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Longitudinal Evaluations of Objectively Measured Physical Activity: Capturing the Full Spectrum of Duration and Intensity

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LONGITUDINAL EVALUATIONS OF OBJECTIVELY MEASURED PHYSICAL ACTIVITY: CAPTURING THE FULL SPECTRUM OF DURATION AND INTENSITY

by

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DEDICATION

To my three besties:

My best friend, Jim; my best gal, Taylor, and my best pup, Beanie

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ABSTRACT

Most physical activity research to date narrows its focus toward intensities and durations only encompassed in the Physical Activity Guidelines of moderate to vigorous intensity in at least 10 minute bouts (MVPA-10). Examining activity in this manner excludes light activity and shorter bouts, sometimes referred to as baseline physical activity (BPA) as it consists of the activity accumulated during daily life at durations and/or intensities below what is recommended. This dissertation provides an evaluation of the entire spectrum of physical activity (PA). Physical activity was studied in a unique way by looking at MVPA-10, then adding shorter bouts and light intensity to see if these additions further influence study outcomes. This dissertation incorporated this concept into the analyses while linking behavioral investigations of physical activity to a physiological investigation of how such activity influences adiposity and weight. Thus, it transitioned from what characteristics influence physical activity behavior to how physical activity influences health. Three separate papers used this concept to 1) *examine the intrapersonal-level determinants of the full spectrum of PA 2) examine how the total number of life events and the self-reported stress of life events influences the full spectrum of PA; and 3) examine the longitudinal relationship of the full spectrum of PA with adiposity and weight.* This dissertation used objectively measured physical activity data collected as part of The Energy Balance Study to examine the three specific aims. The purpose of the Energy Balance Study was to examine the extent to which variation in

total energy expenditure (TEE) and variation in total energy intake (TEI) contribute to changes in body weight and fat among adults. A secondary aim was to examine specific components of TEE and TEI that drive changes in body weight and fat. This dissertation contributes answers to this secondary aim, by examining the physical activity component of TEE.

Study 1 showed that intrapersonal variables within categories of biological, socioeconomic, family structure, behavioral, and psychological can influence activity. The associated characteristics differ based on whether physical activity is quantified as MVPA-10, total MVPA, or total PA. Adding components of baseline PA, first short bouts of total MVPA followed by light intensity PA influences the results.

In the second study, the average number and associated stress of life events per quarter did not have much influence on physical activity. However, many life events when examined separately had significant associations with MVPA-10, total MVPA and total PA. For young adult men, changing jobs and marriage had negative impacts on activity while starting/ending a relationship and beginning a mortgage had positive influences. For young adult women, starting a new job, moving, engagement, and the loss of a family/friend had negative consequence while quitting a job resulted in increases in PA. The degree of influence on activity often went beyond the typical recommendations of MVPA in 10 minute bouts.

In the third study, physical activity had an influence on various anthropometric measures and varied by gender. The accumulation of greater amounts of activity was associated with a lower body fat percentage for both men and women. There were also associations with PA for waist circumference, hip circumference, and BMI for the women. For all anthropometric associations there were similar degrees of association for MVPA-10 and total MVPA, suggesting that the accumulation of all MVPA regardless of bout length can have a similar influence on anthropometrics. The association of anthropometrics with total PA was typically half of the impact when comparing the MVPA categories.   Thus an increase of MVPA has a greater influence on anthropometric outcomes than an increase in total PA.

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N	Sample size
β	Regression slope
SE_{β}	Standard Error of the regression slope

List of Abbreviations

BF%	Body Fat Percent
BMI	Body Mass Index
BPA	Baseline Physical Activity
HC	Hip Circumference
LTPA	Leisure Time Physical Activity
MVPA	Moderate to Vigorous Physical Activity
MVPA-10	Moderate to Vigorous Physical Activity in 10 minute bouts
PA	Physical Activity
TEE	Total Energy Expenditure
TEI	Total Energy Intake
WC	Waist Circumference

CHAPTER I

INTRODUCTION

Physical Activity and Public Health

Physical activity holds vital importance for health and well-being. Abundant evidence shows that higher levels of physical activity are associated with reduced risk of all-cause mortality, cardiovascular disease, cancer, mental health disorders and other morbidities, and enhanced quality of life (Haskell et al. 2009; Moore et al., 2012). As physical activity assessments have improved over the past several decades, research continues to support the benefits of physical activity. This goes beyond leisure time physical activity to account for total activity throughout the day across all domains (occupational, leisure, household, and daily living) (Samitz et al., 2011).

Although physical activity has vital importance to health, the majority of adults do not achieve the recommended amounts of moderate to vigorous physical activity (MVPA). Metzger et al. performed a latent class analysis on the accelerometer data from NHANES 2003-2004 in order to evaluate patterns of physical activity among adults. The results showed that 79% of the total population fell into the two lowest classes of total MVPA. These two classes average less than 25 minutes/day of total accumulated MVPA. Furthermore, when defining MVPA based on the 2008 Guidelines in which MVPA must be accumulated in at least 10 minute bouts, the proportion of the population with low activity levels increases. In fact, 93% of the population fell into the two lowest classes, average 21 minutes/day of MVPA accumulated in 10 minute bouts (Metzger et al., 2008). Tucker et al. found similar results, in which only 9.6% of the population met the 2008 guidelines based on NHANES 2005-2006 accelerometry data (Tucker et al., 2011).

Defining Baseline Physical Activity

Physical activity is any bodily movement produced by skeletal muscles that expends energy (Caspersen et al., 1985). However, typically the focus narrows to include only moderate to vigorous intensities and durations considered physical activity according to the current guidelines. The 2008 Physical Activity guidelines suggest that MVPA in bouts of at least 10 minutes per session be achieved above baseline levels, thus creating a differentiation of bodily movement into two categories: health-enhancing physical activity and baseline physical activity. Health-enhancing physical activity is the moderate to vigorous activity that, when added to baseline activity, produces health benefits (U.S. Dept. of Health and Human Services, 2008). For the purposes of this dissertation, this activity will be referred to as MVPA-10. Baseline physical activity (BPA) is considered the light intensity activities of daily living and the very short bouts of MVPA less than 10 minutes in duration. The 2008 guidelines do not formally recommend a particular dose of BPA nor address how doses of BPA may impact health due to the fact that little research has been done to explore such questions. However, the guidelines document and expert panel advisory report do mention that BPA most likely plays an important role in public health. Baseline physical activity is a part of a normal daily lifestyle. Replacing sedentary behaviors with increases in BPA could provide a simple way to increase caloric expenditure, which could promote weight maintenance. Additionally, the weight bearing activities falling within baseline activities, although of light intensity could provide benefits such as maintaining bone health. Promoting individuals to increase their BPA could also be beneficial when seeking behavior change, especially for the currently inactive individuals, elderly, or those with chronic conditions where their ability to become active is limited, as BPA can be easier to incorporate into daily living vs. incorporating MVPA.

BPA can vary drastically among individuals depending on various lifestyles. Those individuals who only do BPA are considered inactive according to the 2008 PA Guidelines. Interesting questions arise when we start to reflect on different lifestyles. Is a nurse who is on her feet partaking in light intensity activity 8 hours a day the same in terms of health benefits as the women working a desk job seated 8 hours a day? For both, the vast majority of their work day would be considered "baseline" activity or below, but clearly these two women are vastly different in behavior. What if both achieve the recommended amount of MVPA according the guidelines, or what if both neglect to achieve the recommendations, is this MVPA all that matters? Is there any additional benefit the nurse may be obtaining because of her higher baseline activity levels? The analyses in the dissertation will consider any activity above sedentary as worth evaluating, thus will include both BPA and MVPA-10 for comparison.

Powell et al. briefly summarizes the evidence of how much physical activity is essential for health benefits. Within this overview, they discuss the need to further understand the health effects of lower volumes and intensities of physical activity below the recommended amounts (Powell et al., 2011). This examination would allow for a deeper understanding of the entire spectrum of physical activity. Rather than approach physical activity as a definitively required intensity and duration, a novel approach is to see physical activity as a continuum across all intensities and durations.

This is not to take away from the benefits of higher intensity and longer durations, as exercise physiologists and epidemiologists have shown the independent benefits of extended bouts of MVPA for many health outcomes. It is likely that these lower intensities and bouts can not replace the benefits from the volume suggested in the current PA guidelines. However, it should be a constant goal as promoters of public health to seek the answers that help define the optimal dose and how this can be accumulated in order to reach the mass population, which is increasingly becoming more sedentary and less healthy at daunting rates.

Paradigm Shifts in Physical Activity Recommendations

The American College of Sports Medicine (ACSM) was a primary leader in developing physical activity recommendations with its first publication in 1978 (American College of Sports Medicine, 1978) focusing on higher intensity continuous aerobic activities with the goal to improve performance-based fitness. Twelve years later the paradigm shifted to physical activity for health-related fitness as ACSM revised the Position Statement to include moderate intensity activity as well. ACSM made this revision in recognition that physical activity recommendations had to be feasible for the increasingly inactive U.S. population. As evidence grew on the link between health outcomes and physical activity, in particular evidence by the American Heart Association declaring physical inactivity the fourth leading risk factor for mortality (Fletcher et al., 1992), the CDC and ACSM collaborated to develop the first public health recommendations on physical activity (Pate et al., 1995). These guidelines first introduced the concept of accumulating activity in bouts of 10 minutes or more throughout the day rather than one ≥30 minute continuous bout. The 2008 Physical Activity Guidelines provide the most recent physical activity recommendations for the U.S. These guidelines are for a total volume for the entire week of 150 minutes of moderate intensity or 75 minutes of vigorous intensity activity (or an equivalent combination of both intensities, with one minute of vigorous activity being equivalent to two minutes of moderate intensity activity) that can be accumulated in 10 minute bouts (U.S. Dept. of Health and Human Services, 2008).

There is a clear driving influence to the slight changes from one recommendation/guideline to the next. The changes take shape due to the public health perspective to advise levels of physical activity that are achievable to the vast majority of the adult population (such as transitions to moderate intensities and accumulating PA in bouts) with a volume of PA that still harvests considerable health benefits.

Since first introduced in the 1990's, the recommendation to include moderate intensity and accumulate MVPA in 10 minute bouts has become widely accepted. Regardless of the study design, whether a clinical trial, intervention or observational study, studies typically utilize this approach when examining physical activity. Most clinical trials or interventions prescribe activity in at least 10 minute bouts of MVPA and most epidemiological analyses take into account only the physical activity that fits within these PA guidelines. Thus, very little research has been pursued looking beyond these parameters. One of the questions left unanswered to this point is - On Top of What? Is there a baseline activity level on top of which the physical activity guidelines are achieved that is essential for health benefits to occur? If so, could the next paradigm shift in physical activity promotion transition to an even greater emphasis on overall active living? And can we promote an active lifestyle at very modest intensities and duration, with or without the need for the typical MVPA?

A committee of experts developed an Advisory Committee Report summarizing the known health benefits of physical activity as well as recommendations for areas of future research, and this report was used by the government to produce the 2008 Guidelines. The report suggests future experimental and observational studies should examine lower intensities and smaller amounts of activity than are currently recommended, as these activity levels could potentially provide health benefits, especially for inactive and/or unfit individuals. The report also calls for accurate quantification using assessment methodologies that would allow for the evaluation of the effect of accumulating very short bouts independent of the total volume of activity (Physical Activity Guidelines Advisory Committee, 2008a).

Objective Quantification of Physical Activity

Over the past several decades technological advancements have allowed for advanced physical activity measurements. Where once self-report was the only method researchers could rely on to assess leisure time physical activity (LTPA), the measurement field has advanced to objective measures that provide not only assessments of LTPA, but a comprehensive profiling of physical activity. Researchers now have the capability to capture minute by minute (or even shorter) detailed assessments throughout the entire day. In general, LTPA only encompasses a very small portion of a 24 hour period and of total energy expenditure (TEE), and thus can result in a limited ability to demonstrate relationships with health outcomes (Tremblay et al., 2007). The objective quantification allows for assessments of not only LTPA, but activity or inactivity taking place at work, around the house, and other activities of daily living. Instinctively, it makes sense that overall activity or inactivity can influence physiological and psychological health, and therefore, it is vital to consider the many patterns, intensities, and doses of activity that can be extracted only by way of objective measurements. The current analyses will utilize the SenseWear Armband, a sensor incorporating high-tech physiological sensors and movement sensors to provide objective estimates of TEE and activity. Details on the Armband will be discussed in the Methodology section.

Literature Review

Paper 1

Rationale for the Study of Intrapersonal Level Correlates and Determinants of Physical Activity

In order to develop and improve upon public health programs and interventions, it is important to understand the causes of physical activity behavior. When examining these causes, there are various factors that influence behavior based on the ecological model including intrapersonal, interpersonal, organizational, community, and public policy influences (Sallis et al., 2006). The Energy Balance study thoroughly examines each participant in the study, and thus has the capability to provide a strong longitudinal analysis of intrapersonal level associations with physical activity. These individual level aspects include demographic, psychological, physiological, behavioral and family situations (Sallis et al., 2006).

The Lancet published a special series on physical activity a few days before the start of the 2012 London Summer Olympic Games. One of the five major papers in the series summarized the existing research on the correlates and determinants of physical activity to help explain why some people are active and why some are not (Bauman et al., 2012). A key message from this paper, as a call to improve the research base, was for future papers to have a stronger focus on determinants research. Examining determinants in longitudinal analyses, rather than correlates from cross-sectional data, strengthens the ability to make causal inferences (Bauman et al., 2012).

Summary of existing evidence of Intrapersonal Level Correlates and Determinants of Physical Activity

Table 1.1 provides a summary of existing evidence from systematic reviews plus a few recent research articles that address both cross-sectional and longitudinal evaluation of the variables to be included in paper 1 of this dissertation. In general, age, being female, and a race/ethnicity that is non-white have an inverse associations with physical activity (Kaewthummanukul & Brown, 2006; Kirk & Rhodes, 2011; Trost et al., 2002). Weight status of overweight/obese also has been consistently shown to have a negative association with MVPA (Sherwood & Jeffery, 2000; Trost et al., 2002). Married (vs. unmarried) individuals and those with children appear to accumulate less MPVA. Based on Kaewthummanukul et al.'s review, having dependent children my have a greater influence on reduced MVPA than being married (Kaewthummanukul & Brown, 2006).

In addition, higher income levels and education levels are associated with greater amounts of activity (Kaewthummanukul & Brown, 2006; Kirk & Rhodes, 2011; Trost et al., 2002). Individuals in white collar or professional jobs tend accumulate more leisure time MVPA (Kirk & Rhodes, 2011). However, Kirk et al. included 10 studies in their review, which concluded that when evaluating total MVPA (beyond just LTPA) individuals in lower status occupations appear to accumulate greater amounts (Kirk & Rhodes, 2011). For example, a study using an objective measure of steps per day found that blue-collar male workers were most likely to achieve 10,000 steps/day. There were 80.2% of blue-collared workers vs. 38.2% of white-collar workers who achieved the 10,000 steps/day recommendation (McCormack et al., 2006). This study provides an example of the benefits of using an objective measure to capture total physical activity throughout the day, and how results can vary depending on how the physical activity outcome is defined.

Mixed results have been found when examining self-reported psychological correlates or determinants, including perceived stress and mood disturbances. In general, results tend to show trends toward associations in which higher stress levels, mood disturbances, depression, and lower quality sleep are associated with the accumulation of less MVPA. The 2008 Advisory Report summarizes the cross-sectional and prospective epidemiological evidence and concludes that the accumulation of MVPA tends to be associated with fewer symptoms of depression, anxiety, and psychological distress and enhanced psychological well-being (Physical Activity Guidelines Advisory Committee, 2008b). It is difficult to tease out and understand the causality for the relationship of mental health with physical activity, as it could be that greater levels of stress or depression could result in an individual partaking in less physical activity. A meta-analysis of interventions showed that both supervised and unsupervised physical activity programs are effective in reducing depressive symptoms with mean effect sizes of 0.37 and 0.52, respectively (Conn, 2010). In the reverse causal direction, an increase or decrease in physical activity could result in the inverse change in stress or depression. One study found that even minor stress is associated with declines or disruptions in an exercise routine, even for those who were classified as exercise maintainers (Stetson et al., 1997).

The behavioral variables for paper 1 include self-reported active transportation, household activities, occupational physical activity, screen-time (computer and television), and diet quality. Active transportation tends to show direct associations with greater total MVPA, but slightly less so with leisure MVPA (Brownson et al., 2005; Dunton et al., 2009; Sahlqvist et al., 2012). For instance, Sahlquist et al. examined associations for changes in active transportation with changes in both recreational and total physical activity among 1628 adults. The results showed that with increasing active transportation there were slight declines in recreational physical activity. Nonetheless, strong evidence exists showing that a change in active travel was associated with a direct association with total physical activity in that those who increase active travel increase total PA, whereas those that decreased active travel showed a decrease in total PA (Sahlqvist et al., 2013). For occupational PA and household PA, different trends tend to be shown depending on whether the analyses evaluate leisure MVPA or total MVPA.

Higher levels of occupation or household PA often show slight negative associations with lower levels of leisure MVPA. However, when evaluating total MVPA accumulated throughout the day beyond just leisure, higher levels of occupation or household PA have positive associations (Brownson et al., 2005). Recent research on screen time has shown that time spent on the television or computer during leisure time is independent from MVPA. However, higher total screen time per day appears to be inversely associated with MVPA (Burton et al., 2012; Dunton et al., 2009) .

Paper 1 of this dissertation will provide further insight into the individual correlates and determinants of physical activity. One of the main strengths of the proposed paper is the ability to use objective measures to quantify physical activity levels, which has been lacking in most prior PA research. In relation to this, the objective measure will allow for assessment of overall total physical activity including all intensities and durations of activity (so to include both MVPA and baseline PA). It is important to note that results on correlates and determinants of physical activity can vary depending on the physical activity outcome (i.e. leisure vs. total MVPA). For example, when analyzing occupation status and its influence on activity, results often show that higher occupation status (i.e. white-collar, higher ranked professional jobs) is associated with higher levels of leisure time PA. However, when defining activity as the total MVPA, often these higher level occupations are associated with less MVPA than lower level (i.e. blue collar) jobs due to the fact that now occupational activity itself it taken into account. Thus, it is important to evaluate the entire spectrum of physical activity in order to capture associations of determinants with physical activity behaviors.

Paper 2

Rationale for the Study of Major Life Event Influences on Physical Activity

The Energy Balance Study examines young adults, age 21-35 years old. Young adulthood often brings about multiple major life events, and these events can result in critical changes to an individual's routine behaviors. Life events during this phase of life include graduation from school, beginning/changing/losing a job, moving, starting or ending a romantic relationship, engagement, marriage, pregnancy/having children, financial distress (such as on or off welfare or taking out a mortgage), major illness or injury, and loss of a family member or close friend. Life events may influence physical activity by way of increasing levels of stress and frustration, which could result in changes in activity and/or by way of simply disrupting an individual's ability to engage in physical activity.

Summary of Existing Evidence on Major Life Event Influences on Physical Activity

A recent review summarized 34 studies that examined one or more major life events on changes in physical activity across at least 2 time points (could be prospective or retrospective) (Engberg et al., 2012). Sixteen of these studies included part or all of the age-range and at least one of the life events examined in the Energy Balance Study.

Changes in occupation have been shown to reduce MVPA in both men and women, including starting a new job, changing job status or job conditions, and graduating from school followed by a transition to a job (Brown et al., 2009; Brown et al., 2003; Zsolt , et al., 2007). Evidence on financial distress is minimal. Brown et al. found that among young Australian women, a reduction in income was longitudinally associated with a 20% greater odds of decreased physical activity levels (OR=1.20, CI: 1.04–1.38) (Brown et al., 2009). A change in residential status tends to result in declines in MVPA (Bell, 2005; Butler et al., 2004).

Mixed results have been found for associations between MVPA and starting or ending marriage, a relationship, or cohabitation. Several studies did not find any association among starting or ending a relationship (Hull, Rofey, 2010; Schmitz , French, 1997). Others found that changing from being single to cohabitating or getting married resulted in decreased MVPA, especially among women (Bell 2005; Brown et al., 2003). In contrast, King et al. found that transitioning from a single to married state resulted in significant positive changes in physical activity, whereas transitioning from married to single had no influence on activity (King et al.,1998). Another study also found that beginning a new close personal relationship was associated with increased MVPA for women (Brown et al., 2009). Divorce showed trends of increasing MVPA among both men and women in two studies (Lee et al., 2005; Ortega et al., 2011). Conversely, Umberson et al. found that MVPA decreased after divorce for men but did not effect women based on a 3 year study of 2800 individuals (Umberson et al., 1992).

The existing literature on the association of injury and illness on changes in physical activity focuses on more major complications, such as spinal cord injuries, cancer, etc. (which would exclude our participants from continuing in the study). For instance, several studies have shown that the occurrence of cancer is associated with declines in physical activity (Courneya et al.,1997; Irwin et al., 2003). Most studies evaluating interpersonal loss are among older adults. In general, the death of a close friend or family member results in lower levels of physical activity. However, for studies able to examine long-term widowhood, physical activity tends to increase (Engberg et al., 2012).

Since the primary outcome of the Energy Balance study includes weight and body fat, women who were pregnant or lactating within 6 months prior to the study or planning to become pregnant during the study were excluded. Thus, we will be unable to examine the effects on women for having a child, although we will be able to do so for men. Hull et al. showed in a longitudinal 2 year study that having a child (vs. remaining childless) was associated with decreased activity among young men (Hull et al., 2010).

Several studies examined how multiple life events influence MVPA. Twisk et al. examined young adults age 27-29 years old. Men and women experienced an average of 15 life events during a 1 year period. The study found no association between the number of life events and changes in PA (Twisk et al., 1999). However, 2 randomized controlled trials found that the occurrence of multiple major life events resulted in declines in participation in PA (Oman et al., 2000; Wilcox et al., 2004) .

The major distinguishing factor that will make these dissertation analyses novel is the objective evaluation of physical activity. All studies included in the review utilized self-reported questionnaires or interviews to obtain levels of physical activity (Engberg et al., 2012). In addition, the vast majority of these studies asked about leisure time physical activity only, thus, the paper included in this dissertation will be the first to use an objective measure of physical activity, including all activity light through vigorous, for analysis with major life events. The review by Engberg et al. concludes calling for future studies to examine gender differences, use a validated measure of physical activity, and have a longitudinal cohort - all of which will be included in this dissertation.

Paper 3

Rationale for the Study of Physical Activity with Anthropometric Outcomes

The National Center for Health Statistics showed that in 2009-2010 two-thirds of U.S. adults fell within the body mass index (BMI) categories of overweight and obese. Of these two-thirds, half are classified as obese (Ogden et al., 2012). Excessive weight has been shown to increase the risk of multiple morbidities such as hypertension, dyslipidemia, type 2 diabetes, osteoarthritis, respiratory problems, depression, and certain cancers (National Heart, Lung, Blood Institute 1998; Renehan et al., 2008). In addition, obesity, particularly class 2 and above, has been linked to increased risk of all-cause mortality (Flegal et al., 2013).

The high rates of overweight and obesity derive from a long-term problem with energy imbalance (Hill et al., 2003). Arguably, energy imbalance is caused by a wide range of individual characteristics and behaviors, one important factor being total energy expenditure (TEE) and its components. Physical activity is a modifiable component of TEE that has substantial variation across individuals and can affect TEE. Thus, physical activity has the potential to influence energy balance. This influence of physical activity on energy balance is not limited to just leisure time MVPA, which is most commonly evaluated. All activity accumulated throughout the entire day should be considered in order to better understand how physical activity influences energy balance and anthropometric outcomes.

