional insights as to the nature of these increases and the causal influence of daily steps on free-living walking cadence.

Perhaps one of the most clinically meaningful findings in these analyses is the median increase in walking speed of 0.10 (IQR: -0.05-0.25) m/s observed in the Intervention group from pre- to post-intervention. Usual walking speeds slower than 0.8 m/s are highly correlated with future mobility deficits, fall risk, morbidity and mortality (Studenski et al., 2011). In a sample of older adults at high risk for future disability engaged in a lifestyle and physical activity intervention, Kwon et al. (2009), determined that an increase in usual walking speed of 0.08 m/s should be considered a clinically meaningful change in gait speed, potentially reducing one’s risk for future mobility disability.

Limitations

Although carefully executed, this study was not without limitations. This was a secondary analysis of an intervention where outcomes related to free-living walking cadence were not considered in the original study design. This was a feasibility study and thus was not statistically powered to detect moderate to large differences between the Intervention and Control groups. A potential limitation is the inclusion of individuals with high physical functioning and physical activity levels at baseline. Nevertheless, improvements in endurance and persistence of effort were observed.

Strengths

This is one of the few interventions to evaluate cadence in a free-living population. Moreover, these analyses included the evaluation of change in cadence
among older cancer survivors with multiple comorbidities. Physical activity was objectively assessed using the ActivePAL3 activity monitor. This technology allowed for an expanded analysis of free-living ambulatory behavior, beyond step count and minutes per day of PA, to include measures of usual walking cadence, persistence of effort, and endurance.

Future directions

Previous interventions using accelerometers to objectively measure physical activity have focused mainly on quantity of physical activity (PA) such as steps per day. The usefulness of the time-stamp feature of most modern accelerometers affords the opportunity to investigate patterns or quality of ambulatory behavior thereby providing a more detailed picture of one’s habitual ambulatory activities. However, an important consideration when evaluating data from accelerometers is that the environmental context for which the PA is taking place is unknown without additional sources of information (GPS, camera, or ecological momentary assessment). While several of our hypotheses regarding peak- and average-cadence metrics were supported, current analyses do not identify specific combinations of intensities used, or to what extent participants self-selected to achieve their daily step goal. Further investigation as to temporal patterns throughout daily waking hours could provide additional insight as to strategies used by participants when given a simple goal in which there are multiple ways to achieve that goal.
Conclusion

This is one of the few studies to evaluate cadence in a free-living population and the first to investigate cadence metrics in a population of older cancer survivors. There were no stipulations on minimum bout duration or minimum walking intensity, yet a substantial number of participants chose to walk at a medium to brisk intensity. Increases in peak 30-minute cadence suggest a persistence of ambulatory effort and that increases in habitual walking speed may have stabilized over the course of the intervention. Increases in average 10- and 30-minute cadence variables suggest that not only did participants self-select to walk faster, they did so while also increasing their bout duration. In conclusion, although the goal of the intervention was to accumulate steps over the course of an entire day, our results indicate that participants self-selected to do so in longer bouts at higher intensities. Evaluation of free-living walking cadence and patterns of ambulatory behavior can inform future interventions targeting behavior change, especially in those populations most at risk for reduced physical activity and vulnerable to mobility deficits and loss of independence.


Busse, M. E., Pearson, O. R., Van Deursen, R., & Wiles, C. M. (2004). Quantified measurement of activity provides insight into motor function and recovery in


Dohrn, I. M., Hagstromer, M., Hellenius, M. L., & Stahle, A. (2016). Gait Speed, Quality of Life, and Sedentary Time are Associated with Steps per Day in Community-
doi:10.1123/japa.2014-0116

sedentary time with physical activity: a 15-year follow-up of mortality in a
national cohort. Clinical Epidemiology, 10, 179-186. doi:10.2147/clep.s151613

disability in activities of daily living independent of physical activity. J Phys Act

Fielding, R. A., Guralnik, J. M., King, A. C., Pahor, M., McDermott, M. M., Tudor-
functioning and disability risk in mobility-limited older adults: Results from the
LIFE study randomized trial. PloS One, 12(8), e0182155.
doi:10.1371/journal.pone.0182155

activity and sedentary behavior distribution patterns in older women. Gait and
Posture, 57, 74-79. doi:10.1016/j.gaitpost.2017.05.014

and Applications, Inc. accelerometer. Medicine and Science in Sports and
Exercise, 30(5), 777-781.

Garber, C. E., Blissmer, B., Deschenes, M. R., Franklin, B. A., Lamonte, M. J., Lee, I.-
M., . . . Swain, D. P. (2011). Quantity and Quality of Exercise for Developing and
Maintaining Cardiorespiratory, Musculoskeletal, and Neuromotor Fitness in


compared with the short physical performance battery. *Journals of Gerontology. Series A: Biological Sciences and Medical Sciences*, 55(4), M221-231.


Kozey, S., Lyden, K., Staudenmayer, J., & Freedson, P. (2010). Errors in MET estimates of physical activities using 3.5 ml x kg(-1) x min(-1) as the baseline oxygen consumption. *J Phys Act Health, 7*(4), 508-516.


a clinical trial in older adults (the LIFE-P study). *The Journal of Nutrition, Health & Aging, 13*(6), 538-544.


Weaver, K. E., Leach, C. R., Leng, X., Danhauer, S. C., Klepin, H. D., Vaughan, L., . . .