Summary of Existing Evidence on Associations of MVPA with Anthropometric Outcomes

As mentioned previously, most observational and experimental studies have focused primarily on MVPA in at least 10 minute bouts. The general consensus of this research is that MVPA has benefits for weight and adiposity. Previous experimental trials have shown that 13 to 26 MET-hours per week of MVPA result in weight maintenance or modest weight loss of 1% to 3%, and reductions in total and abdominal adiposity meaningful enough to show improved metabolic health (Irwin, et al., 2003; Slentz, et al. 2005). A dose of 13 MET-hr/wk of MVPA would consist of walking for 150 minutes per week at a moderate intensity of 4 miles/hr pace, or a vigorous activity of jogging 75 minutes over the week at 6 miles per hour. There is a dose response relation between adiposity and MVPA in which greater volumes above the range of 13-26 MET-hrs result in greater fat loss. For instance, performing 42 MET-hrs per week of MVPA results in 3 to 4 times larger reductions of intra-abdominal adiposity compared with results seen from 13-26 MET-hrs (Ross et al., 2004).

The majority of cross-sectional studies also show inverse associations with 150 to 300 minutes of MVPA and body weight maintenance and/or weight loss (Physical Activity Guidelines Advisory Committee, 2008a). Prospective studies tend to have more modest results, yet show that maintaining or increasing MVPA over multiple years results in the ability to better manage body weight compared with the individuals who have low activity over the entire duration or decrease their activity levels over time (Balkau, et al. 2006; Droyvold, et al. 2004; Kyle, et al 2006; Williams, et al. 2006). Weinsier et al. evaluated 61 premenopausal women using doubly labeled water to measure energy expenditure and dual x-ray absorptiometry for body composition at baseline and follow-up one year later. The findings showed that women successful in maintaining their body weight had significantly greater physical activity energy expenditure (PAEE) and durations of physical activity across the 1 year period. Furthermore, PAEE differed by 887 kj/d, which explained 77% of the positive energy imbalance (Weinsier et al., 2002). Another longitudinal study using 739 middle-age Europeans, found that objectively measured PAEE predicts changes in fat mass and body weight over a 5 year period (Ekelund et al., 2005).

For purposes of this dissertation we are interested in evaluating physical activity beyond simply following the typical guideline criteria to also include BPA which consists of short bouts less than 10 minute of MVPA and light intensity physical activity (LPA). When reviewing the literature, most studies evaluate one or the other, thus the following will discuss the outcomes below separately for short bouts of MVPA and LPA.

Summary of Existing Evidence on Associations of Short Bouts with Anthropometric Outcomes

Several cross-sectional observational studies have been published in recent years focusing on bouts shorter than 10 minutes and the association with anthropometric outcomes. The most recent publication on this topic comes from the 2003-2006 NHANES (Fan et al., 2013). A sample of 4511 adults with 4 days of at least 10 hours/day of accelerometer data were used in the analyses. Four groups of activity were developed so that bouts were grouped into 10+ minutes of high-intensity and < 10 minutes of high-intensity (≥2020 cpm) and 10+ minutes of lower-intensity and < 10 minutes of lower-intensity (760-2019 cpm). In addition, the bouts were quantified to allow for 1-2 minute interruptions within any 10 minute window, to coincide with the

Center for Disease Control and Prevention recommendations. The cross-sectional findings show that the high-intensity short bouts and long bouts were related to BMI and the risk of being overweight or obese. After adjusting for multiple covariates (age, education, marital status, race, family size, income, caloric intake, smoking status, self-reported health status, and total accelerometer wear time), each minute of high-intensity short bouts was associated with 2% lower risk of being obese for men (but no significant association for women). However, the lower-intensity short and long bouts were not related to BMI. The authors conclude that higher-intensity physical activity, regardless of bout length, is related to weight, whereas lower-intensity activities do not matter for weight outcomes (Fan et al., 2013).

A few years earlier, Strath et al. completed analysis on 3,250 adults in the 2003-2004 NHANES data-set who wore Actigraph accelerometers. The analyses compared bouts (≥10 min) vs. non-bouts (< 10 minutes). The main finding showed that accumulating MVPA in bouts lasting less than 10 minutes was associated with lower BMI and waist circumference (WC), independent of bouts of at least 10 minutes. Still when comparing bouts vs. non-bouts, MVPA in bouts had a four times stronger association with lower BMI ($\beta = -0.04$, $P < 0.001$ vs. $\beta = -0.01$, $P = .07$) and a three times stronger association with lower WC ($\beta = -0.09$, $P < .001$ vs. $\beta = -0.03$, $P = .01$) than non-bout MVPA. The authors state that the average intensity of MVPA in bouts was greater than during non-bout MVPA, which could contribute to the substantial difference in association with BMI and WC (Strath et al., 2008).

A similar study was performed in the Framingham Heart Study sample of 2109 adults. The accelerometer data were analyzed by accumulated time in MVPA bouts ≥10 minutes, bouts <10 minutes, and total MVPA minutes. Accumulation of MVPA by all three types had significant associations with lower BMI and WC. However, unlike the NHANES analysis mentioned above, no differences were present in the strength of association between bouts ≥10 minutes vs. bouts <10 minutes (Glazer et al., 2013).

Ayabe et al. went into further detail when exploring shorter bouts of MVPA in their cross-sectional analysis. Forty-two Japanese women wore the Lifecorder accelerometer and completed adiposity measurements of visceral abdominal fat using CT scans, WC and body fat using the two-cites skin fold method. Bouts of physical activity were broken up into at least 32 seconds, 1 min, 3 min, 5 min, or 10 min. In addition, another unique aspect to this analysis is that it examined various intensities beyond just MVPA (including separate analysis for light, moderate, vigorous, and all combined) for each bout duration. The main finding was that the relationship between visceral adipose tissue and physical activity depended on the intensity and the bout duration. MVPA in bouts of 1 minute or greater, and total activity (light, moderate, and vigorous combined) in bouts of 3 minutes of greater were significantly associated with visceral adipose tissue. In addition total MVPA and VPA were significant contributors to visceral adipose tissue, but not LPA (Ayabe et al., 2013).

Healy et al. 2008 approached the examination of bouts by evaluating the number of breaks in sedentary time, which they defined as anything one minute or longer above the sedentary accelerometer cut point of 100 counts/min. The cross-sectional analysis found that the total number of breaks was significantly associated with BMI (β= -0.19, CI:-0.35 to -0.02) and WC (β= -0.16, CI:-0.31 to -0.02). Those in the highest quartile of number of breaks had a 5.95 cm lower WC on average compared with the lowest quartile (p=0.025) (Healy et al., 2008).

A recent study by McGuire et al. evaluated incidental physical activity by examining LPA and MVPA bouts less than 10 minutes with the outcomes of abdominal obesity, visceral adipose tissue, and subcutaneous adipose tissue. Their results show no association of total incidental physical activity with any adiposity measure. Only short bouts of MVPA had significant inverse associations with visceral adipose tissue when adjusting for age and gender (B=−0.13 (−0.26 to −0.00) p= 0.04)) (McGuire & Ross, 2011).

In terms of experimental trials, few studies examined bouts shorter than 10 minutes. One RCT of 22 young women was performed in which 12 of the participants were selected to a stair climbing group. Over a 7 week period the women progressed from one ascent to six ascents per day in a 199 step staircase. They were instructed to distribute their stair climbs over the entire work day and thus would be rather short bouts of activity. No anthropometric changes (BMI and skin fold thickness) occurred for either group, although there were significant differences in other health outcomes (fitness, HDL, and end lactate) between the control and stair climbing group (Boreham et al., 2000).

Swartz et al. sought to quantify total energy expenditure of three different durations of physical activity within a 30 minute sedentary period. Although the main outcome was not anthropometric measures, understanding the differences in energy expenditure of various bout durations may provide insight for energy balance concepts and thus outcomes such as body weight. The participants were instructed to stand up and walk 1 minute, 2 minutes, or 5 minutes to interrupt a 30 minute sitting period. When the data were extrapolated to an 8 hour work day, an individual would expend on average 24, 59, and 132 additional kilocalories per day, for a 1 minute, 2 minute, or 5 minute walk break per hour, respectively. Although these small amounts may not seem like much, the additive effect could reach meaningful levels and potentially influence body weight. For instance, the author's estimate that if an individual took a 5 minute walk break per hour during the 8 hour work day, over an entire month this would account for 2640 additional kcals expended and 31,680 additional kcals expended over an entire year (Swartz et al., 2011).

A second randomized controlled trial by Macfarlane et al. took 30 sedentary adults and half performed 30 minutes of continuous exercise, 3-4 days/week while the other half performed 6 minute bouts, 5 times per day, 4-5 days per week. After the 8 week trial, only the continuous exercise group reduced their body weight, and no changes existed among either group for body fat or waist and hip circumference measures (Macfarlane et al., 2006). From these two randomized controlled trials discussed, the sample size was low and the duration of intervention was short (7 to 8 weeks). These factors could explain such limited findings. In addition, although the stair climbing intervention tried to prescribe intensity, it is difficult to completely control for intensity with such short bouts incorporated into the usual lifestyle of an individual (Boreham et al., 2000; Macfarlane et al., 2006).

Summary of Existing Evidence on Associations of Light Intensity Activity with Weight and Adiposity

Light intensity physical activity has become of growing interest as research has expounded on the independent detrimental health effects of sedentary behavior, including negative impacts on waist circumference, blood pressure, fasting glucose, triglycerides, cholesterol to name a few (Hamilton et al., 2012). Only a few studies have examined the independent effect of LPA on anthropometric outcomes.

The McGuire et al. study mentioned previously regarding the evaluation of incidental physical activity, examined LPA separately in their analyses as well. The findings showed no significant association with LPA and abdominal adiposity (McGuire & Ross, 2011).

A large cross-sectional analysis of 5,836 adults from the Australian Diabetes, Obesity, and Lifestyle Study examined the association of metabolic risk and LPA, in which WC was included. The accelerometry data showed that on average adults spent 39% of the time in LPA, whereas only 4% of the time was spent in MVPA during waking hours. After adjustment for MVPA, the results showed a significant association of LPA and WC (β= -0.20, CI: -0.32 to -0.06) (Healy et al., 2007).

The Nurses' Health Study included self-report measures of time spent standing or walking at home or work. Hu et al. performed a longitudinal assessment of 50,277 women over a 6 year duration examining the association of light activities of standing or walking around home with the risk of obesity. They found that standing or walking around home was associated with a lower risk of obesity (considered a BMI $\geq$ 30). For each 2 hours per day time in standing/walking around home, there was a 10% lower risk of obesity (Hu et al., 2003).

A pilot study observed 10 lean and 10 obese sedentary adults (Levine et al., 2005). The main purpose of the study was to evaluate the differences in NEAT (non-exercise activity thermogenesis), by examining their posture behavior (seated, upright, lying down, etc.) for 10 consecutive days. The results from this pilot study showed that the obese adults sat an average of 164 minutes more per day, whereas, the lean individuals were upright an average of 152 minutes more per day. The authors state that if the obese individuals had the same posture allocation as the lean, the obese would have expended 352±65 kilocalories more per day. In addition, they found that total body movement, 89% of which was ambulation, was negatively associated with fat mass (body fat %: R^2=0.52; body fat (kg): R^2=0.57) (Levine et al., 2005). The major limitation to this study was the case-control design, which limits the ability to make causal conclusions. In the proposed dissertation, the use of longitudinal assessment can help provide further insight into the association of LPA with anthropometric outcomes.

A prior pilot study by Levine et al. took both sides of the energy balance equation into account when looking at weight/fat gain. The aim was to evaluate the variation in NEAT with overfeeding of 1000 kcal/day in 16 adults (4 females). The end result of the 8 week trial showed that NEAT was the main resistor to weight gain during overfeeding, with a correlation coefficient of r= -0.77 between fat gain and NEAT. Thus with excess energy intake, the activation of NEAT can eliminate the surplus energy to prevent fat gain, but with improper activation of NEAT an individual may be predisposed to obesity (Levine et al., 1999).

Scope of the Dissertation

Research focused on physical activity often only examines moderate to vigorous intensities, and often only in bouts of 10 minutes or more. Examining activity in this manner excludes light activity and shorter bouts, sometimes referred to as baseline physical activity (BPA) as it consists of the physical activity accumulated during daily life at durations and/or intensities below what is recommended in the 2008 Physical Activity Guidelines (U.S. Dept. of Health and Human Services, 2008). Recent evidence shows that light activity and short bouts of MVPA may have health benefits, and thus should not be ignored. Therefore, the purpose of this dissertation is to examine activity as an entire spectrum, rather than use strict cut-point points to only include moderate to vigorous intensity physical activity in 10+ minute bouts (MVPA). Several variables within physical activity will be used including MVPA-10 (MVPA according to the 2008 PA Guidelines, requiring durations of at least 10 minutes), total MVPA (all MVPA regardless of bout length), and total physical activity (all activity from light to vigorous in any bout duration; all activity >1.5 METs). Thus, the analyses will gradually add components of BPA, by first adding short bouts of MVPA to obtain total MVPA and then light intensity PA to obtain total PA.

This dissertation incorporates analyses linking a behavioral investigation of physical activity to a physiological investigation of how such activity influences adiposity and weight. Thus, it transitions from what characteristics influence physical activity behavior to how physical activity influences health. The dissertation first examines the individual level determinants of PA. The second paper examines how major life events influence changes in PA. This second paper takes into consideration the determinants from paper one, as these could play a role as covariates in this analysis. The final paper examines longitudinal associations of physical activity with anthropometric outcomes. This dissertation provides novel assessments of examining the full spectrum of total physical activity by comparing across physical activity categories of MPVA-10, total MVPA, and total PA.

Novelty of Dissertation:

1. With the advancements of objective measures, we have the capability to capture the full range of activity, over each entire 24 hour day.

2. This project will bring attention to the often neglected baseline physical activity. The current definition of BPA is all light PA and shorts bouts of MVPA less than 10 minutes in length. This dissertation will shed light on the effect of the addition of baseline activity to account for differences in total MVPA and total PA from the typical MVPA in 10 minute bouts.

3. Few studies have examined individual factors associated with the full spectrum of physical activity and what differences may exist across the intensity spectrum. Understanding these correlates and determinants could provide valuable and unique insight for future programs.

4. Few studies have had the capability to perform prospective longitudinal assessment of physical activity changes using objective measurements to examine how life events influence changes in physical activity. In addition, few have examined physical activity beyond what would be considered leisure time.

5. This dissertation can contribute to evidence of the health importance, particularly for anthropometric outcomes, for physical activity and provide insight to what influences behavior change that can then utilized for behavioral strategies supporting programs and interventions that promote active lifestyles rather than structured exercise.

Specific Aims

Specific Aim 1: Examine the intrapersonal-level determinants of physical activity

Research Question 1.1: What intrapersonal-level variables are associated with the duration of moderate to vigorous physical activity in at least 10 minute bouts to coincide with the PA Guidelines (MVPA-10)?

Research Question 1.2: What intrapersonal-level variables are associated with the duration total moderate of vigorous physical activity, regardless of bout length (total MVPA)? Are there differences in determinants for total MVPA vs. MVPA-10?

Research Question 1.3: What intrapersonal-level variables are associated with total physical activity including all minutes of activity light intensity and above (total PA)? Are there differences in determinants for total PA vs. total MVPA or MVPA-10?

Specific Aim 2: Examine how the total number of life events and the self-reported stress of life events influence changes in physical activity.

Research Question 2.1: Does the total number of life events and the associated self-reported stress influence changes in the duration of moderate to vigorous physical activity in at least 10 minute bouts to coincide with the PA Guidelines (MVPA-10)?

Research Question 2.2: Does the total number of life events and the associated self-reported stress influence changes in the duration of total moderate to vigorous physical activity regardless of bout length (total MVPA)? Is there a difference in the impact that life events have on total MVPA vs. just MVPA according to the guidelines?

Research Question 2.3: Does the total number of life events and the associated self-reported stress influence changes in the duration of total physical activity including all minutes of activity light intensity and above (total PA)? Is there a difference in the impact that life events have on total physical activity including light PA, vs. total MVPA (or vs. MVPA according to guidelines)?

Specific Aim 3: Examine the longitudinal relationship of physical activity with anthropometric outcomes.

Research Question 3.1: Is the duration of MVPA in at least 10 minute bouts according to the PA Guidelines (MVPA-10) associated with BMI, waist circumference, hip circumference and/or % body fat after controlling for socio-demographics and health-related variables?

Research Question 3.2: Is the duration of total moderate to vigorous physical activity regardless of bout length (total MVPA) associated with BMI, waist circumference, hip circumference and/or % body fat after controlling for socio-demographics and health-related variables? Does the added duration of short bouts of MVPA provide additional influence on these anthropometrics beyond what is seen with MVPA-10 alone?

Research Question 3.3: Is the duration of total physical activity, including all minutes of activity light intensity and above (total PA), associated with BMI, waist circumference, hip circumference and/or % body fat after controlling for socio-demographics and health-related variables? Does the added duration of light PA provide additional influence on these anthropometrics, beyond what is seen with total MVPA?

Table 1.1 Existing evidence of correlates and determinants and the degree of association with total moderate to vigorous physical activity

Correlate/Determinant	Association	References
Demographic and Biological		
Age	- -	Kaewthummanukul et al., 2006; Kirk et al., 2011; Trost et al., 2002
Gender (male)	+ +	Kaewthummanukul et al., 2006; Kirk et al., 2011; Trost et al., 2002
Race/Ethnicity (non-white)	- -	Trost et al., 2002
Occupation	+	Kaewthummanukul et al., 2006; Kirk et al., 2011; Trost et al., 2002
Income	+	Kaewthummanukul et al., 2006; Trost et al., 2002
Education	+ +	Kaewthummanukul et al., 2006; Trost et al., 2002
Weight Status	- -	Kaewthummanukul et al., 2006; Trost et al., 2002; Sherwood et al., 2000
Family Situation		
Marital Status (married)	-	Trost et al., 2002
Children	-	Kaewthummanukul et al., 2006
Psychological		
Perceived Stress	-	Trost et al., 2002; Sherwood et al., 2000
Mood Disturbances	-	Trost et al., 2002; Sherwood et al., 2000; Steptoe et al., 1998
Perceived Sleep Quality	+	Steptoe et al., 1998
Behavioral		
Active Transportation	+	Brownson et al., 2005; Sahlqvist et al., 2013; Sahlqvist et al., 2012; Dunton et al., 2009
House-hold related activities	+	Brownson et al., 2005
Occupational Activities	+	Brownson et al., 2005
Screen time (computer and TV)	-	Burton et al., 2012; Dunton et al., 2009; Brownson et al., 2005

- - : convincing evidence for negative association;
 - : some evidence, but not convincing, for negative associations
+ +: convincing evidence for negative association;
+ : some evidence, but not convincing, for negative associations

CHAPTER II

METHODS

The Energy Balance Study

This dissertation will use data collected as part of The Energy Balance Study to examine the three specific aims stated in the previous chapter. The aim of the Energy Balance Study is to examine the extent to which variation in total energy expenditure (TEE) and variation in total energy intake (TEI) contribute to changes in body weight and fat among adults. One of the secondary aims is to examine specific components of TEE and TEI that drive changes in body weight and fat. This dissertation will help answer questions focused on this secondary aim, in which we will examine physical activity including MVPA in ≥ 10 minute bouts according to the 2008 guidelines, and BPA (encompassing light intensity physical activity (LPA) and short bouts of MVPA less than 10 minutes) that contribute to an individual's TEE. It is clear the prevalence of obesity has been increasing for the past several decades, yet, there is a definite lack of understanding of the causes of weight gain. The regulation of body weight and fat involves a complicated intermingling of physiological, environmental, behavioral, genetic, and psychosocial variables. Thus, it is difficult to isolate specific causes of weight gain. Questions remain unanswered on weight/fat gain in large part due to the lack of proper research to adequately measure both sides of the energy balance equation plus these additional influencing variables. The Energy Balance Study is attempting to measure the potential determining variables of energy balance more accurately than ever before in a large prospective study.

Sample population

The study recruited 430 healthy young adults, age 21-35 years, with a body mass index (BMI) of 20-35. Inclusion/exclusion criteria were based on ensuring the participants would be available to participate for at least the first year, overall healthy (absent of diagnosed chronic disease), and no other known health or behavioral complications that would influence body weight or fat that could interfere with findings from the study. Exclusion criteria included moving from the area within the next 15 months, using medications to lose weight, started or stopped smoking within the last 6 months, planned weight loss surgery, hypertensive (150mmHg systolic and/or 90mmHg diastolic), ambulatory blood glucose levels ≥ 145 mg/dl, currently diagnosed or taking medications for a major chronic health conditions, history of depression, taking selective serotonin reuptake inhibitors, giving birth within the past 12 months, planning to start or stop birth control in the next 12 months while participating in the first year of the study. All study protocols were approved by the University of South Carolina Institutional Review Board. To be included in analyses each participant must have completed the required measurements for at least two time point assessments (baseline plus one additional). In addition, outliers will be removed based on influential diagnostic statistics for each separate study.

Of the 430 participants completing their baseline assessment, the mean age is 27.7±3.8 years, 218 females and 212 males, 66.5% were Caucasian, 12.6% African

American, 10.7% Asian, 3.0% Hispanic, and 7.2% reported themselves as other or mixed. Most of the participants were college graduates (83.7%). In addition, about half are students (46.7%), half were not married (52.1%), and most do not have any children (85.1%).

Study timeline

Each participant is examined every 3 months over a 2 year period. This dissertation will include data collected through the 12 month assessment. Table 2.1 and Table 2.2 include a list the measurements conducted at each quarter. Below are detailed descriptions of all measurements to be used in the analyses within this dissertation.

Outcome and Exposure Measurements

Anthropometry: Anthropomorphic measures consist of weight, height, body mass index (BMI), body composition (including total fat and lean tissue mass, as well as arm, leg and torso fat and lean mass, and bone mineral density), and waist and hip circumferences. To ensure measurement consistency, participants wore medical scrubs and were bare foot. BMI (kg/m^2) was calculated from height measured by stadiometer and weight from an electronic scale. Dual X-ray absorptiometry (DXA) (GE Healthcare, Waukesha, WI), measured body composition. Using a calibrated, spring-loaded tape measure (rounding to the nearest 0.1 cm), waist circumference was measured 2 inches above the umbilicus, at the point midway between the coastal margin and iliac crest in the mid-axillary line, and hip circumference was measured at the widest point around the greater trochanter.

Energy Intake: The Energy Balance study used 24 hour dietary recalls to examine TEI and its underlying nutrients. Although the measure has error, it is considered the gold standard for the measurement of dietary intake. Registered dieticians performed 3 recalls on randomly selected days within a 2 week time frame during each quarterly assessment. The dieticians would use a multi-pass interview method and follow the Nutrient Data System for Research software (NDSR Version 2012), when conducting the assessments. NDSR is a comprehensive research tool that includes over 19,000 foods and over 120 nutrients and this extensive list is updated on a yearly basis. The multi-pass method involved reviewing an individual's dietary intake over the day multiple times in an attempt to reduce leaving out any calories and/or nutrients consumed (Dwyer et al., 2001). In addition, all participants are given a food portion visual and a brief training on its use every 6 months, as a way to help increase the likelihood of correctly reporting portion sizes (Posner et al., 1992).

Energy Expenditure: The SenseWear Mini Armband (BodyMedia Inc. Pittsburgh, PA) is used as the primary measure of energy expenditure. The Armband is worn on the upper left arm over the triceps muscles. Energy expenditure and activity are measured using a combination of a tri-axial accelerometer with biological sensors measuring heat flux, galvanic skin response, near-body ambient temperature, and skin temperature. Using the combination of sensors allows for increased sensitivity beyond the typical accelerometer, such as an enhanced ability to detect activities such a lifting and carrying loads, moving at a gradient, and non-ambulating activities (Welk et al., 2007). The Armband's algorithms use a Naïve Bayes classifier for pattern recognition that can allow for the ability to estimate the context of an activity. The Armband categorizes activity into several classes including walking, running, stationary biking, road biking, rest, resistance activities, and other activity. The Armband takes into account all the sensor values collected on a minute by minute basis to determine the best fit activity category and then calculates kilocalories and METs. The Armband has been shown to be a valid and reliable device under both laboratory (against indirect calorimetry) and free-living conditions (against doubly labeled water (DLW) and other validated accelerometers) (Fruin et al., 2004; Jakicic et al., 2004; Johannsen et al., 2010; King et al., 2004; St-Onge et al., 2007). For instance, Johannsen et al. examined a sample of 30 young adults measuring free-living energy expenditure by DLW and the Armband Mini simultaneously over a 14 day period. The Armband Mini showed strong validity, underestimating TEE by an average of 22 kcal/day, with error rates of 8.3±6.5%. Regression analysis showed good agreement between the Armband and DLW, R^2=0.71, and intraclass correlations of 0.85, suggesting that only 15% of the variance was due to the difference in DLW and Armband methods, while the other 85% is due to differences among the individuals (Johannsen et al., 2010).

At each quarterly assessment, participants are instructed to wear the monitor for 10 consecutive days, 24 hours a day, except during water activities (i.e. swimming, bathing, or showering). When the monitor is removed from the body, the participants record these “non-wear” activities on a log. They include the time the Armband was removed, put back on, and a detailed reasoning for why they removed the Armband. These logged non-wear activities are then incorporated into the Armband data in order to have entire 24 hour estimates of energy expenditure and activity for each day. Non-wear activities are filled in based on the corresponding MET values according to the 2011

Compendium of Physical Activities ((Ainsworth et al., 2011). Energy expenditure for these non-wear periods is calculated as the MET value (MET-minutes) times the individuals laboratory measured resting metabolic rate. Compliance was considered completion of 7 days of wear (including 2 weekend days) with at least 23 hours of verifiable time (armband worn on body plus logged non-wear activities) on each of the days.

Resting metabolic rate (RMR) is measured every 6 months using indirect calorimetry with a ventilated hood (True One 2400, Parvo Medics, Sandy, UT). Participants are asked to fast for 12 hours prior and refrain from exercise within the 24 hour prior to the RMR test. The test involves lying awake, still and quiet, for approximately 45 minutes - 15 minute relaxation period followed by a 30 minute data collection period. RMR is then calculated from oxygen consumption and carbon dioxide production measured continuously during this assessment.

Questionnaires: Participants completed a series of questionnaires on a quarterly basis. Table 2.2 provides a list of the questionnaires that will be included in these analyses along with the time points at which they are administered. Demographics, such as age, race/ethnicity, occupation, and income are taken at baseline, 12 months, and 24 months. A medical history questionnaire is completed at baseline that covers inclusion/exclusion criteria concerns, as well as other medications, smoking status, and alcohol consumption.

The psychological measures of interest, including Perceived Stress Scale (PSS) and Profiles of Mood States (POMS) are obtained at baseline, 12 months, and 24 months. The PSS measures the degree to which life situations are evaluated as stressful. The questionnaire provides information on how much the individual perceives their life as unpredictable, overloaded, and/or uncontrollable (Cohen et al., 1983). The PSS has been shown to be highly correlated with health status and has become one of the most widely used instruments for measuring stress (Cohen et al.,1988). The POMS measures 6 factors of mood including tension-anxiety, depression-dejection, anger-hostility, fatigue-inertia, vigor-activity, and confusion-bewilderment. The 6 factors can be combined into one score to represent mood or be evaluated as separate entities (Pollock et al., 1979).

A questionnaire on physical activities/inactivities as well as a life-events questionnaire is completed at each quarterly visit. The Life Events questionnaire is a modified version of what is used in the CARDIA study (Bild et al., 1993; Friedman et al., 1988). The questionnaire includes 17 potential life events and for each that occurred the participant is asked how much emotional stress this caused them on a five point scale from "no stress" to "a great deal of stress". Table 2.3 lists the life events included in the questionnaire. The Energy Balance study also incorporated additional questions on physical activity specifically developed to understand some context behind an individual's activity/inactivity. Questions are asked inquiring about the previous three months on whether or not a person took part in active transportation (walking or biking), household-related activities (e.g. sweeping, vacuuming, cleaning, yard work, etc.), and occupational activity (e.g. walking, heavy lifting, construction etc.) Then the person reports on average how many days per week and minutes per day the activity was performed over the previous 3 months. For sedentary behaviors, the participants report watching television during leisure time on the weekdays and weekends, and on the computer during leisure time on the weekdays and weekends.

Statistical Analyses

Several statistical themes will be utilized throughout all three studies. All three studies utilize data collected on a quarterly basis over the 12 month period. Each study will employ linear mixed models to examine both between and within individual effects. This will allow for an evaluation of both chronic and acute effects. The chronic effects will be between subjects, looking at the averages across the entire year. Since the Energy Balance study was completely observational, without any intervention to consciously influence behaviors, there was no expectation for drastic changes in the outcomes of interest. Therefore, it is appropriate to examine the overall averages across the year. On the other hand, the within individual effects will allow for reflection on changes. The within effects examine acute changes within a specific 3 month assessment period within each separate individual. This is based on how a deviation from the overall yearly average in the independent variables impacts the dependent variable within that same quarterly assessment.

STUDY 1

Purpose

This study will address Aim 1: Examine the intrapersonal level correlates and determinants of the full spectrum of physical activity

Research Questions and Hypotheses

Research Question 1.1: What intrapersonal-level variables are associated with the duration of moderate to vigorous physical activity in at least 10 minute bouts to coincide with the PA Guidelines (MVPA-10)?

Hypothesis 1.1: Age will be inversely associated with accumulation of MVPA-10, women will accumulate less MVPA-10 compared with men, and overweight status will be associated with less MVPA-10 compared with normal weight (based on BMI categories of normal vs. overweight/obese). There will also be significant differences in accumulation of MVPA-10 by race/ethnicity and occupation, in which non-white and full-time employed (non-student) will be negatively associated with MVPA-10. Screen time during leisure, both TV and computer, will be negatively associated, whereas active transportation will be positively associated with MVPA-10. Negative mood and perceived stress will be negatively associated with MVPA-10.

Research Question 1.2: What intrapersonal-level variables are associated with the duration total moderate of vigorous physical activity, regardless of bout length (total MVPA)? Are there differences in determinants for total MVPA vs. MVPA-10?

Hypothesis 1.2: The same determinants will be present when considering either MVPA-10 or total MVPA, indicating that the behavior of accumulating short bouts of less than 10 minutes of MVPA has similar intrapersonal determinants as the longer bouts of 10 + minutes included in MVPA-10.

Research Question 1.3: What intrapersonal-level variables are associated with total physical activity including all minutes of activity light intensity and above (total PA)? Are there differences in determinants for total PA vs. total MVPA or MVPA-10?

Hypothesis 1.3: The same demographic variables of age, race, and socioeconomic status will remain significant for total PA, however the effect will not be as great. In addition, behaviors including work PA, household PA, computer and TV time will have a greater influence on total PA than on the MVPA categories.

Study Design

This study is a prospective cohort design evaluating the independent and dependent variables from baseline through 12 months.

Study Population

Healthy, young adults age 21-35, meeting the inclusion/exclusion criteria (see summary of Sample Population in Methods section for details) and recruited to participate in the Energy Balance Study will take be used as the sample for this analysis. Participants who completed at least 2 laboratory visits within the first year, completed the required questionnaires, and have at least 5 days (including both weekend days) of physical activity data from the Armband at these two or more time points were included.

Measurement Methods

The dependent variable in this analysis will be minutes per day of physical activity. Physical activity will be measured using the SenseWear Mini Armband and results will be explained in durational units of minutes/day. Several variables within physical activity will be used including MVPA-10 (MVPA according to the 2008 PA Guidelines, requiring durations of at least 10 minutes), total MVPA (all MVPA regardless of bout length), and total physical activity (all activity from light to vigorous in any bout duration; all activity >1.5 METs). Thus, the analyses will sequentially add the components of BPA to MVPA-10, by first adding the short bouts of MVPA to obtain total MVPA and then adding light PA to obtain total PA. In order to account for stoppage time during a sustained physical activity session (such as waiting to cross the street, or stopping to tie a shoe), at least 8 of 10 consecutive minutes at or above moderate intensity (≥3.0 METs) will be considered the criteria for MVPA-10 (Fan et al., 2013).

The independent variables will include the demographic, physiological, behavioral and psychological measures. The demographics measures will derive from the demographic questionnaire administered at the baseline assessment. The demographic variables consist of gender, age, children (none, one or more), marital status (married, unmarried), occupation (student vs. employed), income, and race/ethnicity (black, white, Hispanic, Asian, mixed, other). Weight status will be determined by BMI (kg/m^2) and categorized into normal weight (<25 kg/m^2), overweight (25-29.9 kg/m^2), and obese (≥30 kg/m^2).

Behavioral variables consist of self-reported screen time (both television and computer during leisure), active transportation (walking or biking), household activities (such as cleaning or yard work), and occupational activity (such as lifting heavy objects or walking). These measures are all assessed by self-report questionnaires at each quarterly visit.

The psychological variables of interest consist of perceived stress and mood. Perceived stress will be evaluated using the perceived stress scale (PSS). Mood will be evaluated using the Profile of Mood States (POMS). These three questionnaires are administered at baseline and at the 12 month follow-up visit.

Statistical Analysis

Descriptive characteristics for the sample will be presented as means ± SDs. T-tests will examine differences between gender for continuous variables and chi-square tests used for categorical variables. Linear mixed models will be used to explore the relation between the various individual level determinants and physical activity measures. All models will be stratified by gender. Analyses will be performed separately for each of the physical activity measures including MVPA-10, total MVPA, total PA. Prior to pursuing final analyses, model assumptions will be checked to ensure the residuals and estimates of the random intercepts are normally distributed and iterative influence diagnostics performed in order to identify any outliers. Initially, bivariate models will be used for each of the potential determinants with each of the physical activity measures. Then multivariable models will be used, consisting of the individual level determinants that are significant (those with a p-value <0.05) in the bivariate analyses. In order to aid interpretation given the known co-linearity of some of the covariates, variables will be added in blocks. The blocks contain variables in categories including biological, socioeconomic, family, smoking/drinking, active behaviors, sedentary behaviors, and psychological. Therefore, if more than one variable within a category is significant, both will be added simultaneously as a block and the multivariate model will be used to test whether the entire category (block) significantly contributes to the model. To determine whether each block of variables adds significant explanatory value to the model, likelihood ratio tests were performed. In addition, a pseudo R^2 value was computed in order to assess if adding the blocks increases the explained variance (Raudenbush and Bryk, 2002). Statistical significance will be set at $P < 0.05$ in all analyses. Analyses will be performed using SAS version 9.4 (SAS Institute, Cary, North Carolina)

STUDY 2

Purpose

This study will address Specific Aim 2: Examine how the total number of life events and the self-reported stress of life events influence the total spectrum of physical activity.

Research Questions and Hypotheses

Research Question 2.1: Does the total number of life events and the associated self-reported stress influence the duration of moderate to vigorous physical activity in at least 10 minute bouts to coincide with the PA Guidelines (MVPA-10)?

Hypothesis 2.1: The accumulation of life events will be associated with reductions in MVPA-10. This relationship will be more prominent if the life event score considering the associated self-reported stress is high.

Research Question 2.2: Does the total number of life events and the associated self-reported stress influence the duration of total moderate to vigorous physical activity regardless of bout length (total MVPA)? Is there a difference in the impact that life events have on total MVPA vs. just MVPA according to the guidelines?

Hypothesis 2.2: The accumulation of more life events will be associated with reductions in total MVPA. This relationship will be more prominent if the life event score considering the associated self-reported stress is high The impact of life events will become even greater when considering total MVPA compared to just MVPA-10, indicating the number and stress score of life events influences shorter bouts of MVPA as well.

Research Question 2.3: Does the total number of life events and the associated self-reported stress influence the duration of total physical activity including all minutes of activity light intensity and above (total PA)? Is there a difference in the impact that life events have on total physical activity including light PA, vs. total MVPA (or vs. MVPA according to guidelines)?

Hypothesis 2.3: The accumulation of life events will be associated with reductions in total physical activity. This relationship will be more prominent if the life event score considering perceived stress is high. The impact of life events will be similar for total PA compared with total MVPA, indicating that the number and stress score of life events does not influence light physical activity.

Study Design

This study is a prospective cohort design evaluating life event and physical activity on a quarterly basis from baseline through 12 months.

Study Population

Healthy, young adults age 21-35, meeting the inclusion/exclusion criteria (see summary of Sample Population in Methods section for details) and recruited to participate in the Energy Balance Study will take be used as the sample for this analysis. Participants who completed at least 2 laboratory visits within the first year, completed the required questionnaires, and have at least 5 days (including 2 weekend days) of physical activity data form the Armband at these two or more time points will be included.

Measurement Methods

The dependent variable in this analysis is minutes per day of physical activity. Physical activity will be measured using the SenseWear Mini Armband and results will be explained in durational units of minutes per day. Several variables within physical activity will be used including MVPA-10 (MVPA according to the 2008 PA Guidelines, requiring durations of at least 10 minutes), total MVPA (all MVPA regardless of bout length), and total physical activity (all activity from light to vigorous in any bout duration; all activity >1.5 METs). Thus, the analyses will sequentially add the components of BPA to MVPA-10, by first adding the short bouts of MVPA to obtain total MVPA and then adding light PA to obtain total PA. In order to account for stoppage time during a sustained physical activity session (such as waiting to cross the street, or stopping to tie a shoe), at least 8 of 10 consecutive minutes at or above moderate intensity (≥3.0 METs) will be considered the criteria for MVPA-10 (Fan et al., 2013).

The independent variables consist of self-reported life events occurring within the previous three months reported by questionnaire. This questionnaire inquiring about 17 potential life events was administered at each quarterly laboratory visit. See Table 2.4 for the list of life events included in the questionnaire. For each event that occurred the participant is asked how much emotional stress this caused them on a five point scale from "no stress" to "a great deal of stress". The cumulative number of life event occurrences over the 12 month period as well as aggregate stress score will be considered in the analyses. The stress score is a summative score of all self-reported stress ratings for all occurring life events.

Statistical Analysis

Descriptive characteristics for the sample will be summarized using means and standard deviations of demographic variables. T-tests will examine differences between gender for continuous variables and chi-square tests for categorical variables. Linear mixed models will be used to examine whether experiencing life events and the perceived stress of the life events are associated with physical activity. Prior to pursuing final analyses, model assumptions will be checked to ensure the residuals and estimates of the random intercepts are normally distributed and iterative influence diagnostics will identify any outliers. Analyses will be performed separately for each of the physical activity measures including MVPA-10, total MVPA, and total PA. Multivariable models will adjust for covariates including the individual level determinants that were significant in analyses from Study 1. First, the cumulative number of life event occurrences over the 12 month period as well as aggregate stress score will be considered in the analyses. The stress score is a summative score of all self-reported stress ratings for all occurring life events. Both the mean number/stress score of life events per quarter and the deviation from the mean number/stress score of life events (i.e. time-specific number minus the mean number) will be used in the models. The coefficient for the mean value provides the between individual associations, and the coefficient for the deviation value provides the within individual associations (Rabe-Hesketh and Skrondal, 2008). Then each separate life event that has at least 30 occurrences within the sample will be analyzed using the same method to obtain both the between and within individual effects. All statistical analyses will be stratified by gender. Statistical significance will be set at $P <$ 0.05 in all analyses. Analyses will be performed using SAS version 9.4 (SAS Institute, Cary, North Carolina).

STUDY 3

Purpose

This study will address Aim 3: Examine the relationship of physical activity with anthropometric outcomes.

Research Questions and Hypotheses

Research Question 3.1: Is the duration of MVPA in at least 10 minute bouts according to the PA Guidelines (MVPA-10) associated with anthropometrics after controlling for socio-demographics and health-related variables?

Hypothesis 3.1: Accumulation of MVPA-10 will independently result in improvements in all anthropometric outcomes, including body fat, weight, WC, and HC.

Research Question 3.2: Is the duration of total moderate to vigorous physical activity regardless of bout length (total MVPA) associated with anthropometrics after controlling for socio-demographics and health-related variables? Does the added duration of short bouts of MVPA provide additional influence beyond what is seen with MVPA-10 alone?

Hypothesis 3.2: Accumulation of total MVPA will result in improvements in all anthropometric outcomes, including body fat, weight, WC, and HC. The added duration of short bouts to summate total MVPA will result in a greater influence on all anthropometric outcomes when compared to MVPA-10 alone.

Research Question 3.3: Is the duration of total physical activity, including all minutes of activity light intensity and above (total PA), associated with anthropometrics after controlling for socio-demographics and health-related variables? Does the added duration of light PA provide additional influence, beyond what is seen with total MVPA?

Hypothesis 3.3: Accumulation of total PA will independently result in improvements in all anthropometric outcomes, including body fat, weight, WC, and HC. However, there will be no further influence of total PA beyond what is seen with total MVPA, suggesting that the addition of light intensity activity has little influence on adiposity and weight outcomes.

Study Design

This study is a prospective cohort design evaluating anthropometrics and physical activity on a quarterly basis from baseline through 12 months.

Study Population

Healthy, young adults age 21-35, meeting the inclusion/exclusion criteria (see summary of Sample Population in Methods section for details) and recruited to participate in the Energy Balance Study will take be used as the sample for this analysis. Participants who completed at least 2 laboratory visits, completed the required questionnaires, and have at least 5 days (including 2 weekend days) of physical activity data form the Armband at these two or more time points will be included.

Measurement Methods

The dependent variable in this analysis will be anthropometric measures including body fat percentage (BF %), BMI, hip circumference (HC, cm), and waist circumference (WC, cm). BF% was measured using DXA at each quarterly visit. Body weight was measured using an electronic scale with participants wearing medical scrubs at each quarterly visit. A calibrated, spring-loaded tape measure (rounding to the nearest 0.1 cm) was used to measure WC two inches above the umbilicus and measure HC at the widest point around the greater trochanter. WC and HC were measured every six months, at the baseline, 6 month and 12 month laboratory visits.

The independent variable in this analysis will be physical activity. Physical activity was measured using the SenseWear Mini Armband and results are explained in durational unites of minutes per day. Several variables within physical activity will be used including MVPA-10 (MVPA according to the 2008 PA Guidelines, requiring durations of at least 10 minutes), total MVPA (all MVPA regardless of bout length), and total physical activity (all activity from light to vigorous in any bout duration; all activity >1.5 METs). Thus, the analyses will sequentially add the components of BPA to MVPA-10, by first adding the short bouts of MVPA to obtain total MVPA and then adding light PA to obtain total PA. In order to account for stoppage time during a sustained physical activity session (such as waiting to cross the street, or stopping to tie a shoe), at least 8 of 10 consecutive minutes at or above moderate intensity (≥3.0 METs) will be considered the criteria for MVPA-10 .

Statistical Analysis

Descriptive characteristics for the sample will be summarized using means and standard deviations of demographic variables. T-tests will examine the differences between gender for continuous variables and chi-square tests for categorical variables. Linear mixed models will be used to examine the association of physical activity with anthropometrics. Included in all multivariable models will be adjustments for covariates that coincide with the results from paper 1 as well as TEI and the average duration the Armband was worn. Analyses will be performed separately for each of the physical activity categories including MVPA-10, total MVPA, and total PA. By creating the physical activity variables so that the components of BPA are added, first short bouts followed by light intensity PA, the analyses will allow for an understanding of the degree to which BPA adds additional benefits beyond what is seen with MVPA-10. The average duration of MVPA-10, total MVPA, and total PA across 12 months as well as the deviation from these averages (i.e. time-point specific duration minus the mean duration) will be included in the models. The coefficient for the mean value provides the between individual associations, and the coefficient for the deviation value provides the within individual associations (Rabe-Hesketh and Skrondal, 2008). Prior to pursuing final analyses, model assumptions will be checked to ensure the residuals and estimates of the random intercepts are normally distributed and iterative influence diagnostics will identify any outliers. All statistic analyses will be stratified by gender. Statistical significance will be set at $P < 0.05$ in all analyses. Analyses will be performed using SAS version 9.4 (SAS Institute, Cary, North Carolina).

Table 2.1 Laboratory measures administered in the Energy Balance Study

	Baseline	3M	6M	9M	12M	15M	18M	21M	24M
Physical activity assessment	X	X	X	X	X	X	X	X	X
Dietary assessment	X	X	X	X	X	X	X	X	X
Body composition assessment	X	X	X	X	X	X	X	X	X
Resting metabolic rate	X		X		X		X		X

Table 2.2 List of questionnaires administered in the Energy Balance Study

Questionnaire	**Baseline**	**3m**	**6m**	**9m**	**12m**	**15m**	**18m**	**21m**	**24m**
Demographics	X				X				X
Medical History	X								
Perceived Stress Scale	X				X				X
Profile of Mood State	X				X				X
Physical Activity	X	X	X	X	X	X	X	X	X
Life events (Past 3 months)	X	X	X	X	X	X	X	X	X

Table 2.3 Definitions of Determinants as used in Paper 1 Analyses

Determinant	Definition (numerical/categorical and additional descriptions)	Assessment Time Points
Biological		
Age	numerical	Baseline
Race/Ethnicity	Categorical: White, Black, Asian, Hispanic, Mixed, Other	Baseline
BMI category	Healthy weight (BMI 18.5-24.9) Overweight (BMI 25.0 -29.9) Obese (BMI ≥ 30.0)	Baseline
Socioeconomic		
Occupation	Categorical: Student, Non-student	Baseline
Income	Categorical: <$30,000; vs. $30,000-59,999; vs. ≥$60,000	Baseline
Education	Categorical : 4 + years vs. less than 4 years college	Baseline
Family Situation		
Marital Status	Categorical: Married vs. Not married	Baseline.
Children	Categorical: 1+ vs. none	Baseline.
Psychological		
Perceived Stress	Numerical	Baseline, 12 mo.
Mood Disturbances	Numerical	Baseline, 12 mo.
Behavioral		
Travel PA	Numerical (min per week)	Baseline, 3 mo., 6 mo., 9 mo., 12 mo.
Household PA	Numerical (min per week)	Baseline, 3 mo., 6 mo., 9 mo., 12 mo.
Work PA	Numerical (min per week)	Baseline, 3 mo., 6 mo., 9 mo., 12 mo.
Screen time (computer and TV)	Numerical (hrs per day)	Baseline, 3 mo., 6 mo., 9 mo., 12 mo.
Smoking Status	Categorical: Current smoker vs. non-smoker	Baseline
Alcohol Intake	Categorical: Heavy drinker (men = 15+ drinks/week; women = 8+ drinks/week) vs. not a heavy drinker	Baseline

Table 2.4 List of items included in Life Events Questionnaire

1.	Graduated from school or training program
2.	Started first, full-time permanent job
3.	Quit, fired or laid off from a job
4.	Changed jobs
5.	Moved out of parents' home
6.	Moved to a different residence
7.	Went on or off welfare
8.	Took out a mortgage on a house
9.	Was arrested and/or went to jail
10.	Major physical illness or injury
11.	Problems from the use of alcohol
12.	Started or ended a romantic relationship
13.	Became engaged
14.	Got married
15.	Got pregnant
16.	Separated or divorced from your spouse
17.	Death of a close friend, child, spouse/mate, parent or other family member

CHAPTER III

INTRAPERSONAL LEVEL CORRELATES AND DETERMINANTS OF THE FULL SPECTRUM OF PHYSICAL ACTIVITY

Abstract

Objective: The purpose of this study was to examine the intrapersonal-level correlates and determinants of the full spectrum of physical activity among young adults.

Methods: Physical Activity data were collected on a quarterly basis across 12 months among 407 healthy, young adults. The SenseWear Armband measured physical activity and questionnaires captured individual-level variables related to biological, socioeconomic, family structure, behaviors, and psychological wellness. Mixed linear models were used to examine both between and within individual effects of these variables on the full spectrum of PA, examining MVPA in 10 minute bouts (MVPA-10), all MVPA regardless of bout duration (total MVPA), and all PA at or above light intensity (total PA).

Results: Age, BMI, education, employment, marital status, work PA, travel PA, computer time, and perceived stress were associated with at least one of the categories of PA among the males. The full multivariable models had a pseudo R^2 of 0.54 for MVPA-10, 0.56 for total MVPA, and 0.26 for total PA. Among the females, intrapersonal variables including race, BMI, smoking status, TV and computer durations, household

PA, work PA, perceived stress and mood score were associated with at least one or all three categories of PA. The full multivariable models had pseudo R^2 of 0.61 for MVPA-10, 0.61 for total MVPA, and 0.41 for total PA.

Conclusion: The results from this study show that variables within categories of intrapersonal factors including biological, socioeconomic, family structure, behavioral, and psychological can influence PA. The associated characteristics differ based on whether physical activity is quantified as MVPA-10, total MVPA, or total PA. When adding components of baseline PA on top of MVPA-10, first short bouts of total MVPA followed by light intensity PA, the results are drastically influenced.

Keywords: physical activity, correlates, determinants, intrapersonal, longitudinal

Introduction

Physical activity plays an important role in overall health. Strong evidence exists that higher levels of physical activity are associated with enhancing quality of life and reducing the risk of all-cause mortality and many chronic conditions such as cardiovascular disease, some cancers, hypertension, metabolic syndrome, and mental health disorders (Haskell et al., 2009; Lee et al., 2012). Despite the known vital importance for health, the majority of adults do not achieve the recommended amounts of physical activity (Hallal et al., 2012). Therefore, it remains important to continue creating effective interventions and programs focused on the promotion of physical activity. In order to develop and improve upon such public health programs, a key step requires understanding the causes of physical activity behavior.

The ecological model provides a framework of the various levels of influence including intrapersonal, interpersonal, organizational, community, and public policy (Sallis et al., 2006). Developing interventions with this model involve a multilevel framework, with a clear perception of how each level influences behavior. This paper will focus on the most direct/nearest level to the individual – the intrapersonal level, including demographic, psychological, behavioral, and family situations (Sallis et al., 2006).

The Energy Balance study thoroughly examined each participant at the individual level (Hand et al., 2013). The study allows for longitudinal analysis of intrapersonal level determinants and correlates of physical activity, including how changes in these determinants and correlates are associated with changes in physical activity. Most studies have been cross-sectional in design and thus can not make casual inferences. Longitudinal determinant research is required for an improved understanding of what makes individuals active or inactive, and what can predict a change in physical activity (Bauman et al., 2012). In addition, prior cross-sectional studies tend to assess activity at one single time point and then make assumptions that the single assessment of PA is adequate in representing chronic or habitual physical activity. The present study evaluates activity measures collected across multiple time points throughout the year to obtain a representation of chronic PA behavior.

Another limitation of much of the research is the reliance on self-reported leisure time physical activity. Furthermore, only a few used objective measures of physical activity, of which most define and quantify activity as MVPA (moderate to vigorous physical activity) of at least 10 minute bouts to coincide with the 2008 Physical Activity

Guidelines. Therefore, the examination of correlates and determinants of physical activity to date has excluded light intensity activity and short bouts of activity, sometimes referred to as baseline physical activity (BPA). BPA consists of the physical activity accumulated during daily life at durations and/or intensities below what is recommended in the 2008 Guidelines (U.S. Dept. of Health and Human Services, 2008). Recent evidence shows that light intensity activity and short bouts of MVPA may have health benefits, and thus should not be ignored (Healy et al., 2007; Levine, Vander Weg, Hill, & Klesges, 2006). As this evidence grows, more programs may focus efforts on replacing sedentary behavior with light activity and/or activities brief in duration. Consequently, it is important to understand what intrapersonal determinants could drive such behavior changes. Therefore, this paper uses objective quantification of activity across the entire spectrum. Any activity of light intensity and above (>1.5 METs) was evaluated and referred to as total physical activity (Total PA). In addition, the analyses will also distinguish between the typical MVPA in 10+ minute bouts (MVPA-10) vs. total MVPA including all bout lengths, and total PA to include light activities as well, so to examine if determinants differ if physical activity is defined in various ways.

The purpose of this study is to examine the intrapersonal-level correlates and determinants of the full spectrum of physical activity among young adults.

Methods

Study Population

This paper used data collected from June 2011 through August 2013 as part of The Energy Balance Study. Details regarding the rationale and overall study design have been summarized previously (Hand et al., 2013). The sample included 407 healthy young adults, age 21-35 years, with a body mass index (BMI) of 20-35 kg/m^2. Exclusion criteria included moving from the area within the next 15 months, using medications to lose weight, started or stopped smoking within the last 6 months, planned weight loss surgery, hypertensive (150 mmHg systolic and/or 90 mmHg diastolic), ambulatory blood glucose levels $\geq$ 145 mg/dl, currently diagnosed or taking medications for a major chronic health conditions, history of depression, taking selective serotonin reuptake inhibitors, giving birth within the past 12 months, planning to start or stop birth control in the next 12 months while participating in the first year of the study. All study protocols were approved by the University of South Carolina Institutional Review Board. Participants who completed at least the baseline plus one other follow-up visit, completed the required questionnaires, and have at least 5 days (including both weekend days) of 18.5 hours/day of verifiable activity data at these two or more time points were included in this analysis.

Measurements

Physical Activity: The SenseWear Mini Armband (BodyMedia Inc. Pittsburgh, PA) was used as the primary measure of physical activity. The Armband is worn on the upper left arm over the triceps muscles. Energy expenditure and activity are measured using a combination of a tri-axial accelerometer with biological sensors measuring heat flux, galvanic skin response, near-body ambient temperature, and skin temperature. Using the combination of sensors allows for increased sensitivity beyond the typical accelerometer, such as an enhanced ability to detect activities such a lifting and carrying loads, moving at a gradient, and non-ambulating activities (Welk GJ et al., 2007). The

Armband's algorithms use a Naïve Bayes classifier for pattern recognition that can allow for the ability to estimate the context of an activity. The Armband takes into account all the sensor values collected on a minute by minute basis to determine the context and then calculates kilocalories and METs. At each quarterly assessment, participants were instructed to wear the monitor for 10 consecutive days, 24 hours a day, except during water activities (i.e. swimming, bathing, or showering). When the monitor was removed from the body, the participants recorded these "non-wear" activities on a log. These logged non-wear activities were then incorporated into the Armband data in an attempt to obtain entire 24 hour estimates of energy expenditure and activity for each day.

Results are explained in units of duration of physical activity (minutes/day). Several variables within physical activity were used: MVPA-10 (MVPA according to the 2008 PA Guidelines, requiring durations of at least 10 minutes), total MVPA (all MVPA regardless of bout length), and total physical activity (all activity from light to vigorous in any bout duration; all activity >1.5 METs). Thus, the analyses will sequentially add the components of BPA to MVPA-10, by first adding the short bouts of MVPA to obtain total MVPA and then adding light PA to obtain total PA. In order to account for common interruptions in lifestyle physical activity (such as waiting to cross the street, or stopping to tie a shoe), at least 8 of 10 consecutive minutes at or above moderate intensity (≥3.0 METs) were considered the criteria for MVPA-10 (Fan et al., 2013).

Anthropometry: Anthropomorphic measures consisted of weight, height, body mass index (BMI), and body composition (body fat percentage). To ensure measurement consistency, participants wore medical scrubs and were bare foot. BMI (kg/m^2) was calculated from height measured by stadiometer and weight from an electronic scale.

Dual X-ray absorptiometry (DXA) (GE Healthcare, Waukesha, WI), measured body composition.

Questionnaires: The independent variables included the demographic, physiological, behavioral and psychological measures. The demographics measures were derived from the demographic questionnaire administered at the baseline assessment. The demographic variables consist of age, children (yes/no), marital status (married vs. single), occupation (student vs. employed), income, and race/ethnicity (black, white, Hispanic, Asian, mixed, or other). Weight status was determined by BMI (kg/m^2) at the baseline assessment and categorized into normal weight (<25 kg/m^2), overweight (25-29.9 kg/m^2), and obese (≥30 kg/m^2). A medical history questionnaire was completed at baseline that covers inclusion/exclusion criteria concerns, as well as other medications, smoking status, and alcohol consumption. "Heavy drinkers" were considered women who reported consuming 8 or more drinks per week and men who consumed 15 or more drinks per week, based on the recommended sex-specific weekly upper limits of the National Institute on Alcohol Abuse and Alcoholism (National Institute on Alcohol Abuse and Alcoholism, 1995) .

The psychological measures of interest, including Perceived Stress Scale (PSS) and Profiles of Mood States (POMS) were conducted at baseline and 12 months. The PSS measures the degree to which life situations are evaluated as stressful. The questionnaire seeks to understand how much the individual perceives their life as unpredictable, overloaded, and/or uncontrollable (Cohen et al., 1983). The POMS measures 6 factors of mood including tension-anxiety, depression-dejection, anger-hostility, fatigue-inertia, vigor-activity, and confusion-bewilderment. The 6 factors can be combined into one score to represent mood or be evaluated as separate entities (Pollock et al., 1979).

A questionnaire on physical activity and sedentary behavior was completed at each quarterly visit in order to gain contextual information regarding an individual's activity/inactivity. Questions were asked about the previous three months on whether or not a person took part in active transportation (walking or biking), household-related activities (e.g. sweeping, vacuuming, cleaning, yard work, etc.), and occupational activity (e.g. walking, heavy lifting, construction etc.). The participants reported how many days per week and minutes per day on average an activity was performed over the previous three months. For sedentary behaviors, the participants reported the typical duration per day spent watching television during leisure time and on the computer during leisure time.

Statistical Analysis

Descriptive characteristics for the sample are summarized using means and standard deviations of demographic variables. T-tests examined differences between gender for continuous variables and chi-square tests were used for categorical variables. The primary analyses used linear mixed models. All models were stratified by gender. The dependent variable, physical activity was quantified in units of minutes/day and assessed in three categories: MVPA according to the 2008 PA Guidelines, requiring bouts of at least 10 minutes ≥ 3.0METs (MVPA-10); all MVPA regardless of bout length ≥ 3.0METs (Total MVPA); and all PA > 1.5 METs so to include all baseline activity (Total PA). The duration of physical activity at each quarterly time point across 12 months were used in the analyses. Prior to pursuing final analyses, model assumptions were checked to ensure the residuals and estimates of the random intercepts were normally distributed and iterative influence diagnostics were performed in order to identify any outliers. First, unadjusted linear mixed models explored the relationship of each intrapersonal variable with each physical activity category. For the biological, socioeconomic, and demographic variables, as well as smoking and alcohol intake behavior, the measurement at baseline was used to compare with physical activity across the 12 month period. These models examined the between individual associations, with the comparison being whether a different status in a demographic variable is correlated with differential accumulation of physical activity across the 12 months between the participants. For the active and sedentary behaviors the mean duration per quarter as well as the deviation from the mean duration (i.e. time-specific duration minus the mean duration of the behavior) will be used in the models. The coefficient for the mean value provides the between individual associations, and provides insight into whether a variable is correlated with PA. In other words, it examined the chronic effects between subjects by looking at the averages across the entire year. The coefficient for the deviation value provides the within individual associations, and examines the variable as a determinant of PA (Rabe-Hesketh and Skrondal, 2008). The within effects examined acute changes within a specific 3 month assessment period. This was based on how a deviation from the overall yearly average in the independent variables impacts the dependent variable within that same quarterly assessment. Between and within variables are also used for the psychological variables in which the mean score of PSS and POMS between the baseline and 12 month assessments and the deviation from the mean will be utilized.

Then multivariable models were performed, consisting of the individual level determinants that were significant (those with a p-value <0.05) in the bivariate analyses. In order to aid interpretation given the known co-linearity of some of the covariates, variables were added in blocks. The block categories were biological (age, race, and BMI category); socioeconomic (education, occupation, and income); family (children and marriage); smoking/drinking; active behaviors (travel, work, and household PA); sedentary behaviors (TV and computer time); and psychological (PSS and POMS). Therefore, if more than one variable within a category was significant, both were added simultaneously as a block and the multivariate model tested whether the entire category (block) significantly contributed to the model. To determine whether each block of variables added significant explanatory value to the model, likelihood ratio tests were performed. In addition, a pseudo R^2 value was computed in order to assess if adding the blocks increases the explained variance (Raudenbush and Bryk, 2002). All computations were performed using SAS version 9.4 (SAS Institute, Cary, N.C.).

Results

Participant Characteristics

Table 3.1 provides a summary of participant characteristics. For the biological characteristics, the mean age was 27.8±3.8 years, BMI was 25.4±3.8 kg/m^2, and white was the most prominent race (65%), followed by black (13%) and Asian (11%). There was a significant difference is BMI category proportions between men and women in which 49% of men and 56% of women where normal weight, 41% of men and 24% of women were overweight, and 10% of men and 20% of women were obese, according to the BMI classifications at their baseline assessments. Slightly over half the population was employed for wages (56%) and the other half classified themselves as students. Additionally, this sample was highly educated with 85% having four or more years of college. Most of the sample was unmarried (67%) and had no children (85%). Only 3% were current smokers at baseline and 10% were classified as heavy drinkers. There was a significant difference in proportion of heavy drinkers between men and women (3% vs. 18%, $p<.0001$).

Table 3.2 provides the average durations per quarter of the self-reported active and sedentary behaviors across the 12 months. On average men tended to reported higher durations of travel PA (0.83± 1.1 vs. 0.72± 1.1 hrs/week, $p=0.05$), and lower durations of household PA (1.2±0.99 vs. 1.6±1.4 hrs/week, $p<.0001$) compared with women. There was no a significant difference between genders for work PA (2.5±5.4 vs. 2.0±5.0 hrs/week, $p=0.056$). Men also reported greater amounts of television watching and computer usage during leisure time than women (TV: 4.6±2.3 vs. 4.4±2.2 hrs/day, $p=0.03$; computer: 4.02±1.96 vs. 3.8±1.9 hrs/day, $p=0.0028$). Among the sample, 32% reported participating in no travel PA and 23% of the observations reported no work PA, most people reported at least some household PA, and only 1.5% reported no household PA. When considering the averages for only those who did at least some work PA, the average was 3.06±5.95 hrs/week for men and 2.62±5.31 hrs/week for women and for travel PA the average was 1.20±1.06 hrs/week for men and was 1.07±1.20 hrs/week for women (data not shown).

The average PSS was significant greater for women (13.1±5.4) than men (12.3±5.0). There were no differences detected between men and women in the POMS, the entire population averaged a score of 1.6±19.5 across the baseline and 12 month assessments. Table 3.3 provides a summary of the averages for the psychological measures.

The participants in this study had excellent compliance in their activity monitor wear averaging 23.0±1.1 hrs/day of wearing the Armband over an average of 9.9±0.9 days per quarterly assessment. Table 3.4 also provides the averages across the 12 months for each of the three PA categories. Men obtained significantly greater amounts of MVPA-10 (90.2±63.5 min/day for men vs. 53.8±46.5 min/day for women, $p<0.0001$) and total MVPA (149.9±75.7 min/day for men vs. 106.3±58.5 min/day for women, $p<0.0001$) than women. However, both genders were similar in their average accumulation of total PA (men: 345.8±89.3 min/day; women: 340.9±84.5 min/day, $p=0.23$).

Unadjusted associations of intrapersonal characteristics with physical activity

Table 3.5 and 3.6 provide the coefficients for each intrapersonal variable association with the three categories of PA. For males, age, BMI, work physical activity, and computer time were significantly inversely associated with all PA categories. In addition, males who had four or more years of college accumulated less PA in all categories compared with the males who had less than four years of college. Computer time's association with PA was at the between individual level, indicating that men who spent more of their leisure time using a computer had accumulated less activity compared to those with less computer time. Work PA had a positive association at the within individual level. Several differences exist across the PA categories. Travel PA only had a significant influence on MVPA-10 (between effect: β =10.2, SE_β= 3.5, $p=0.004$). Males who were students accumulated 26.8±7.7 min/day more MVPA-10 than those employed for wages ($p=0.001$). The association remained significant for total MVPA, although the effect is reduced to 20.3±9.6 min/day (p=0.034) and no longer showed an association for total PA. Marital status was significant for only the MVPA categories in which being married was associated with an average of 16.6±8.1 min/day less MVPA-10 (p=0.041) and 19.5±9.8 min/day less total MVPA (p=0.047). Race only played an influence on total PA in which Asian and those who classified their race as "other" accumulated significantly less total PA than those who were white (Asian vs. white: -41.4±15.4 min/day, p=0.007; Other vs. white: -59.3±29.4 min/day, p=0.04). Among the psychological factors, the only significant association was a within individual effect of PSS with total PA. A one unit increase in PSS was associated with -2.7±1.1 min/day reduction in total PA.

For the females in this study, BMI, race, computer and TV time, and POMs had significant associations when comparing the 12 month average durations for all PA categories. For race, African American women accumulated significantly less activity than white, Asian, or Hispanic women in both MVPA-10 (β =-37.8±7.3, p<.0001; β =-34.9±12.2, p=.004; and β =-70.0±20.9, p<.001, respectively) and total MVPA (B=-44.9±9.4, p<.0001; β =-35.5±15.6, p=.02; and β =-59.5±16.4, p<.001, respectively). Women who were African American or Asian had significantly less total PA compared with white women (β =- 30.1±13.7, p=0.03; β =-46.9±20.3, p=.02, respectively). Similar to the result seen for men, women who were students accumulated significantly more MVPA-10 and total MVPA than women employed for wages (β =17.7, SE_{β}= 5.8, p=0.002; total MVPA: β =16.4, SE_{β}= 7.4, p=0.027), but no differences in total PA. Women who were non-smokers accumulated more MVPA-10 of 32.8±16.7 min/day compared with the current smokers. Work PA positively influenced total MVPA (p=0.01, within effect) and total PA (p=0.006, between effect and p=0.026, within effect) and household PA positively influenced total PA (p=0.03, between effect). Whereas for men POMs influenced total PA only, for women this psychological variable resulted in within subject changes for the MVPA categories. A one unit increase in POMs resulted in a -1.3±0.5 min/day and -1.4±0.6 min/day change in MVPA-10 and total MVPA, respectively (p=0.018 and p=0.036).

Multivariable models

Multivariable models were developed using the significant variables discussed above. Because all variables had to be available for these models, the sample for the multivariate models was reduced to 172 males and 175 females. However, the intrapersonal characteristics and average durations of activity did not significantly differ between the two samples of n=407 vs. n=347 (data not shown). For males all blocks of intrapersonal variables significantly added to the explanation of the models for each of the PA categories. The full model for MVPA-10 explained 54% of the variance when including age, BMI, education, employment, marital status, work PA, travel PA and computer time. The full model for total MVPA (age, BMI, education, marital status, work PA, and computer time) explained 56% of the variance. The multivariable model for total PA included age, BMI, education, work PA, computer time and PSS, and explained 26% of the variance.

The final model for MVPA-10 for women included race, BMI, smoking status, TV and computer durations, and both PSS and POMS. This model had a pseudo R^2 of 0.611. All blocks significantly contributed to the model except for the final addition of the psychological variables (Likelihood Ratio test, p=0.33). Similar results were seen with the model for total MVPA, with a pseudo R^2 of 0.613 and the psychological block did not significantly contribute to the model upon addition based on the likelihood ratio test (p=0.08). Finally a model including BMI, household PA, work PA, TV and computer time, and POMS explained 41% of the variance for total PA. All of these variables significantly added to the model.

Discussion

For the basic biological demographics, age was significantly and negatively associated with all PA categories for men but not for women. The inverse association with age has been shown in previous research (Bauman et al., 2012; Trost et al., 2002), however, few have stratified by gender and seen a difference between males and females. When reflecting on the β coefficients, the impact of age on total PA is about half degree of impact of the MVPA categories, which may indicate that age may not be as influential on light PA as it is on higher intensity activity of any bout length.

Race had more influential effects for women than men. Specifically, African American women tended to accumulated much less activity especially in the MVPA categories. Overweight or obesity has been shown to be an inverse correlate similar to the present findings (Bauman et al., 2012). BMI category was significantly associated with all PA categories. Those in the normal weight category at baseline consistently accumulated greater durations of PA vs. those who were overweight or obese. For men, there were no differences in the duration of total MVPA or total PA between the overweight and obese individuals, suggesting that their baseline PA of short bout and light PA did not differ between individuals in overweight vs. obese categories. Male and female students accumulated an average of 26 min/day and 17 min/day more MVPA-10 than their counterparts employed for wages. The associations with total MVPA remained significant; however the impact of association was reduced (20 min/day difference among men and 16 min/day difference among women) indicating that MVPA in 10 minute bouts may be the primary difference in activity behavior between these two categories of employment. Most studies in the past have examined only leisure time PA finding that education was directly associated (Bauman et al., 2012; Trost et al., 2002). However, when looking at the full spectrum of activity in our study, the results show an inverse association. Males with four or more years of education accumulated less PA in all categories compared to those with less education. Most of the evidence on marriage has been inconclusive (Kaewthummanukul & Brown, 2006; Kirk & Rhodes, 2011; Trost et al., 2002). The results of this study suggest that there are differences in amounts of MVPA by marital status for males, but not females. Males who were married accumulated significantly less PA than males who were not married.

Psychological variables varied in association with PA between men and women. Perceived stress was a significant within effect determinant for only total PA among the males, whereas stress was a determinant for MVPA-10 and total MVPA among the females. These results suggest that a change in stress may have a negative impact on the light intensity activities for men and the moderate to vigorous intensity activities for women. Mood state was inversely associated for females at the between individual level and appears to impact all PA categories. Although significant, the coefficients were rather modest for the psychological outcomes. Furthermore, when added to the multivariable model for women, the psychological block did not significantly contribute to the model for MVPA-10 and MVPA. The modest results associated with the psychological variables are similar to what has been shown in other studies. For studies that have explored stress variables the results are inconclusive and the associations tend to be small or lack significances all together (Bauman et al., 2012; Kaewthummanukul & Brown, 2006; Trost et al., 2002).

The duration of computer time was significantly associated with all PA categories for both genders. Leisure time TV was significantly associated for women but not men. The associations were seen at the between individual level for all sedentary behaviors. Furthermore, the between effect tends to increase across the PA categories from MVPA-10 to total PA, which suggests the time spent in sedentary behaviors during leisure can influence all activity regardless of intensity and bout length. Our results differ slightly from recent research on screen time showing time spent on the television or computer during leisure time is independent from MVPA. However, the total screen time per day was inversely associated with MVPA (Burton et al., 2012; Dunton et al., 2009) . It is also notable that the impact on PA is greater for computer time vs. TV time. Whereas the association of TV to PA has been a main concern over the past several decades, as technology continues to develop as a rapid rate, the influence of sedentary computer usage during leisure time may become of greater concern.

When reflecting on the active behaviors, work, travel, and household PA had varying degrees of influence and differences in the PA categories where associations were found. For work PA, previous studies had conflicting results because the analyses showed that increases in work PA resulted in a decrease in leisure time PA (Hillsdon, 2011; Kirk & Rhodes, 2011), however, with the examination of the full-spectrum of PA throughout each entire 24 hour day, the current analysis showed that PA at work had substantial positive influences across all categories of PA. In a longitudinal study of adults in the UK, the authors found that a change active travel was associated with corresponding change in overall physical activity (Sahlqvist et al., 2013, 2012). This study found a significant association of MVPA-10 with travel PA among the male sample at the between individual level, such that men who reported more travel PA had more MVPA-10, but not the within individual level. However, the lack of significant within-individual association could be partially due to the fact that few participants did substantial amounts of travel PA and thus we were unable to detect an effect. One third of the participants did not report any travel PA throughout the study and for those that did report active travel over half of these subjects accumulated less than one hour per week of active travel. The similar lack of significant association with household PA among the male sample could also be partially explained in this manner. Men reported accumulating much less household PA than women and with less variation. With the majority consistently reporting such low levels throughout the year, it could be difficult to detect either between or within individual effects. Women who reported greater durations of household PA had significantly greater amounts of total PA, which could be due to the increase in light intensity PA required with many house-related tasks.

This paper contributes to the literature on correlates and determinants of PA through its strong study design. The longitudinal, repeated measure framework allowed for the examination of some determinants based on the within-individual changes for the active behaviors, sedentary behaviors, and psychological variables. For the demographic variables for which changes were not possible, correlates were evaluated based on the measurement at baseline with the average duration of PA across the 12 months. The durations of PA across the year allow for a reflection on chronic PA behavior that is likely to be a better representation of typical behavior rather than a single assessment of only a few days of accelerometry or relying on subjective, self-report measures. With the excellent compliance from the participants in wearing the Armband, we were able to capture an average of 23 hrs/day for nearly 10 days per quarterly assessment. Considering 5 possible assessment time points, this study has nearly 50 complete days of objective activity data over the one year period for the vast majority of the sample. The objective measurement also allowed for examination of the full spectrum of PA, well beyond just leisure time PA which has been typically used in previous research on correlates and determinants. However, this analysis did rely on self-reported measures for active and sedentary behaviors because the Armband lacks the ability to capture specific behavioral context. This is the first study to the authors' knowledge that examined the full spectrum of physical activity. Future research should continue to examine activity beyond what is typically explored in MVPA among other populations to expand the generalizability beyond what is shown here among our sample of educated, young adults.

Physical activity is a complex behavior that is influenced by a variety of intrapersonal variables. The results from this study show that variables within categories of intrapersonal factors including biological, socioeconomic, family structure, behavioral, and psychological can influence PA. Considering the overall magnitude of influence based on the pseudo R^2 these intrapersonal characteristics explain similar variance for MVPA-10 and total MVPA, but less for total PA. Furthermore, the associated characteristics differ based on how physical activity is defined. The correlates and determinants of MVPA in 10 minute bouts are different from those associated with total MVPA and total PA. Therefore, adding components of baseline PA, first short bouts of total MVPA followed by light intensity PA influences the results. Considering the growing interest and recent research finding health associations with lighter intensity and shorter bouts of activity, it is important to understand such differences in correlates and determinants in order to improve upon our public health efforts to promote physical activity.

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Table 3.1 Participant Demographic Characteristics at Baseline:
Biological, Socioeconomic, Family and Smoking/Alcohol Consumption

	All (n=407)		Males (n=198)		Females (n=209)		
	Mean	S.D.	Mean	S.D.	Mean	S.D.	p-value for gender
Age	27.8	3.8	27.7	3.8	27.8	3.7	0.8
BMI	25.4	3.8	25.4	3.2	25.4	4.3	1.0
BMI Group	n	%	n	%	n	%	
<25.0 kg/m^2	216	52.94	98	49.40	118	56.34	<.0001
25-29.9 kg/m^2	130	31.99	80	40.52	50	23.8	
$\geq$30.0 kg/m^2	61	15.07	20	10.08	41	19.85	
Race							
white	266	65.36	131	66.16	135	64.59	0.0097
AA	54	13.27	16	8.08	38	18.18	
Hispanic	12	2.95	5	2.53	7	3.35	
Asian	45	11.06	30	15.15	15	7.18	
Other	15	3.69	7	3.54	8	3.83	
mixed	15	3.69	9	4.55	6	2.87	
Employment							
Student	180	44.23	92	46.46	88	42.11	0.4356
Employed for wages	227	55.77	106	53.54	121	57.89	
Income							
<$30,000	139	34.32	60	30.30	79	38.16	0.1394
$30,000 - 59,999	151	37.28	73	36.87	78	37.68	
≥$60,000	115	28.4	65	32.83	50	24.15	
Education							
4+ years of college	345	84.77	157	79.29	188	89.95	0.0019
<4 years college	62	15.23	41	20.71	21	10.05	
Marital Status							
Married	135	33.17	76	38.38	59	28.23	0.0303
Unmarried	272	66.83	122	61.62	150	71.77	
Children							
None	345	84.98	164	82.83	181	87.02	0.2387
1+	61	15.02	34	17.17	27	12.98	
Smoking Status							
Current Smoker	14	3.45	8	3.90	6	3	0.4531
Non-smoker	397	96.55	190	96.10	202	97	
Alcohol Intake							
Heavy Drinker	43	10.50	6	3.00	37	17.78	<.0001
Not a heavy drinker	364	89.50	192	97.00	172	82.22	

"Heavy Drinker": women = 8+ drinks per week ; men = 15+ drinks per week

Table 3.2 Durations of Self Reported Active and Sedentary Behaviors Overall and by Gender - Averages across 12 months

	All (n=407)		Males (n=198)		Females (n=209)		
	mean	S.D.	mean	S.D.	mean	S.D.	p-value for gender
Active Behaviors (hrs/week)							
Work PA	2.26	5.24	2.50	5.45	2.04	5.02	0.06
Household PA	1.45	1.25	1.20	1.01	1.68	1.40	<.0001
Travel PA	0.78	1.11	0.83	1.10	0.73	1.12	0.05
Sedentary Behaviors (hrs/day)							
TV duration	4.48	2.27	4.60	2.29	4.38	2.24	0.03
Computer Duration	3.89	1.92	4.02	1.96	3.76	1.88	0.00

Table 3.3 Psychological Variables Overall and by Gender - Averages across 12 months

	All (n=347)		Males (n=172)		Females (n=175)		
	mean	S.D.	mean	S.D.	mean	S.D.	p-value for gender
PSS	12.68	5.21	12.29	5.00	13.06	5.38	0.04
POMS	1.25	19.41	0.78	20.11	1.70	18.72	0.52

PSS = perceived stress score

POMS = Profile of Mood States Score

Table 3.4 Activity monitor values overall and by gender – Averages across 12 months

	All (n=407)		Males (n=198)		Females (n=209)		
	mean	S.D.	mean	S.D.	mean	S.D.	p-value for gender
Average Wear Time (hrs/day)	23.02	1.09	23.06	1.20	22.99	0.98	0.20
Number of Days	9.86	0.92	9.90	1.00	9.83	0.85	0.45
MVPA-10 (min/day)	71.67	58.40	90.21	63.54	53.88	46.55	<.0001
Total MVPA (min/day)	127.65	70.90	149.91	75.72	106.31	58.50	<.0001
Total PA (min/day)	343.31	86.93	345.79	89.33	340.94	84.54	0.23

Average Wear Time: Hrs/day the Armband was worn

Number of Days: compliant days of Armband wear (≥18.5 hrs/day) per quarterly assessment

MVPA10: activity ≥ 3.0 METs in 10 minute bouts (following 8 of 10 minute criteria)

Total MVPA: all activity ≥ 3.0 METs, regardless of bout length

Total PA: activity > 1.5 METs, regardless of bout length

Table 3.5 Unadjusted Associations of Intrapersonal Demographics with MVPA-10, Total MVPA and Total PA

	Males (n=198)						Females (n=209)					
	MVPA-10		Total MVPA		Total PA		MVPA-10		Total MVPA		Total PA	
	β	SE_β	β	SE_β	β	SE_β	β	SE_β	β	SE_β	β	SE_β
age	-5.80**	0.96	-6.48**	1.18	-3.45*	1.42	-1.18	0.79	-1.57	0.99	-1.72	1.41
race												
AA	-15.05	14.94	-20.00	17.97	-18.51*	20.14	-37.85**	7.36	-44.92**	9.36	-30.07	13.72
Asian	-3.71	11.43	-18.14	13.74	-41.43	15.41	-2.91	10.91	-9.46	13.88	-46.93	20.35
Hispanic	7.96	25.83	5.71	31.04	-0.32	34.85	21.70	15.44	25.05	19.65	6.26	28.76
Other	-24.48	21.85	-37.91	26.28	-59.33	29.45	-8.38	14.49	-11.14	18.45	-37.85	27.00
Mixed	1.95	19.40	7.69	23.33	21.15	26.14	-6.64	16.62	-11.22	21.15	-29.64	30.95
White	.		.		.		.		.		.	
BMI												
healthy weight	80.13**	11.66	98.85**	13.98	61.16*	18.00	58.49*	6.25	77.76**	7.80	62.64**	13.12
overweight	32.68	11.90	40.00	14.27	25.56	18.37	15.53	7.15	26.48	8.93	33.25	15.03
obese	.		.		.		.		.		.	
employment												
student	26.81*	7.77	20.33*	9.57	-1.02	11.05	17.71*	5.82	16.41	7.42	-5.27	10.60
employed for wages	.		.		.		.		.		.	
income												
<$30,000	14.70	10.01	12.91	12.15	-4.73	13.90	0.49	7.68	-3.37	9.68	-24.16	13.49
$30-60,000	1.78	9.55	2.28	11.58	-1.03	13.26	-7.67	7.70	-9.23	9.70	-15.13	13.52
>$60,000	.		.		.		.		.		.	
education												
4+ yrs of college	-22.65*	9.72	-31.60*	11.71	-31.34*	13.42	15.21	9.76	14.52	12.34	-9.19	17.52
< 4 years of college							.		.		.	
marital status												
married	-16.63*	8.12	-19.53*	9.83	-7.39	11.32	5.93	6.51	9.50	8.20	15.60	11.56
not married							.		.		.	
children												
None	12.53	10.54	10.91	12.78	-11.12	14.59	10.24	8.74	10.35	11.04	-20.40	15.58
1 +	.		.		.		.		.		.	

*p<0.05 **p<.0001

Table 3.6 Unadjusted Associations of Intrapersonal Self-Reported Behaviors with MVPA-10, Total MVPA and Total PA

	Males (n=198)						Females (n=209)					
	MVPA-10		Total MVPA		Total PA		MVPA-10		Total MVPA		Total PA	
	β	SE_{β}	β	SE_{β}	β	SE_{β}	β	SE_{β}	β	SE_{β}	β	SE_{β}
Smoking Status												
nonsmoker	-10.78	20.28	-18.50	24.51	-20.73	27.99	32.88*	16.28	33.01	20.59	20.00	29.31
current smoker	.		.		.		.		.		.	
Alcohol Intake - Heavy Drinker												
No	18.95	23.33	12.71	28.24	2.23	32.28	-4.54	7.69	-9.67	9.69	-19.19	13.66
Yes	.		.		.		.		.		.	
Work PA (hrs/week)												
Between Effect (Avg)	0.62	0.73	1.73*	0.88	2.61*	1.01	-0.76	0.57	-0.14	0.72	2.68*	0.98
Within Effect (Dev)	0.65*	0.27	0.88*	0.31	1.56*	0.41	0.33	0.23	0.73*	0.28	1.05*	0.47
Household PA (hrs/week)												
Between Effect (Avg)	-5.81	3.92	-4.72	4.75	-0.77	5.45	-3.24	1.98	-1.44	2.51	7.85*	3.59
Within Effect (Dev)	-1.67	1.34	-2.25	1.50	-2.18	2.02	-0.03	0.70	-0.10	0.88	-1.13	1.48
Travel PA (hrs/week)												
Between Effect (Avg)	10.24*	3.54	8.16	4.29	1.90	4.91	3.40	2.61	0.53	3.32	-8.11	4.66
Within Effect (Dev)	0.21	0.96	0.06	1.09	-0.36	1.48	0.77	0.90	-0.16	1.10	-2.57	1.86
TV total (min/day)												
Between Effect (Avg)	-0.89	1.78	-0.68	2.14	0.62	2.46	-3.81*	1.29	-5.00*	1.62	-7.03*	2.30
Within Effect (Dev)	-0.59	0.49	-0.65	0.55	-0.78	0.73	0.19	0.33	0.34	0.40	1.03	0.67
Computer total (min/day)												
Between Effect (Avg)	-5.84*	2.02	-7.46*	2.44	-7.52*	2.81	-4.98*	1.52	-6.90*	1.90	-9.72*	2.69
Within Effect (Dev)	-0.41	0.68	-0.59	0.76	-0.16	1.02	0.03	0.43	0.07	0.53	0.73	0.90

*p<0.05

Between effects examine the differences between participants' average durations across the 12 months;

Within effects examine the deviation from the 12 month average duration within each individual participant within a 3 month assessment period

Table 3.7 Unadjusted Associations of Intrapersonal Psychological Variables with MVPA-10, Total MVPA and Total PA

	Males(n=198)						Females (n=209)					
	MVPA-10		Total MVPA		Total PA		MVPA-10		Total MVPA		Total PA	
	β	SE_{β}	β	SE_{β}	β	SE_{β}	β	SE_{β}	β	SE_{β}	β	SE_{β}
PSS												
Between Effect	0.22	0.87	0.00	1.03	0.08	1.15	-1.05	0.58	-1.49*	0.74	-1.71	1.02
Within Effect	-0.63	0.67	-1.02	0.77	-2.67*	1.09	-1.29*	0.54	-1.42*	0.67	-0.43	1.06
POMS												
Between Effect	-0.13	0.22	-0.24	0.26	-0.44	0.29	-0.37*	0.17	-0.52*	0.21	-0.87*	0.29
Within Effect	-0.16	0.14	-0.21	0.16	-0.45	0.23	-0.17	0.14	-0.12	0.17	0.03	0.27

*$p<0.05$, PSS= Perceived Stress Score; POMS = Profile of Mood States ;
Between effects examine the differences between participants' average durations across the 12 months;
Within effects examine the deviation from the 12 month average duration within each individual participant within a 3 month assessment period

Table 3.8 Sequential Multivariate Models for MVPA-10, total MVPA and total PA for males (n=172)

MVPA-10	Likelihood Ratio Test p-value	Pseudo R^2
age	<0.0001	0.268
age + BMI	<0.0001	0.487
age + BMI + education + employment	0.0118	0.479
age + BMI + education + employment + marital status	0.0388	0.476
age + BMI + education + employment + marital status + work PA + travel PA	<0.0001	0.481
age + BMI + education + employment + marital status + work PA + travel PA + computer	<0.0001	0.542
TOTAL MVPA	**Likelihood Ratio Test p-value**	**Pseudo R^2**
age	<0.0001	0.238
age + BMI	<0.0001	0.496
age + BMI + education + employment	0.0026	0.502
age + BMI + education + employment + marital status	0.0388	0.497
age + BMI + education + employment + marital status + work PA	<0.0001	0.517
age + BMI + education + employment + marital status + work PA + computer	<0.0001	0.560
TOTAL PA	**Likelihood Ratio Test p-value**	**Pseudo R^2**
age	<0.0001	0.147
age + BMI	<0.0001	0.218
age + BMI + education	0.0193	0.214
age + BMI + education + work PA	<0.0001	0.226
age + BMI + education + work PA + computer	<0.0001	0.244
age + BMI + education + work PA + computer + PSS	0.0302	0.257

Table 3.9 Sequential Multivariate Models for MVPA-10, total MVPA and total PA for females (n=175)

MVPA-10	Likelihood Ratio Test p-value	Pseudo R^2
race	<0.0001	0.174
race + BMI	<0.0001	0.588
race + BMI + employment	0.0202	0.595
race + BMI + employment + smoking status	0.0005	0.611
race + BMI + employment + smoking status + TV + Computer	<0.0001	0.606
race + BMI + employment + smoking status + TV + Computer + PSS + POMS	0.3329	0.611
Total MVPA	**Likelihood Ratio Test p-value**	**Pseudo R^2**
race	<0.0001	0.148
race + BMI	<0.0001	0.596
race + BMI + employment	0.0429	0.594
race + BMI + employment + work PA	<0.0001	0.584
race + BMI + employment + work PA + TV + computer	<0.0001	0.600
race + BMI + employment + work PA + TV + computer + PSS + POMS	0.0863	0.613
Total PA	**Likelihood Ratio Test p-value**	**Pseudo R^2**
BMI	<0.0001	0.190
BMI + household PA + work PA	<0.0001	0.331
BMI + household PA + work PA + TV + computer	<0.0001	0.374
BMI + household PA + work PA + TV + computer + POMS	0.0151	0.409

CHAPTER IV

THE INFLUENCE OF LIFE EVENTS DURING YOUNG ADULTHOOD ON THE TOTAL SPECTRUM OF PHYSICAL ACTIVITY

Abstract

Introduction: Understanding how the occurrence of a major life event influences physical activity can provide important insight on the large scale issue of inactivity. There is a lack of research examining a wide range of life events and influence on the full spectrum of physical activity from light to vigorous intensity of all durations.

Objective: The purpose of this study was examine how life events and the associated self-reported stress of life events influence the full spectrum of physical activity among a cohort of young adults.

Methods: 407 healthy, young adults completed questionnaires on life event occurrences and associated stress and wore a SenseWear Armband accelerometer for 10 days on a quarterly basis across a 12 month period.

Results: The average number and associated stress of life events per quarter did not influence physical activity. For young adult men, changing jobs and marriage had negative impacts on activity while starting/ending a relationship and beginning a mortgage had positive influences. For young adult women, starting a new job, moving,

engagement, and the loss of a family/friend had negative consequence while quitting a job resulted in increases in PA. The degree of influence on activity often went beyond the typical recommendations of MVPA in 10 minute bouts. Many life events had significant associations with total MVPA and total PA.

Conclusion: When evaluating the total number of life events and the accumulated stress, there was a lack of association with physical activity. However, a wide span of life events separately impact activity in both positive and negative ways and differently based on the PA category.

Introduction

A change in lifestyle can have a dramatic influence on health, one potential avenue being physical activity. Reductions in physical activity levels are associated with an increased risk of all-cause mortality and many chronic conditions such as cardiovascular disease, some cancers, hypertension, metabolic syndrome, and mental health disorders as well as a reduced quality of life (Haskell et al., 2009; Lee et al., 2012). Understanding how the occurrence of a major life event influences physical activity can provide important insight on the large scale issue of inactivity. Life events may influence physical activity by way of increasing levels of stress which could result in changes in activity and/or by way of simply disrupting an individual's ability to engage in physical activity.

The Energy Balance Study examined young adults, age 21-35 years old. Young adulthood often brings about multiple major life events, and these events can result in critical changes to an individual's routine behaviors. In addition, behavior changes in young adulthood can often be permanent, creating new habits carried on throughout the rest of life. Common life events during this phase include graduation from school, beginning/changing/losing a job, moving, starting or ending a romantic relationship, engagement, marriage, pregnancy/having children, financial situation changes, major illness or injury, and loss of a family member or close friend.

Most research to date examining life event influences on physical activity have utilized self-reported questionnaires or interviews to obtain levels of physical activity (Engberg et al., 2012). In addition, the vast majority of these studies asked about only leisure time physical activity. A change in lifestyle may not only impact leisure time physical activity, rather it can influence any activity of daily living. With the ability to objectively quantify intensity and duration of physical activity, this paper examined the total spectrum of activity from light to vigorous in all durations. Any activity with an intensity above sedentary (>1.5 METs) was evaluated and referred to as total physical activity (Total PA). This included the typical moderate to vigorous physical activity in 10 minute bouts (MVPA-10) to coincide with the 2008 Guidelines and also baseline physical activity (BPA). BPA consists of the physical activity accumulated during daily life at durations and/or intensities below what is recommended in the Guidelines (U.S. Dept. of Health and Human Services, 2008). BPA is a component of all individuals' daily life, can vary drastically in dose, and this dose has the potential to be influenced by life events. Therefore, it is important to gain an understanding of the impact on life events on the full spectrum of physical activity. The analyses distinguished between the typical MVPA in 10+ minute bouts *(MVPA-10)* vs. total MVPA (including short bouts), and total

PA (including light intensity activities). The purpose of this study was to examine how life events and the associated self-reported stress of life events influence changes in the full spectrum of physical activity.

Methods

Study Population

This paper used data collected as part of The Energy Balance Study. Details regarding the rationale and overall study design have been published previously (Hand et al., 2013). The sample included 407 healthy young adults, age 21-35 years, with a body mass index (BMI) of 20-35 kg/m^2. Exclusion criteria included moving from the area within the next 15 months, using medications to lose weight, started or stopped smoking within the last 6 months, planned weight loss surgery, hypertensive (150mmHg systolic and/or 90mmHg diastolic), ambulatory blood glucose levels $\geq$ 145 mg/dl, currently diagnosed or taking medications for a major chronic health condition, history of depression, taking selective serotonin reuptake inhibitors, giving birth within the past 12 months, and planning to start or stop birth control while participating in the first year of the study. All study protocols were approved by the University of South Carolina Institutional Review Board. Participants who completed laboratory visits and required questionnaires in at least two of the quarterly time points within the first year and have at least 5 days (including 2 weekend days) of 18.5 hours/day of verifiable activity data for these two or more time points were included in this analysis.

Measurements

Physical Activity: The SenseWear Mini Armband (BodyMedia Inc. Pittsburgh, PA) was used as the primary measure of physical activity. The Armband is worn on the upper left arm over the triceps muscles. Energy expenditure and activity are measured using a combination of a tri-axial accelerometer with biological sensors measuring heat flux, galvanic skin response, near-body ambient temperature, and skin temperature. Using the combination of sensors allows for increased sensitivity beyond the typical accelerometer, such as an enhanced ability to detect activities such a lifting and carrying loads, moving at a gradient, and non-ambulating activities (Welk et al., 2007). The Armband's algorithms use a Naïve Bayes classifier for pattern recognition that can allow for the ability to estimate the context of an activity. The Armband takes into account all the sensor values collected on a minute by minute basis to determine the context and then calculates kilocalories and METs. At each quarterly assessment, participants were instructed to wear the monitor for 10 consecutive days, 24 hours a day, except during water activities (i.e. swimming, bathing, or showering). When the monitor was removed from the body, the participants recorded these "non-wear" activities on a log. These logged non-wear activities were then incorporated into the Armband data in order to have entire 24 hour estimates of energy expenditure and activity for each day.

Results were explained in durational units of physical activity (min/day). Several variables within physical activity were used including MVPA-10 (MVPA according to the 2008 PA Guidelines, requiring durations of at least 10 minutes), total MVPA (all MVPA regardless of bout length), and total physical activity (all activity from light to vigorous in any bout duration; all activity >1.5 METs). Thus, the analyses will sequentially add the components of BPA to MVPA-10, by first adding the short bouts of MVPA to obtain total MVPA and then adding light PA to obtain total PA. In order to account for common interruptions in lifestyle physical activity (such as waiting to cross the street, or stopping to tie a shoe), at least 8 of 10 consecutive minutes at or above moderate intensity (≥3.0 METs) was considered the criterion for MVPA-10 (Fan et al., 2013).

Anthropometry: Anthropomorphic measures consist of weight, height, and body mass index (BMI) collected at each quarterly visit. To ensure measurement consistency, participants wore medical scrubs and were bare foot. BMI (kg/m^2) was calculated from height measured by stadiometer and weight from an electronic scale.

Questionnaires: At each quarterly visit participants recalled life events occurring within the previous three months reported by questionnaire. This questionnaire inquired about 17 potential life events. See Table 4.3 for the list of life events included in the questionnaire. For each event that occurred the participant was asked how much emotional stress this caused them on a five point scale from "no stress" to "a great deal of stress". A cumulative life event stress score was quantified based on adding the stress scores of all self-reported life events. In addition, a questionnaire on demographics, such as age, race/ethnicity, occupation, education, and income was taken at baseline. A medical history questionnaire was completed at baseline that covers inclusion/exclusion criteria, as well as smoking status, and alcohol consumption.

Statistical Analysis

Descriptive characteristics for the sample are summarized using means and standard deviations of demographic variables. T-tests examined differences between gender for continuous variables and chi-square tests were used for categorical variables. The primary analyses used mixed linear models. The covariates to include in the models were determined based on the results from paper 1. The statistically significant intrapersonal demographic variables were considered important to include in these analyses. Thus, all models were stratified by gender and adjusted for age, race, BMI, education, and occupation. Physical activity was quantified in units of minutes/day and assessed in three categories: MVPA according to the 2008 PA Guidelines, requiring bouts of at least 10 minutes ≥ 3.0METs (MVPA-10); all MVPA regardless of bout length ≥ 3.0METs (Total MVPA); and all PA > 1.5 METs so to include all baseline activity (Total PA). The duration of physical activity at each quarterly time point across 12 months was considered in the analyses. Prior to pursuing final analyses, model assumptions were checked to ensure the residuals and estimates of the random intercepts were normally distributed and iterative influence diagnostics were performed in order to identify any outliers.

The cumulative number of life event occurrences over the 12 month period as well as aggregate stress score is considered in the analyses. The stress score is a summative score of all self-reported stress ratings for all occurring life events. Both the mean number/stress score of life events per quarter and the within-person deviations of each participant from their own mean number/stress score of life events (i.e. time-specific number minus the mean number) were used in the models. The coefficient for the mean value provides the between individual associations, and the coefficient for the deviation value provides the within individual associations (Rabe-Hesketh and Skrondal, 2008). As a post-hoc analysis, each separate life event that had at least 30 occurrences within the sample were analyzed using the same modeling method to obtain both the between and within individual effects. The between individual effects describe differences in PA between those who had the specific life event occur vs. those who did not. The within individual effects describe whether the life event caused a substantial acute change in PA within the individual in the same 3-month time period.

Results

Participant Characteristics

Table 4.1 provides a summary of participant characteristics at baseline. The mean age of the sample was 27.8±3.8 years and an average BMI of 25.4±3.8 kg/m^2. Approximately two-thirds of the participants were white and 13% were black. Slightly less than half (44.4%) were students while the other half were employed for wages. The population is highly educated, with 84.8% having at least four years of college.

This sample population had excellent compliance with activity monitor wear in which nearly the entire 24 hour period of each day was verifiable, with 23 hours per day of Armband wear and 9.9±0.9 days of compliant wear per quarter. The compliance remained strong throughout the 12 months, in which there was no significant difference in compliance statistics between quarterly assessments (data not shown). Additionally, 83% of the sample (n=336) completed all five of the possible quarterly assessment time points, followed by 19 individuals having four assessments, 25 having three assessments, and 27 individuals having two assessment time points completed adequately for use in this analyses. Table 4.2 also provides the 12 month averages of each PA category for all participants and stratified by gender. Men obtained significantly more MVPA-10 and total MVPA compared with women (MVPA-10: 90.2±63.5 vs. 54.3±47.3 min/day, p<0.0001; total MVPA: 149.9±75.7 vs. 106.9±59.3 min/day, p<0.0001). However, men and women were similar in durations of total PA (345.8±89.3 vs. 341.5±84.9, p=0.29).

A total of 1198 life events were reported among the 407 young adults within the 12 months of assessment. The most common included moving (n=243), starting or ending a romantic relationship (n=226), and a job change (n=206). The life events perceived as most stressful among those that reported an occurrence include divorce, death of family/friend, and starting a new job (mean stress ratings of 4.27±0.96, 3.44±1.15, and 3.44±1.31, respectively). Table 4.3 provides a summary of the total number of occurrences for each life event as well as the average self-reported stress associated with the life event. On average, this sample experienced 0.64± 0.56 life events per quarter and an aggregate stress score of 1.85±1.86 per quarter. Table 4.4 breaks down the average number of life events per subject and average aggregate stress score per subject by quarterly visit.

Associations of cumulative life events and stress score with physical activity

Table 4.5 summarizes the linear mixed model analyses examining the associations of the average number of life events per quarter as well as the average aggregate stress score per quarter with physical activity. The only significant association was between individual effect of average stress score per quarter with total PA among males (p=0.03), however, the coefficient was rather small (β = 7.00, SE_β = 3.20).

Associations of specific life events and associated stress scores with physical activity

In order to understand what may drive the lack of association with the average number and stress score of life events, a post hoc analysis was performed examining all life events with at least 30 occurrences separately. Tables 4.6, 4.7, 4.8, and 4.9 show the associations of each life event broken in groups of occupational related, moving related, relationship related, and death or serious person injury/illness, respectively. For occupational related life events, males who experienced a job change had more total PA than males who did not experience a job change. In addition, a greater stress score for job changes was directly associated with increases in total PA (B= 26.46, SE_{β} =11.56, p = .02). There were no associations with MVPA-10 or total MVPA for males with a change in job. Also, no associations were found in males among the other occupational-related life events with any category of PA.

For females, the within individual effect was significant for multiple occupational related life events. Quitting a job resulted in an increase in all categories of PA (for MVPA-10: β = 12.82, SE_{β} =4.15, p <.01; for total MVPA: β = 15.35, SE_{β}=5.03, p <.01; for total PA: β = 17.15, SE_{β}=8.30, p = .04). The stress rating of quitting a job had no associations. Starting a new job and the associated stress score both impacted women's activity in a negative manner. The experience of starting a new job resulted in an average decrease of 19.20±5.46 minutes/day (p<0.01) of MVPA-10 and a decrease of 23.11±6.62 minutes/day (p<0.01) of total MVPA, after adjustment for covariates. Furthermore, each one point increase in reported stress score resulted in a decrease of about 5 minute/day for each PA category (for MVPA-10: β = -5.43, SE_{β} =1.36, p< 0.001; for total MVPA: β = -6.54, SE_{β}= 1.65, p < 0.001; for total PA: β = -5.65, SE_{β}= 2.73, p = .04). Changing a job and its associated stress score had within individual effects among females for MVPA-10 and total MVPA. Finally, the stress score of graduation had a significant inverse association with total MVPA for women (β = -3.38, SE_{β}=1.47, p = 0.02).

Moving related life events had different impacts for men and women. For men, the event of starting a home mortgage resulted in an increase in total MVPA of 24.98±10.89 min/day (p=0.02) and total PA of 32.37±14.55 min/day (p=0.03) within that quarterly assessment, although there were no associations for the mortgage stress score. For women, mortgage and moving caused significant between individual effects. Each unit increase in stress score for beginning a mortgage was associated with greater duration of total PA (β = 94.52, SE_β=36.37, p = 0.01). In addition, women who experienced a move had significantly lower average durations of total MVPA compared to women who did not move (β = -47.65, SE_β=22.80, p = 0.04).

Table 4.8 displays the results of relationship type life events' associations with physical activity. Males were significantly impacted by the start or end of a romantic relationship, especially considering the associated stress score. For between individual effects, men with greater stress scores from a change in a relationship had greater durations of MVPA-10, total MVPA, and total PA (MVPA-10: β = 14.08, SE_β=5.12, p = 0.01; total MVPA: β = 19.31, SE_β=6.22, p < 0.01; total PA: β = 22.70, SE_β=7.42, p = 0.01). In addition, the within individual effects were significant, in which an increase in the stress score resulted in an increase in MVPA-10 (β =2.72, SE_β=1.28, p = 0.03) and total MVPA (β =3.03, SE_β=1.43, p = 0.03). The event of starting or ending a relationship influenced the MVPA categories for between individual effects (MVPA-10: β =37.81, SE_β=18.42, p = 0.04; total MVPA: β =51.26, SE_β=22.44, p = 0.02). Engagement did not influence males' physical activity durations, however, marriage did negatively impact males. Men who got married during the 12 month assessment period averaged 137.21±57.21 min/day (p=0.02) less MVPA-10 and 151.38±70.10 min/day (p=0.03) less total MVPA compared with men who did not get married. The associated stress score of marriage had similar results (MVPA-10: β = -48.41, SE_β=18.58, p = 0.01; total MVPA: β = -57.38, SE_β=23.73, p = 0.01). Women showed much different results. When a woman experienced the life event of engagement her MVPA decreased (MVPA-10: β = -14.44, SE_B=5.82, p = 0.01; total MVPA: β = -15.81, SE_β=7.05, p = 0.03). Engagement stress score showed no associations for women. Adversely, marriage resulted in slight increases in MVPA-10 within an individual of 9.37±5.56 min/day (p=0.01) and its associated stress score showed positive influences on total MVPA (β =3.88, SE_β=1.90, p = 0.04).

Neither personal injury/illness nor death of a family/friend influenced physical activity behavior for males. Female's physical activity was inversely associated with the stress associated with a death of a family member or friend. Women who reported greater levels of stress due to a death had significantly less total MVPA (β = -14.77, SE_β=6.76, p = 0.03) than women who had lower stress scores.

Discussion

The primary finding of this study is that the accumulation of life events over a 12 month period during young adulthood did not significantly impact physical activity. In addition, the associated stress score of life events did not impact physical activity. There was statistical significance for the association of cumulative stress score with total PA for men, however, the association of 7 minute/day differences per one unit stress score is rather small; especially considering that 7 minutes would be added to a large duration of total PA (men averaged 5.76±1.48 hrs/day of total PA).

One possibility for the lack of effect is that the highest average number of life events appeared during the baseline assessments (see Table 4.4). There is a possibility that the individuals experiencing many life events and/or perceived a great deal of stress from the life events withdrew from the study earlier on. Thus, the people most influenced by life events may have been lost to follow-up, and resulting in a downward bias in the effects of total number and stress score of life events. Similarly, if the highest amount of life events happened the 3 months prior to baseline this could have resulted in a change in PA at baseline and levels could remain similar for the entire year, thus, we would be unable to detect any of such change.

Another possibility for the lack of association with the cumulative number and stress score of life events could derive from including life events that have either positive or negative associations with PA in the same model, and thus cancelling each other. When analyzing life events as separate entities the results vary drastically by gender and in the degree and direction of association. In addition, the results varied by between and within individual effects.

Among the male participants, several specific life events were positively associated with physical activity. When looking at between effects, men who changed their job had on average 75 min/day more total PA than those who did not change jobs after adjustments for covariates. In addition, each one unit greater stress score for job change among men was associated with 27 min/day greater total PA. The guidelines based MVPA-10 or total MVPA were not influenced by changing a job, thus only when the addition of light intensity PA was added do we see associations. The stress of starting or ending a relationship was associated with greater amount of all activity ranging from

14 minutes for MVPA-10 to 21 minutes of total PA for each unit greater stress score. Conversely, the life event of marriage had a negative impact on activity at the between-individual level. After adjustments for covariates, men who got married in the 12 month time frame had over 2 hours/day less MVPA-10 (137 min/day) and total MPVA (151 min/day) compared with men who did not get married. Additionally, every one unit greater stress score was associated with 48 min/day less MVPA-10 and 57 min/day less total MVPA. This suggests that both the event of marriage and the stress score drastically influence the chronic higher intensity activities of MVPA and regardless of bout length for the males in our study. The vast difference in effects on relationship change vs. marriage may suggest that the transition from single to married may be an important life event influencing activity for men and it could prove beneficial to focus public health efforts on finding solutions to prevent such a drop in activity after marriage.

The only within individual association that showed meaningful significance was mortgage with total MVPA and total PA. Opening a mortgage on a home resulted in 25 min/day increase in total MVPA and 32 min/day increase in total PA on average within an individual, after adjustments for covariates. The lack of association with MVPA-10 but increases in total MVPA and total PA could possibly be explained considering that owning a new home can substantially increase a male's baseline physical activity, which is often the incidental light intensity or short moderate intensity tasks of taking care of a house.

For females, the only positive association with PA was quitting a job. The event of quitting a job resulted in increases in activity in all categories, ranging from 13 min/day of MVPA-10 to 17 min/day of total PA within an individual. The stress of quitting had no association. One possible explanation for the increase in physical activity across all categories could be that quitting a job resulted in more available time for physical activity. This could also be a partial explanation for the negative impact of starting a new job, especially the higher intensities activities of at least 3.0 METs. When women reported starting a new job their MVPA-10 and total MVPA decreased by about 20 minutes/day on average. There were some significant within individual associations for graduation and changing a job, however, the associations were much smaller than is seen with quitting or starting a new job. Women differed from men drastically in the relationship-type life event's influence on PA. Whereas starting or ending a relationship and marriage influences activity for men, engagement was the primary event within this category to impact women's PA. The event of engagement (but not stress) resulted in decreases in MVPA within an individual of about 14 min/day of MVPA-10 and 17 min/day of total MVPA.

For between individual effects, women who moved within the 12 month assessment period had drastically lower levels of total MVPA (-48 min/day, after adjustments) compared to women who did not move. The stress of losing a close family/friend also had significant between individual effects, primarily for total MVPA. Each unit greater in stress score resulted in an average of 15 min/day less total MVPA. These results suggest that the stress associated with the loss of a family/friend can result in decrease in typical baseline PA movement of short bouts of MVPA. A serious injury or illness had no impact on PA in men or women which may suggest that this young adult population had the ability to spring back from an injury or illness and return to their usual activity levels.

Comparison with previous literature

Mixed results have been shown in the association of cumulative number of life events with PA. In agreement with the current results, Twisk et al. found a lack of association for cumulative number and stress score of life events. In their longitudinal study of 27-29 year old men and women, the total number of life events and the total subjective appraisal of life events over 2 years was not associated with changes in interview measured subjective physical activity (Twisk, Snel, Kemper, 1999). Conversely, two randomized controlled trials did show that accumulating life events resulted in less physical activity during the interventions, although these studies focused on older adults (Oman, 2000; Wilcox, 2004). Oman found that adherence to an exercise program was impacted when 3-4 life events occurred (Oman RF, 2000).

The kind of life event appears to impact the degree of influence on life events. The large variation in impact of different life events and the differential results by gender hold similar to previous studies (Allender, Hutchinson, & Foster, 2008; Engberg et al., 2012). Physical activity levels were greater for men with changing a job or starting or ending a relationship. An explanation for this increase could be that physical activity could act as a coping mechanism for stress for events and/or, for type A personalities, a high level of stress and a high level of physical activity could come hand in hand. A previous study showed that the physical activity intervention was more successful among highly stressed young adult men. Johnson-Kozlow et al further explains that men more often used PA as a stress-reducing mechanism compared to the women (Johnson-Kozlow, Sallis, & Calfas, 2004). The substantial negative influence of starting a new job among women was similar to previous results. A longitudinal study from the Australian Longitudinal Study of Women's Health found that women who began paid work during a 4 year follow-up were significantly less active than women who did not start a job (Brown. and Trost, 2003).

Results are mixed for relationship type life events with physical activity. In the present study, men who started or ended a relationship had greater levels of PA than those who did not experience this life event, whereas men who got married had significantly lower levels of PA compared to those who did not get married. One possible reason for the opposite associations could be that men who are not married, and thus start/end relationships, tend to participate in more PA than married men. These results are similar to Schmitz et al.'s findings that among males who remained single in a 2 year follow-up had greater amount of self-reported PA (Schmitz, French, 1997). For females the only significant life event within the relationship category was a negative influence of engagement. Previous studies have shown that marriage resulted in a decline of physical activity among young women (Brown & Trost, 2003; Brown, Heesch, 2009; Brown, and Trost, 2003; Engberg et al., 2012). However, most studies do not take into account the transition from single, to engagement, then to marriage, and thus may miss whether the actual decline occurred pre or post the event of marriage. King et al. evaluated marital transitions, finding that women decreased their PA during the pre-marriage/engagement period and then level-off at lower levels during post-marriage (King et al., 1998). These results agree with our findings in which the life event of engagement decreased a woman's activity, but marriage did not.

Past studies that examined the influence of death involved older adults and specifically the death of a spouse/partner. Older woman tended to increase their physical activity upon widowhood in two studies while another found that older men and women had less participation in class-based exercise, but not home-based exercise (Brown, Heesch, 2009; Wilcox, 2004; Wilcox et al., 2003). Therefore, there is a lack of literature to compare our findings showing the only women who experienced the loss of a loved one decline their activity.

Strengths and limitations

The current study had many strengths that help to contribute to the knowledge base of life event influences on PA. This study used a repeated measure longitudinal study design, allowing for the detection of changes in PA within each participant. Most of the past studies used self-reported questionnaires in assessing PA. The Energy Balance study used a validated, objective measurement, the SenseWear Armband. In addition, the compliance in wearing the Armband was excellent. The vast majority of the sample had 50 days of data per person over the 12 month period, which allows for a strong representation of the sample's overall activity levels. Rather than looking at just a few life events, this study examined a wide variety of life events that are common among young adults. Furthermore, the perceived stress score was also included which allows for this study to distinguish whether the life event itself and/or the stress associated with the life event caused the disturbance in PA. In addition, the analyses were performed for both between and within effects to allow for an understanding of how a life event can change activity within an individual and also the difference between individuals who did and did not experience a life event. By nature of the within-individual analysis, short term effects are evaluated by exploring whether the specific quarter at which the life event was reported had significantly different levels of PA than the overall PA averages across the 12 months. The between individual analyses examined chronic associations with life events as it compared total averages of activity across the 12 months between the subjects. Future studies could benefit from a long follow-up in order to gain an understanding of how young adult life events could impact physical activity extending out through the rest of adult life.

Conclusion

In conclusion, the average number of life events and average aggregate stress score of life events per quarter had little influence on physical activity. However, specific life events had influences on various categories of PA and these differed by gender. For young adult men, changing jobs and marriage had negative impacts on activity while starting/ending a relationship and beginning a mortgage had positive influences.

For young adult women, starting a new job, moving, engagement, and the loss of a family/friend had negative consequence, while quitting a job resulted in increases in PA. Furthermore, these results varied in their impact on category of physical activity in which many of associations influence activity beyond the Guideline-based MVPA in 10 minute bouts. Many life events had significant associations with total MVPA and total PA. With the growing evidence of the link between light intensity PA and short bouts of MVPA, the results of this study suggest that future studies on life events and PA should consider the full spectrum of activity to include baseline physical activity.

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Table 4.1 Participant demographic baseline characteristics overall and by gender

Demographic Variable	All (n=407)	Males (n=198)	Females (n=209)	p-value for gender
Age (years)	27.8±3.8	27.7±3.8	27.8±3.7	0.8570
BMI (kg/m^2)	25.4±3.8	25.4±3.2	25.4±4.3	0.9678
Race				
White	65.4%	66.2%	64.8%	0.0035
African American	13.2%	8.1%	18.1%	
Employment				
Student	44.4%	46.5%	42.4%	0.3833
Employed	55.6%	53.5%	57.6%	
Education				
4+ years of college	84.8%	79.3%	90.0%	0.0026
Income				
<$30,000	34.5%	30.3%	38.5%	0.1098
$30-59,999	37.2%	36.9%	37.5%	
≥$60,000	28.3%	32.8%	24.0%	
Smoking Status				
Current Smoker	3.7%	4.0%	3.3%	0.3848
Alcohol Intake				
Heavy Drinker	10.5%	3.0%	17.6%	<0.0001

"Heavy Drinker": women = 8+ drinks per week; men = 15+ drinks per week

Table 4.2 Activity monitor values overall and by gender – Averages across 12 months

	All	Males (n=198)	Females (n=209)	p-value for gender
Average Wear Time (hrs/day)	23.0±1.1	23.1±1.2	22.9±1.	0.20
Compliant days of wear (days/quarterly assessment)	9.9±0.9	9.9±1.0	9.8±0.8	0.45
MVPA-10 (min/day)	71.7±58.4	90.2±63.5	54.8±46.6	<0.0001
Total MVPA (min/day)	127.7±71.0	149.9±75.7	106.3±58.5	<0.0001
Total PA (min/day)	343.3±86.9	345.8±89.3	340.9±84.5	0.23

Average Wear Time: Hrs/day the Armband was worn
Number of Days: compliant days of Armband wear (≥18.5 hrs/day) per quarterly assessment
MVPA10: activity ≥ 3.0 METs in 10 minute bouts (following 8 of 10 minute criteria)
Total MVPA: all activity ≥ 3.0 METs, regardless of bout length
Total PA: activity > 1.5 METs, regardless of bout length

Table 4.3 Number of occurrences and associated perceived stress score by life event

	ALL		MALES		FEMALES	
Life Event	Total Number of Occurrences	Average Stress Score	Total Number of Occurrences	Average Stress Score	Total Number of Occurrences	Average Stress Score
Changed job	206	2.71±1.26	88	2.55±1.18	118	2.84±1.31
Quit job	83	2.39±1.35	39	2.38±1.27	44	2.39±1.43
Started new job	43	3.44±1.31	18	2.83±1.20	25	3.88±1.24
Graduated	92	2.78±1.28	46	2.52±1.15	46	3.04±1.37
Left parent's home	19	2.63±0.90	7	2.14±0.69	12	2.92±0.90
Moved	243	2.73±1.23	122	2.48±1.18	121	2.98±1.23
Went on welfare	6	3.00±0.89	1	3	5	3.00±1.00
Mortgage	32	2.38±1.24	18	2.50±1.34	14	2.15±1.14
Jail	3	3.33±1.53	3	3.33±1.53	0	-
Death of friend/family	105	3.44±1.15	47	3.13±1.21	58	3.69±1.05
Serious Injury or Illness	47	3.00±1.27	24	2.96±1.23	23	3.04±1.33
Started/ended a relationship	226	3.15±1.33	104	3.24±1.33	122	3.07±1.33
Engaged	36	2.22±1.12	16	2.56±1.15	20	1.95±1.05
Married	39	3.10±1.29	17	2.82±1.24	22	3.32±1.32
Pregnant	3	3.33±2.08	2	2.50±2.12	1	5.00
Divorce	15	4.27±0.96	8	4.25±0.89	7	4.29±1.11

Table 4.4 Average number and stress score of life event occurrences across 12 months - overall and by gender

	ALL		MALES		FEMALES	
Time point	Average Number of Life Events	Average Stress Score	Average Number of Life Events	Average Stress Score	Average Number of Life Events	Average Stress Score
Baseline (n=198 Males; 209 Females)	0.83±1.16	2.24±3.73	0.88±1.22	2.23±3.70	0.77±1.10	2.25±3.76
3 month (n=195 Males; 209 Females)	0.57±0.85	1.50±2.45	0.53±0.81	1.37±2.44	0.60±0.88	1.61±2.45
6 month (n=184 Males; 191 Females)	0.53±0.83	1.53±2.71	0.53±0.78	1.47±2.51	0.53±0.88	1.59±2.90
9 month (n=177 Males; 179 Females)	0.62±0.92	1.96±3.20	0.49±0.75	1.50±2.44	0.75±1.04	2.42±3.76
12month (n=170 Males; 172 Females)	0.61±0.88	1.92±3.06	0.56±0.84	1.72±2.96	0.67±0.92	2.12±3.14
Total	2.93±2.54	8.45±8.46	2.82±2.37	7.76±7.59	3.03±2.70	9.01±9.18

Table 4.5 Relationship Between Average Number of Life Events and Average Aggregate Stress Score per Quarter Across 12 Months with Physical Activity

	MALES (n=198)						FEMALES (n=209)					
	Between Individual Effect			Within Individual Effect			Between Individual Effect			Within Individual Effect		
	β	$SE_β$	p	β	$SE_β$	p	β	$SE_β$	p	β	$SE_β$	p
Average Number of Life Event Occurrences per Quarter												
MVPA-10	6.13	7.24	0.40	-0.65	1.46	0.66	-8.20	5.12	0.11	-0.73	0.94	0.44
Total MVPA	10.57	8.82	0.23	0.02	1.64	0.99	-10.29	6.60	0.12	-0.79	1.14	0.48
Total PA	20.02	10.56	0.06	1.24	2.19	0.57	-11.21	9.70	0.25	0.75	1.87	0.69
Life Event Average Aggregate Stress Score per Quarter												
MVPA-10	2.43	2.19	0.27	-0.06	0.47	0.90	-2.13	1.51	0.16	-0.39	0.28	0.18
Total MVPA	4.16	2.67	0.12	0.19	0.53	0.72	-2.63	1.95	0.18	-0.50	0.35	0.15
Total PA	7.00	3.20	0.03	0.24	0.71	0.73	-3.25	2.86	0.25	-0.21	0.57	0.72

Adjusted for age, race, BMI, education, occupation

Table 4.6 Relationship Between Occupational Related Life Events and Physical Activity

	MALES (n=198)						FEMALES (n=209)					
	Between Individual Effect			Within Individual Effect			Between Individual Effect			Within Individual Effect		
	β	$SE_β$	p	β	$SE_β$	p	β	$SE_β$	p	β	$SE_β$	p
Changed Job												
MVPA-10	12.18	22.99	0.60	1.11	4.43	0.80	-11.96	15.25	0.43	-6.45	2.68	0.02
Total MVPA	24.50	28.03	0.38	1.28	4.97	0.80	-15.71	19.67	0.42	-9.07	3.25	0.01
Total PA	74.69	33.39	0.03	6.69	6.65	0.31	-25.88	28.86	0.37	-0.82	5.36	0.88
Changed Job Stress Score												
MVPA-10	6.65	7.96	0.40	-0.10	1.56	0.95	-3.28	4.71	0.49	-2.54	0.86	<0.01
Total MVPA	11.95	9.69	0.22	0.33	1.75	0.85	-3.41	6.07	0.57	-3.85	1.04	<0.01
Total PA	26.46	11.56	0.02	2.34	2.34	0.32	-7.83	8.90	0.38	-1.54	1.72	0.38
Quit Job												
MVPA-10	-8.63	35.72	0.81	-5.23	6.38	0.41	-4.91	24.87	0.84	12.82	4.15	<0.01
Total MVPA	-6.53	43.61	0.88	-8.96	7.15	0.21	-7.87	32.08	0.81	15.35	5.03	<0.01
Total PA	18.61	52.45	0.72	-13.58	9.57	0.15	4.16	47.05	0.93	17.15	8.30	0.04
Quit Job Stress Score												
MVPA-10	-4.45	12.50	0.72	-2.52	2.40	0.30	1.95	9.04	0.83	1.59	1.49	0.29
Total MVPA	-4.97	15.26	0.75	-3.81	2.69	0.16	1.22	11.67	0.92	2.33	1.81	0.20
Total PA	-0.49	18.36	0.94	-6.10	3.60	0.09	-0.75	17.11	0.96	6.10	2.96	0.04

Adjusted for age. race, BMI, education, occupation

Table 4.6 Relationship Between Occupational Related Life Events and Physical Activity (continued)

	MALES (n=198)						FEMALES (n=209)					
	Between Individual Effect			Within Individual Effect			Between Individual Effect			Within Individual Effect		
	β	SE_{β}	p	β	SE_{β}	p	β	SE_{β}	p	β	SE_{β}	p
Start New Job												
MVPA-10	38.33	50.12	0.44	-14.40	9.23	0.12	-31.72	33.80	0.35	-19.20	5.46	<0.01
Total MVPA	29.87	61.20	0.63	-14.57	10.35	0.16	-36.84	43.65	0.40	-23.11	6.62	<0.01
Total PA	52.62	73.61	0.47	14.21	13.86	0.31	-23.42	64.00	0.71	-14.96	10.95	0.17
Start New Job Stress Score												
MVPA-10	12.42	14.98	0.41	-4.26	3.03	0.16	-3.31	8.03	0.68	-5.43	1.36	<.0001
Total MVPA	9.85	18.26	0.59	-3.55	3.40	0.30	-3.41	10.37	0.74	-6.54	1.65	<.0001
Total PA	8.26	22.05	0.71	5.48	4.56	0.23	-1.09	15.19	0.94	-5.65	2.73	0.04
Graduated												
MVPA-10	1.91	34.76	0.96	-1.51	6.86	0.83	38.59	26.90	0.15	-5.42	4.33	0.21
Total MVPA	-4.46	42.65	0.92	-1.41	7.72	0.86	55.79	34.32	0.10	-6.77	5.26	0.20
Total PA	-7.81	51.91	0.48	7.28	10.22	0.88	80.40	49.56	0.11	2.19	8.76	0.80
Graduated Stress Score												
MVPA-10	-6.94	12.80	0.59	-2.13	2.10	0.31	9.67	7.54	0.20	-2.32	1.22	0.06
Total MVPA	-10.78	15.64	0.49	-1.39	2.35	0.55	13.12	9.73	0.18	-3.38	1.47	0.02
Total PA	-6.48	18.81	0.73	0.19	3.15	0.95	18.53	14.25	0.19	-2.34	2.43	0.33

Adjusted for age. race, BMI, education, occupation

Table 4.7 Relationship Between Moving Related Life Events and Physical Activity

	MALES(n=198)						FEMALES(n=209)					
	Between Individual Effect			Within Individual Effect			Between Individual Effect			Within Individual Effect		
	β	SE_{β}	p	β	SE_{β}	p	β	SE_{β}	p	β	SE_{β}	p
Moved												
MVPA-10	1.39	23.14	0.95	-2.09	3.78	0.58	-33.84	17.71	0.06	-1.12	2.54	0.66
Total MVPA	5.12	28.25	0.86	-0.53	4.23	0.90	-47.65	22.80	0.04	-0.26	3.08	0.93
Total PA	18.04	33.96	0.60	1.75	5.67	0.76	-60.06	33.53	0.07	5.47	5.06	0.28
Moved Stress Score												
MVPA-10	-3.47	8.13	0.67	-0.11	1.38	0.94	-8.36	5.41	0.12	-0.84	0.79	0.29
Total MVPA	-1.03	9.94	0.92	0.68	1.55	0.66	-10.84	6.98	0.12	-0.60	0.95	0.53
Total PA	7.22	11.93	0.55	1.11	2.07	0.59	0.55	1.57	0.73	-17.56	10.21	0.09
Mortgage												
MVPA-10	-34.40	42.10	0.41	12.64	9.72	0.19	-13.76	35.43	0.70	-8.04	7.36	0.27
Total MVPA	-22.86	51.47	0.66	24.98	10.89	0.02	10.24	45.69	0.82	-9.01	8.92	0.31
Total PA	30.96	62.00	0.62	32.27	14.55	0.03	124.97	66.51	0.06	3.08	14.65	0.83
Mortgage Stress Score												
MVPA-10	-10.86	19.44	0.58	4.03	3.39	0.24	6.03	19.55	0.76	-3.78	3.12	0.23
Total MVPA	-1.39	23.78	0.95	7.01	3.79	0.07	36.58	25.12	0.15	-3.87	3.79	0.31
Total PA	6.46	28.57	0.82	8.72	5.08	0.09	94.52	36.37	0.01	1.40	6.23	0.82

Adjusted for age. race, BMI, education, occupation

Table 4.8 Relationship Between Relationship Type Life Events and Physical Activity

	MALES(n=198)						FEMALES(n=209)					
	Between Individual Effect			Within Individual Effect			Between Individual Effect			Within Individual Effect		
	β	$SE_β$	p	β	$SE_β$	p	β	$SE_β$	p	β	$SE_β$	p
Start or Ended a Relationship												
MVPA-10	37.81	18.42	0.04	6.72	4.48	0.10	-6.42	14.22	0.65	4.18	2.78	0.13
Total MVPA	51.26	22.44	0.02	8.33	5.02	0.10	2.25	18.34	0.90	6.17	3.36	0.07
Total PA	49.80	27.12	0.07	2.15	6.74	0.75	-4.27	26.91	0.87	-3.10	5.54	0.58
Start or Ended a Relationship Stress Score												
MVPA-10	14.08	5.12	0.01	2.72	1.28	0.03	-2.37	4.43	0.59	1.23	0.81	0.13
Total MVPA	19.31	6.22	<0.01	3.03	1.43	0.03	-0.51	5.72	0.93	1.83	0.98	0.06
Total PA	20.70	7.52	0.01	0.22	1.92	0.91	-2.65	8.39	0.75	0.27	1.62	0.87
Engaged												
MVPA-10	-83.54	56.37	0.14	4.59	9.81	0.64	33.17	43.71	0.45	-14.44	5.82	0.01
Total MVPA	-68.85	68.93	0.32	6.84	10.99	0.53	41.61	56.45	0.46	-15.81	7.05	0.03
Total PA	9.18	80.02	0.91	-6.47	14.72	0.66	-5.88	82.97	0.94	-9.34	11.63	0.42
Engaged Stress Score												
MVPA-10	-33.55	18.02	0.06	0.68	3.58	0.85	1.02	20.20	0.96	-4.39	2.64	0.10
Total MVPA	-26.66	22.10	0.23	1.07	4.01	0.79	-3.87	26.08	0.88	-4.18	3.20	0.19
Total PA	9.54	26.69	0.72	-6.48	5.37	0.23	-52.69	38.02	0.17	-3.94	5.26	0.45
Married												
MVPA-10	-137.21	57.21	0.02	4.87	9.34	0.60	-0.73	38.06	0.98	9.37	5.56	<0.01
Total MVPA	-151.38	70.10	0.03	-1.21	10.47	0.91	-25.53	49.05	0.60	12.39	6.74	0.07
Total PA	-115.05	84.85	0.18	-8.00	14.02	0.57	13.93	72.03	0.85	13.93	72.03	0.85
Married Stress Score												
MVPA-10	-48.41	18.58	0.01	0.64	3.04	0.83	3.35	10.29	0.74	2.84	1.57	0.07
Total MVPA	-57.38	22.73	0.01	-1.51	3.41	0.66	0.65	13.26	0.96	3.88	1.90	0.04
Total PA	-53.92	27.48	0.05	-3.57	4.56	0.43	15.60	19.45	0.42	3.64	3.13	0.25

Adjusted for age. race, BMI, education, occupation

Table 4.9 Relationship Between Personal Injury/Illness or Death of a close friend/family member with Physical Activity

	MALES(n=198)						FEMALES(n=209)					
	Between Individual Effect			Within Individual Effect			Between Individual Effect			Within Individual Effect		
	β	SE_{β}	p	β	SE_{β}	p	β	SE_{β}	p	β	SE_{β}	p
Injury/Illness												
MVPA-10	14.79	39.89	0.71	-4.28	8.48	0.61	-24.87	33.82	0.46	-3.38	5.51	0.54
Total MVPA	38.67	48.66	0.43	1.32	9.51	0.89	-46.01	43.57	0.29	-5.02	6.68	0.45
Total PA	35.18	58.55	0.55	0.93	12.74	0.94	-67.54	63.89	0.29	8.06	10.97	0.46
Injury/Illness Stress Score												
MVPA-10	-2.65	12.19	0.83	-0.72	2.88	0.80	-8.62	10.98	0.43	-1.71	1.80	0.34
Total MVPA	-2.95	2.21	0.18	-2.95	2.21	0.18	-16.74	14.25	0.24	-2.95	2.21	0.18
Total PA	9.89	18.35	0.59	-3.56	4.29	0.41	-13.92	21.87	0.52	1.39	3.72	0.71
Death of a family/friend												
MVPA-10	15.79	31.90	0.62	-3.87	5.84	0.51	-35.99	21.72	0.10	7.21	3.67	0.05
Total MVPA	21.73	38.95	0.58	-3.98	6.55	0.54	-52.66	27.96	0.06	7.96	4.45	0.07
Total PA	28.01	46.84	0.55	1.72	8.77	0.84	-62.65	41.13	0.13	6.87	7.32	0.35
Death of a family/friend Stress Score												
MVPA-10	3.05	9.15	0.74	-0.60	1.75	0.73	-0.32	1.96	0.87	1.77	0.98	0.07
Total MVPA	5.07	11.16	0.65	-0.32	1.96	0.87	-14.77	6.76	0.03	1.74	1.18	0.14
Total PA	8.08	13.43	0.55	1.24	2.62	0.64	-17.70	9.96	0.08	0.90	1.96	0.65

Adjusted for age. race, BMI, education, occupation

CHAPTER V

Longitudinal Associations of the Total Spectrum of Physical Activity with Anthropometric Outcomes

Abstract

Objective: The purpose of this study is to examine the associations of the total spectrum of physical activity with anthropometric outcomes.

Methods: A sample of healthy, young adults from the Energy Balance Study (n=403) were measured on a quarterly basis for one year. The SenseWear Armband measured physical activity. Percent body fat (BF) was measured by dual x-ray absorptometry (DXA). BMI was calculated from laboratory measured height and weight. Waist and hip circumference (WC and HC) were measured using a calibrated, spring-loaded tape measure. Mixed linear models were used to examine the between and within individual effects on anthropometric outcomes from three categories of physical activity (PA) including MVPA in 10 minute bouts (MVPA-10), all MVPA regardless of bout duration (total MVPA), and all PA at or above light intensity (total PA).

Results: BF was associated with all categories of PA for both males females at the between individual level. BMI, %BF, WC, and HC also had significant within individual associations among the females, in which changes within all three PA categories were associated with inverse changes in BMI and WC; %BF was inversely related to MVPA-

10 and total MVPA; and HC was inversely related to MVPA-10 changes within a 3-month assessment period.

Conclusion: Physical activity had an influence on various anthropometric measures and varied by gender. The accumulation of greater amounts of activity was associated with a lower body fat percentage for both men and women. There were also associations with PA for WC, HC, and BMI for the women. For all anthropometric associations there were effects fromMVPA-10 and total MVPA, suggesting that the accumulation of all MVPA regardless of bout length can have a similar impact on anthropometrics. The association was half of the impact when comparing the MVPA categories with total PA. Thus an increase of MVPA has a greater influence on anthropometric outcomes than an increase in total PA.

Keywords: BMI, body fat, waist and hip circumference, physical activity, longitudinal

Introduction

Excessive weight has been shown to increase the risk of multiple morbidities such as hypertension, dyslipidemia, type 2 diabetes, osteoarthritis, respiratory problems, depression, and certain cancers (National Heart, Lung, Blood Institute 1998; Renehan et al., 2008). In addition, obesity, particularly class 2 and above, has been linked to increased risk of all-cause mortality (Flegal et al., 2013). The National Center for Health Statistics showed that in 2009-2010 two-thirds of U.S. adults fell within the body mass index (BMI) categories of overweight and obese. Of these two-thirds, half are classified as obese (Ogden et al., 2012). The high rates of overweight and obesity derive from a long-term problem with energy imbalance (Hill et al., 2003). Arguably, energy imbalance is caused by a wide range of individual characteristics and behaviors, one important factor being total energy expenditure (TEE) and its components. Physical activity is a modifiable component of TEE that has substantial variation across individuals and can affect TEE. Thus, physical activity has the potential to influence energy balance, and in turn, body weight and composition.

The majority of research on physical activity and body composition and weight examines physical activity in terms of the 2008 Physical Activity Guidelines, focusing on moderate to vigorous intensities, and typically only in bouts of 10 minutes or more. Examining activity in this manner excludes light activity and shorter bouts, referred to as baseline physical activity (BPA) as it consists of the physical activity accumulated during daily life at durations and/or intensities below what is recommended in the 2008 Guidelines (U.S. Dept. of Health and Human Services, 2008). The 2008 guidelines do not formally recommend a particular dose of BPA nor address how doses of BPA may impact health due to the fact that little research has been done to explore such questions. However, the guidelines document in an advisory report that BPA most likely plays an important role in public health. Baseline physical activity is a part of a normal daily lifestyle and recent evidence shows that greater amounts of light activity and short bouts of MVPA may have health benefits including anthropometric outcomes, and thus should not be ignored (Levine et al., 2006; Physical Activity Guidelines Advisory Committee, 2008a).

Powell et al. briefly summarizes the evidence of how much physical activity is essential for health benefits. Within this overview, they discuss the need to further understand the health effects of lower volumes and intensities of physical activity below the recommended amounts (Powell et al., 2011). This examination would allow for a deeper understanding of the entire spectrum of physical activity. Rather than approach physical activity as a definitively required intensity and duration, a novel approach is to see physical activity as a continuum across all intensities and durations. Therefore, this paper examined activity as an entire spectrum. Any activity with an intensity above sedentary (>1.5 METs) was evaluated and referred to as total physical activity (Total PA). The analyses distinguished between the typical MVPA in 10+ minute bouts (MVPA-10) vs. total MVPA (including short bouts), and total PA (including light intensity activities). This allows for a deeper understanding of whether activity beyond what is recommended in the Guidelines has influences on anthropometric outcomes.

The purpose of this study was to examine the longitudinal relationship of the full spectrum of physical activity with adiposity and body weight.

Methods

Study Population

This paper used data collected from June 2011 through August 2013 as part of The Energy Balance Study. Details regarding the rationale and overall study design has been published previously (Hand et al., 2013). The sample included 403 healthy, young adults, age 21-35 years, with a body mass index (BMI) of 20-35 kg/m^2. Exclusion criteria included moving from the area within the next 15 months, using medications to lose weight, started or stopped smoking within the last 6 months, planned weight loss surgery, hypertensive (150 mmHg systolic and/or 90 mmHg diastolic), ambulatory blood glucose levels ≥ 145 mg/dl, currently diagnosed or taking medications for a major chronic health conditions, history of depression, taking selective serotonin reuptake inhibitors, giving birth within the past 12 months, planning to start or stop birth control in the next 12 months while participating in the first year of the study. All study protocols were approved by the University of South Carolina Institutional Review Board. Participants who completed baseline and at least one follow up visit, completed the required questionnaires, and have at least 5 days (including both weekend days) of physical activity data at these two or more time points were included in this analysis.

Measurements

Physical Activity: The SenseWear Mini Armband (BodyMedia Inc. Pittsburgh, PA) was used as the primary measure of physical activity. The Armband is worn on the upper left arm over the triceps muscles. Energy expenditure and activity are measured using a combination of a tri-axial accelerometer with biological sensors measuring heat flux, galvanic skin response, near-body ambient temperature, and skin temperature. Using the combination of sensors allows for increased sensitivity beyond the typical accelerometer, such as an enhanced ability to detect activities such a lifting and carrying loads, moving at a gradient, and non-ambulating activities (Welk et al., 2007). The Armband's algorithms use a Naïve Bayes classifier for pattern recognition that can allow for the ability to estimate the context of an activity. The Armband takes into account all the sensor values collected on a minute by minute basis to determine the context and then calculates kilocalories and METs. At each quarterly assessment, participants were instructed to wear the monitor for 10 consecutive days, 24 hours a day, except during water activities (i.e. swimming, bathing, or showering). When the monitor was removed from the body, the participants recorded these "non-wear" activities on a log. These logged non-wear activities were then incorporated into the Armband data in order to have entire 24 hour estimates of energy expenditure and activity for each day.

Results were explained in durational units of physical activity (minutes per day). Several variables within physical activity will be used including MVPA-10 (MVPA according to the 2008 PA Guidelines, requiring durations of at least 10 minutes), total MVPA (all MVPA regardless of bout length), and total physical activity (all activity from light to vigorous in any bout duration; all activity >1.5 METs). Thus, the analyses will sequentially add the components of BPA to MVPA-10, by first adding the short bouts of MVPA to obtain total MVPA and then adding light PA to obtain total PA. In order to account for common interruptions in lifestyle physical activity (such as waiting to cross the street, or stopping to tie a shoe), at least 8 of 10 consecutive minutes at or above moderate intensity (≥3.0 METs) were considered the criteria for MVPA-10 (Fan et al., 2013).

Anthropometry: Anthropomorphic measures consist of weight, height, body mass index (BMI), waist circumference (WC), hip circumference (HC), and body composition (body fat percentage, BF). To ensure measurement consistency, participants wore medical scrubs and were bare foot. BMI (kg/m^2) was calculated from height measured by stadiometer and weight from an electronic scale. Dual X-ray absorptiometry (DXA) (GE Healthcare, Waukesha, WI), measured body composition. Using a calibrated, spring-loaded tape measure (rounding to the nearest 0.1 cm), WC was measured 2 inches above the umbilicus, at the point midway between the coastal margin and iliac crest in the mid-axillary line, and HC was measured at the widest point around the greater trochanter.

Energy Intake: The Energy Balance study used 24 hour dietary recalls to examine total energy intake (TEI) and its underlying nutrients. Although the measure has error, it is considered the gold standard for the measurement of dietary intake. Registered dieticians performed 3 recalls on randomly selected days within a 2 week time frame during each quarterly assessment. The dieticians used a multi-pass interview method and followed the Nutrient Data System for Research software (NDSR Version 2012), when conducting the assessments. All participants were given a food portion visual and a brief training on its use every 6 months, as a way to help increase the accuracy of reporting portion sizes (Posner et al., 1992).

Questionnaires: Participants completed a series of questionnaires on a quarterly basis. Demographics, such as age, race/ethnicity, education, occupation, and income were taken at baseline. A medical history questionnaire was completed at baseline that covered inclusion/exclusion criteria concerns, as well as other medications and smoking status.

Statistical Analysis

Descriptive characteristics for the sample are summarized using means and standard deviations of demographic variables. T-tests examined differences between gender for continuous variables and chi-square for categorical variables. The primary analyses used linear mixed models. All models were stratified by gender and adjusted for basic demographics including age and race, socioeconomic factors (income, education, and occupation), smoking status, and total energy intake (TEI). Prior to pursuing final analyses, model assumptions were checked to ensure the residuals and estimates of the random intercepts were normally distributed and iterative influence diagnostics were performed in order to identify any outliers that were then removed. The primary independent variables of interest, physical activity, were quantified in units of minutes/day and assessed in three categories: MVPA according to the 2008 PA Guidelines, requiring bouts of at least 10 minutes ≥ 3.0METs (MVPA-10); all MVPA regardless of bout length ≥ 3.0METs (Total MVPA); and all PA > 1.5 METs so to include all baseline activity (Total PA). The average duration of MVPA-10, total MVPA, and total PA across 12 months as well as the deviation from these averages (i.e. each person's time-point specific duration minus their own mean duration) was included in the models. The coefficient for the mean value provides the between individual associations, and the coefficient for the deviation value provides the within individual associations (Rabe-Hesketh and Skrondal, 2008). The between individual effects examine the differences in anthropometric outcomes between subjects who have different PA averages across the 12 months. The within individual effects describe whether an acute change in PA (a quarterly deviation from the individual's average PA) results in a change in anthropometrics within that same 3-month interval.

Results

Participant Characteristics

Table 5.1 provides a summary of the participant demographic characteristics at baseline as well as the average TEI across the 12 months. The mean age was 27.8 ± 2.8 years, about half the population was in the normal weight BMI category at baseline, and one-third classified their race as white. For socioeconomic characteristics, slightly more than half were employed for wages (56.3%) while the others were students (43.7%), most were well educated with four or more years of college (84.9%), and about a third of the sample fell within each income category (<$30,000: 34.2%, $30-59,999: 37.4%, and ≥$60,000: 28.4%). More males were married than females at baseline, with 38% vs. 28%, respectively ($p=0.024$). Only 3.7% of the subjects were current smokers. Across the 12 month assessment, males reported an average TEI of 2385 ±608 kcals/day and women reported an average TEI of 1793±350 kcals/day. The deviation in table 5.1 describes the overall average in the deviation from the 12 month average TEI.

Table 5.2 shows the 12 month averages in BMI, Weight, WC, HC, and BF overall and by gender. The men in the sample had an average BMI of 25.8 kg/m^2, weighed 82.2±12.6 kg, averaged a waist circumference of 84.2±8.9 cm and hip circumference of 100.1±6.7 cm, and average BF of 22±9%. Women were significantly different from men across all anthropometrics except BMI. Their 12 month averages included a BMI of 25.7±4.4 kg/m^2, 70.0±12.9 kg average weight, 76.5±9.8 cm and 101.8±8.8 cm for waist and hip circumference, respectively, and 37±8% body fat.

The participants in this study had excellent compliance in wearing the activity monitor. The Armband was worn for an average of 23.0±1.1 hrs per day throughout the 12 month study and they average of 9.9±0.93 compliant days per quarterly assessment. In addition, there were no differences between quarterly time points for Armband wear or days, indicating the sample remained compliant throughout the 12 month study. Table 5.3 also provides a summary of average PA durations across the 12 months. Men accumulated significantly greater amounts of MVPA-10 and total MVPA than women (MVPA-10: 91.0±58.6 vs. 54.75±45.59 min/day, $p<0.0001$; total MVPA: 150.5±69.7 vs. 107.5±56.6 min/day, $p<0.0001$). Both genders had similar amounts of average total PA, accumulating 344.4±78.0 min/day. Table 5.4 provides the calculated deviation from the average for all categories of PA, as well as descriptive statistics for the range in the deviations. Women on average tended to have greater deviations at quarterly time points away from the yearly average for all categories of PA compared with men.

Associations of PA categories with Anthropometric Outcomes

Table 5.5 and 5.6 provide the between and within individual associations for each anthropometric outcome with MVPA-10, total MVPA, and total PA stratified by gender. The β coefficients shown in these tables explain the influence of the PA categories in 10 minute/day increments. Overall, PA had more influence on anthropometric measures among females compared to males. For the men, the only anthropometric that was significantly associated with activity was BF at the between individual level. For both MVPA-10 and total MVPA, every 10 minutes greater duration was associated with a 0.5 % lower BF (MVPA-10: β =-0.0055, SE_{β} = 0.001, $p<0.0001$; total MVPA: β =-0.0050, SE_{B} = 0.0009, $p<0.0001$). Total PA accumulation was also significantly associated with BF (β =-0.0032, SE_{β} = 0.0008, $p<0.0001$).

Between individual associations with BF also existed for females. Each 10 min/day greater duration of MVPA-10, total MVPA, and total PA was associated with 0.78±.13%, 0.67±.11%, and 0.35±.08% lower BF, respectively ($p<0.0001$ for all). BF was also significantly associated at the within individual level. A 10 minute increase in MVPA-10 and total MVPA resulted in a significant decrease in BF within a female subject by 0.29±.12% (p=0.0096) and 0.26±.10% (p=0.0062), respectively. BMI, WC, and HC also had some significant within individual associations among the females. An increase in all PA categories was associated with a decrease in BMI within the corresponding quarterly time point (MVPA-10: β =-0.043, SE_{β} = 0.020, $p<0.039$; total

MVPA: β =-0.039, SE_β = 0.017, p<0.019; total PA: β =-0.024, SE_β = 0.010, p<0.021). WC was also significantly associated with all PA categories within female subjects. Each 10 minute increase in MVPA-10 and total MVPA resulted in a decrease in WC by an average of 0.22 cm (MVPA-10: β =-0.23, SE_β = 0.09, p<0.010; total MVPA: β =-0.22, SE_β = 0.07, p<0.003) and a 10 minute/day increase in total PA was associated with a 0.12±0.04 cm decrease in WC (p<0.007). Among the females, MVPA-10 at the within individual level was the only category that significantly influenced HC (β =-0.18, SE_β = 0.08, p<0.018).

Discussion

Key study findings

Men with greater average durations of activity across the 12 month period had significantly lower body fat percentage than men who accumulated less activity. The association was significant for all three categories of PA. The β coefficient was similar for MVPA-10 and total MVPA, in which each 10 min/day higher MVPA-10 and total MVPA was associated with 0.5% lower BF. Total PA's effect was slightly less per 10 min/day increment at a 0.3% lower BF. Women had similar between individual results, with similar impact from MVPA-10 and total MVPA (0.8% and 0.7%), whereas, although significant, the impact is reduced by half for total PA (0.4%). The within individual effect was also significant for BF among females, but only for MVPA-10 and total MVPA, both with an impact of -0.3% per 10 minute increase in activity.

In addition to body fat percentage associations, the females in this study had significant within individual effects for BMI, WC and HC. HC was significantly influenced by MVPA-10, whereas WC and BMI had significant associations for all activity categories. Similar to what was seen with BF, the effect is rather similar between MVPA-10 and total MVPA. Waist circumference is reduced by 0.23 cm and BMI is reduced by about 0.04 per 10 minute increase in either MVPA category within the corresponding 3 month assessment period. Although remaining significant, total PA has about half the impact for both, -0.12 cm for WC and -0.024 kg/m^2 for BMI.

Comparison with previous literature

When comparing the results of our findings in total MVPA and total PA, there have been a few studies that specifically examine at least one of the components of baseline physical activity: short bouts of MVPA < 10 minute and /or light intensity PA. The current study's finding that MVPA-10 and total MVPA had similar effects on anthropometrics and may suggest MVPA is critical regardless of bout length is similar to what several previous studies have shown. In a recent NHANES cross-sectional study of 4500 adults wearing accelerometers found that that higher-intensity physical activity, regardless of bout length is related to BMI and risk of overweight/obesity, whereas lower-intensity activities were not associated with weight outcomes (Fan et al., 2013). In the Framingham Heart Study, a sample of 2109 adults with accelerometer data were analyzed by accumulated time in MVPA bouts ≥10 minutes, bouts <10 minutes, and total MVPA minutes. Accumulation of MVPA by all three types had significant associations with lower BMI and WC. In addition, no differences were present in the strength of association between bouts ≥10 minutes vs. bouts <10 minutes (Glazer et al., 2013). Strath et al. completed analysis on 3,250 adults in the 2003-2004 NHANES data set who wore Actigraph accelerometers. The analyses compared bouts (≥10 min) vs. non-bouts

(< 10 minutes). The main finding showed that accumulating MVPA in bouts lasting less than 10 minutes was associated with lower BMI and waist circumference (WC), independent of bouts of at least 10 minutes. However, unlike our results showing similar effects of MVPA-10 and total MVPA, these findings showed that longer bouts of MVPA had four times the impact than shorter bouts, possibly due to the fact that the longer bouts had a higher intensity on average than short bouts (Strath et al., 2008).

Ayabe et al. went into further detail when exploring shorter bouts of MVPA in their cross-sectional analysis. Accelerometry data and adiposity measurements of visceral abdominal fat using CT scans, WC and body fat using the two-cites skin fold method was collected on 42 Japanese women. Similar to our current analyses, Ayabe et al examined various intensities beyond just MVPA (including separate analysis for light, moderate, vigorous, and all combined) for each bout duration. The main finding was that the relationship between visceral adipose tissue and physical activity depended on the intensity and the bout duration. MVPA in bouts of 1 minute or greater, and total activity (light, moderate, and vigorous combined) in bouts of 3 minutes of greater were significantly associated with visceral adipose tissue. In addition, total MVPA was a significant contributor to visceral adipose tissue, but not light PA (Ayabe et al., 2013). McGuire et al. evaluated incidental physical activity by examining LPA and MVPA bouts less than 10 minutes with the outcomes of abdominal obesity, visceral adipose tissue, and subcutaneous adipose tissue. Their results show no association of total incidental physical activity with any adiposity measure. Only short bouts of MVPA had significant inverse associations with visceral adipose tissue when adjusting for age and gender ($B = -0.13$ (-0.26 to -0.00) $p = 0.04$)) (McGuire & Ross, 2011). Conversely, a large cross-sectional analysis of 5,836 adults from the Australian Diabetes, Obesity, and Lifestyle Study showed that, after adjustment for MVPA, there was a significant association of LPA and WC. (Healy et al., 2007).

Strengths and limitations

The quality of our measures is a major strength in this study. The EB study used laboratory measurements for body composition using DXA for body fat and strict protocol use of height, weight, WC, and HC. This study drastically exceeds criteria of accelerometry data for use in other studies in which many require only 10hrs/day for 4 to 5 days of assessment (Fan et al., 2013; Glazer et al., 2013; Strath et al., 2008). We were able to capture an average of 23 hrs/day for nearly 10 days per quarterly assessment. Considering 5 possible assessment time points, this study has nearly 50 complete days of activity data over the one year period for the vast majority of the sample.

In addition, the study used a longitudinal, repeated measurement design. This allowed for the assessment of both between and within individual effects. The between effects provided insight in the association of chronic levels of activity averaged over the year with the average BMI, BF, WC, and HC across the year, comparing between the subjects. The within individual effects provided evidence of how an acute change in PA on a quarterly basis can result in a change in anthropometric within the same 3 month period.

One possible limitation is the generalizability of the sample, in which the majority of the participants were white and well educated and all within the age range of 20-35 years. In addition, the sample appeared to be more active compared to other what other studies have shown (Tucker et al., 2011), especially among the male participants. This could be one reason there may have been a lack of significance among the males is that the majority were very active and thus, there could be a ceiling effect. In addition, as shown in table 5.4, men had significantly smaller deviations from the average compared with women, and could result in the inability to detect change associations of PA with changes in anthropometrics.

Conclusion

For both genders, those who accumulated greater amounts of activity had a lower body fat percentage. There were also associations with the other anthropometric outcomes for the women, but not men. HC was significantly influenced by changes in MVPA-10. An increase in all three categories of activity resulted in a significant decrease in WC and BMI within the corresponding 3-month assessment. For all anthropometric associations there was a similar level of influence fromMVPA-10 and total MVPA. Therefore, these results suggest that the accumulation of all MVPA regardless of bout length can have similar impacts on anthropometrics. Total PA also has some influence on anthropometrics and simply the accumulation of all activity can prove beneficial. However, the association of anthropometrics with total PA was half of the impact when comparing the MVPA categories. Thus each 10 minute increase of MVPA has a greater influence on anthropometric outcomes than a 10 minute increase in total PA.

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Table 5.1 Participant Characteristics Overall and by Gender

	All (n=403)	Males (n=195)	Females (n=208)	p–value for gender
Age (yrs, mean±S.D.)	27.77±3.77	27.72±3.86	27.81±3.69	0.803
BMI categories (n, %)				
Normal Weight (<25kg/m^2)	212 (52.6%)	97 (49.7%)	115 (55.3%)	<.0001
Overweight (25 - <30kg/m^2)	130 (32.3%)	77 (39.5%)	53 (25.5%)	
Obese (≥30 kg/m^2)	61 (15.1%)	21 (10.8%)	40 (19.2%)	
Race				
white	265 (65.8%)	130 (66.7%)	135 (64.9%)	0.007
AA	53 (13.1%)	16 (8.2%)	37 (17.8%)	
Other	85 (21.1%)	49 (25.1%)	36 (17.3%)	
Employment				
Student	176 (43.7%)	89 (45.6%)	87 (41.8%)	0.440
Employed for wages	227 (56.3%)	106 (54.4%)	121 (58.2%)	
Income				
<$30,000	137 (34.2%)	60 (30.8%)	77 (37.4%)	0.191
$30,000 - 59,999	150 (37.4%)	72 (36.9%)	78 (37.9%)	
≥$60,000	114 (28.4%)	63 (32.3%)	51 (24.7%)	
Education				
4+ years of college	342 (84.9%)	154(79.0%)	188 (90.4%)	0.001
<4 years college	61 (15.1%)	41(21.0%)	20 (9.6%)	
Marital Status				
Married	133 (33%)	75 (38.5 %)	58 (27.9%)	0.024
Unmarried	270 (67%)	120 (61.5%)	150 (72.1%)	
Smoking Status				
Current Smoker	15 (3.7%)	8 (4.1%)	7 (3.4%)	0.382
Non-smoker	388 (96.3%)	187(95.9%)	201 (96.6%)	
TEI				
Average TEI (kcals/day)	2079±574	2385±608	1793±350	<.0001
Deviation of TEI (Kcals/day)	-1.83E-14±390	1.42E-13±445	2.84E-14±328	<.0001

All demographics from baseline measurements
TEI measures are averages across the 12 months

Table 5.2 Anthropometrics Overall and by Gender - Averages across 12 months

	All (n=403)		Males (n=195)		Females (n=208)		
Anthropometrics	Mean	S.D.	Mean	S.D.	Mean	S.D.	p-value for gender
BMI	25.76	3.91	25.81	3.38	25.71	4.36	0.7966
Weight (kg)	75.89	14.14	82.19	12.58	69.98	12.94	<.0001
WC (cm)	80.23	10.13	84.22	8.87	76.50	9.83	<.0001
HC (cm)	101.00	7.89	100.14	6.71	101.79	8.80	0.0359
Body Fat %	0.30	0.11	0.22	0.09	0.37	0.08	<.0001

BMI = Body Mass Index WC = Waist Circumference, HC=Hip Circumference

Table 5.3 Activity monitor values overall and by gender – Average across 12 months

	All (n=403)		Males (n=195)		Females (n=208)		
	mean	S.D.	mean	S.D.	mean	S.D.	p-value for gender
Wear Time (hrs/day)	23.0	1.1	23.1	1.2	23.0	1.0	0.214
Number of Days	9.86	0.9	9.9	1.0	9.8	0.9	0.491
MVPA-10 (min/day)	72.3	55.3	91.0	58.6	54.8	45.6	<.0001
Total MVPA (min/day)	128.3	66.8	150.5	69.7	107.5	56.6	<.0001
Total PA (min/day)	344.4	78.0	346.4	78.6	342.6	77.4	0.631

Average Wear Time: Hrs/day the Armband was worn
Number of Days: compliant days of Armband wear (≥18.5 hrs/day) per quarterly assessment
MVPA10: activity ≥ 3.0 METs in 10 minute bouts (following 8 of 10 minute criteria)
Total MVPA: all activity ≥ 3.0 METs, regardless of bout length
Total PA: activity > 1.5 METs, regardless of bout length

Table 5.4 Deviations in Physical Activity Categories – Averages across 12 months

	Mean	95% CL		Min	Max
All (n=403)					
Deviation MVPA-10 (min/day)	1.60E-16	-1.20	1.20	-174.50	173.42
Deviation Total MVPA (min/day)	3.58E-16	-1.36	1.36	-170.30	156.81
Deviation Total PA (min/day)	1.55E-15	-1.93	1.93	-267.71	204.53
Males (n=195)					
Deviation MVPA-10 (min/day)	-4.44E-16	-2.05	2.05	-174.50	158.10
Deviation Total MVPA (min/day)	1.78E-15	-2.26	2.26	-170.30	149.10
Deviation Total PA (min/day)	1.42E-14	-2.92	2.92	-267.70	204.50
Females (n=208)					
Deviation MVPA-10 (min/day)	-3.55E-15	-1.29	1.29	-69.92	173.40
Deviation Total MVPA (min/day)	1.33E-15	-1.57	1.57	-85.74	156.80
Deviation Total PA (min/day)	-1.07E-14	-2.55	2.55	-225.40	169.90

p-value for difference between males and females:
MVPA-10 p <.0001, Total MVPA p<.0001, Total PA p=0.0012

Table 5.5 Within and Between Individual Associations of Anthropometrics with MVPA-10, total MVPA, and total PA - Males (n=195)

	Between Individual Effect			Within Individual Effect		
	β *	$SE_β$	p-value	β *	$SE_β$	p-value
BMI						
MVPA-10	0.054	0.047	0.250	0.001	0.012	0.903
Total MVPA	0.052	0.039	0.188	0.006	0.011	0.608
Total PA	0.021	0.033	0.533	0.013	0.009	0.124
Body Fat %						
MVPA-10	-0.005	0.001	<.0001	-0.001	0.001	0.149
Total MVPA	-0.005	0.001	<.0001	0.000	0.001	0.483
Total PA	-0.003	0.001	<.0001	0.000	0.001	0.517
Waist Circumference						
MVPA-10	0.173	0.130	0.184	0.010	0.058	0.858
Total MVPA	0.166	0.110	0.130	0.016	0.052	0.762
Total PA	0.108	0.092	0.241	0.010	0.039	0.800
Hip Circumference						
MVPA-10	0.096	0.104	0.353	0.027	0.049	0.585
Total MVPA	0.096	0.088	0.273	0.037	0.044	0.398
Total PA	0.044	0.073	0.543	0.050	0.033	0.137

* β - effect of 10 min/day increments of each PA category

All models adjusted for age, race, education, employment, income, marital status, smoking status, average Armband wear time, and average and deviation in TEI

Table 5.6 Within and Between Individual Associations of Anthropometrics with MVPA-10, total MVPA, and total PA - Females (n=208)

	Between Individual Effect			Within Individual Effect		
	β *	SE_{β}	p-value	β *	SE_{β}	p-value
BMI						
MVPA-10	0.041	0.069	0.551	-0.043	0.020	0.032
Total MVPA	0.035	0.055	0.522	-0.039	0.017	0.019
Total PA	0.052	0.038	0.173	-0.024	0.010	0.021
Body Fat Percent						
MVPA-10	-0.008	0.001	<.0001	-0.003	0.001	0.015
Total MVPA	-0.007	0.001	<.0001	-0.003	0.001	0.011
Total PA	-0.004	0.001	<.0001	-0.001	0.001	0.153
Waist Circumference						
MVPA-10	0.272	0.184	0.139	-0.228	0.088	0.010
Total MVPA	0.243	0.146	0.097	-0.225	0.074	0.003
Total PA	0.169	0.101	0.093	-0.119	0.044	0.007
Hip Circumference						
MVPA-10	0.159	0.148	0.284	-0.181	0.076	0.018
Total MVPA	0.093	0.119	0.435	-0.114	0.064	0.074
Total PA	0.072	0.081	0.376	-0.011	0.038	0.780

* β - effect of 10 min/day increments of each PA category

Adjusted for age, race, education, employment, income, marital status, smoking status, average Armband wear time, and average and deviation in TEI

CHAPTER VI

OVERALL SUMMARY AND CONCLUSIONS

Physical activity is a complex behavior that can be influenced by many factors and can in turn influence many aspects of health and quality of life. This dissertation contributed new knowledge of understanding the full spectrum of physical activity.

Generally, this dissertation sought to understand what influenced behavior in the first two studies and then explore how such behavior influenced health, in particular, anthropometrics, in the final study. Specifically, the purpose of this dissertation was to:

1) Examine the intrapersonal-level correlates and determinants of the full spectrum of physical activity among young adults

2) Examine how life events and the associated self-reported stress of life events influences the full spectrum of physical activity among young adults

3) Examine the associations of the total spectrum of physical activity with anthropometric outcomes among young adults

All three studies came from data collected in the first year of the Energy Balance Study. The primary aim of this longitudinal study was to examine how energy intake and energy expenditure influenced body weight and fat. A secondary aim was to understand the components within energy intake and expenditure. The studies discussed here provide insight into this secondary aim in learning about the behavioral physical activity component of energy expenditure

When analyzing the full spectrum of physical activity three separate variables were used in order to compare the 2008 Guideline-based MVPA and with the additional influence of baseline activities. The variables included MVPA-10 (MVPA according to the 2008 PA Guidelines, requiring durations of at least 10 minutes), total MVPA (all MVPA regardless of bout length), and total physical activity (all activity from light to vigorous in any bout duration; all activity >1.5 METs). Thus, the analyses gradually added the components of baseline PA, by first adding the short bouts of MVPA to obtain total MVPA and then light PA to obtain total PA, allowing the exploration of the full spectrum of activity.

All three studies utilized the quarterly data collected over a 12 month period. Each study employed linear mixed models to examine both between and within individual effects. This allowed a unique understanding of both chronic and acute effects. The chronic effects were between subjects, looking at the averages across the entire year. Since the Energy Balance study was completely observational, without any intervention to consciously influence behaviors, there was no expectation for drastic changes in the outcomes of interest. Thus, it seemed appropriate to examine the overall averages across the year. However, the within individual effects did allow for reflection on changes. The within effects examined acute changes within a specific 3 month assessment period. This was based on how a deviation from the overall yearly average in the independent variables impacts the dependent variable within that same quarterly assessment.

The primary results from these analyses include:

1. Intrapersonal variables within categories of biological, socioeconomic, family structure, behavioral, and psychological can influence activity. The associated characteristics differ based on whether physical activity is quantified as MVPA-10, total MVPA, or total PA. Adding components of baseline PA, first short bouts of total MVPA followed by light intensity PA influences the results.
2. The average number and associated stress of life events per quarter did not have much influence on physical activity. However, many life events when examined separately had significant associations with MVPA-10, total MVPA and total PA. For young adult men, changing jobs and marriage had negative impacts on activity while starting/ending a relationship and beginning a mortgage had positive influences. For young adult women, starting a new job, moving, engagement, and the loss of a family/friend had negative consequence while quitting a job resulted in increases in PA. The degree of influence on activity often went beyond the typical recommendations of MVPA in 10 minute bouts.
3. Physical activity had an influence on various anthropometric measures and varied by gender. The accumulation of greater amounts of activity was associated with a lower body fat percentage for both men and women. There also were associations with PA for WC, HC, and BMI for the women. For all anthropometric associations there were similar degrees of association of MVPA-10 and total MVPA, suggesting that the accumulation of all MVPA regardless of bout length can have a similar impact on anthropometrics. The associations were half of the impact when comparing the MVPA categories with total PA. Thus an increase of

MVPA has a greater influence on anthropometric outcomes than an increase in total PA.

These results provide new insight to the influences of physical activity behavior and how such behavior influences anthropometric outcomes. The major novelty of these studies is the examination of the full spectrum of activity with the help of our objective, thorough measurement of physical activity. Not only was the full spectrum evaluated but comparisons were made to what is typically evaluated in MVPA-10. For this dissertation, it is clear that looking at MVPA in 10 minute bouts does not tell the whole story. The third paper shows that health benefits, in particular better anthropometric outcomes, beyond just the accumulation of MVPA-10. Future questions to explore would be using a similar method for categorizing PA so to examine the full spectrum on other health outcomes. With the anthropometric benefits recognized in this paper, it may suggest that interventions and public health program can promote novel strategies of PA promotion, incorporating the full spectrum of activity rather completely focus on the Guideline-based MVPA. Understanding what influences such behavior, as was explored in first and second paper, can help guide such programs. Papers 1 and 2 reinforced the complexity of the behavior and the many demographics, behaviors, and life events that can contribute to increasing or decreasing physical activity. These papers were the first in our knowledge to focus on the individual level influences of the entire spectrum of PA. Therefore, there are many more behavioral-based research questions to explore when reflecting on the full spectrum of PA. For instance, future studies should examine beyond the intrapersonal level, to include other aspects of the ecological model (i.e.

interpersonal, organizational, community, policy) as all of these factors can play a role and interact with each other.

In conclusion, the use of detailed, objective physical activity measurement allowed for a novel way of exploring the behavior of physical activity. The advancements in technology allowing the use of devices, such as the Armband, provide an avenue that has the ability strengthen physical activity and public health research. By using this objective PA measure, it opens the doors for an opportunity to explore activity in a novel approach. In turn, the results of this study added new findings to the research on physical activity and public health. There were various correlates and determinants for activity and these varied by MVPA in 10 minute bouts vs. total MVPA vs. total PA. Additionally, life events differentially influenced these categories of physical activity. Finally, anthropometrics were not only influenced by MVPA in 10 minute bouts, but also the addition of the baseline activity had an influence. Therefore, these three papers show that physical activity is multifaceted, and both research and public health efforts can benefit by acknowledging and incorporating the entire spectrum of physical activity.

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