ANALYSIS OF OBJECTIVELY ASSESSED PHYSICAL ACTIVITY PATTERNS IN AMERICAN FIRST-YEAR MEDICAL STUDENTS, DURING A TYPICAL WORKDAY

By

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Abstract: The purpose of this study was to record the physical activity patterns of American first-year medical students whose daily schedules were known and virtually identical, and to examine the relationship of these activity patterns and BMI-derived weight classifications, among conditions of environmental influence on individual physical activity. Forty-six of 99 potential (46% participation rate) first year medical students completed the activity study in full, and 41 participants' data were included in the final analysis. Participant activity was recorded for a continuous 12-hour period, from 9:00 am through 9:00 pm, across a span of 11 weeks from August to October. The relationships of five activity variables and BMI-derived weight categories were examined across conditions of environmental influence. When environmental constraint upon participant activity was present, results indicated that BMI-derived weight category was positively related to sedentary fidgeting volume. When the environment did not constrain participant activity, relationships between BMI-derived weight categories and sedentary time^{sec}, number of steps taken, stepping time^{sec}, and steps taken^{min} were in the predicted direction, though none reached statistical significance. This study was the first of its kind to simultaneously quantify aspects of each of the three energetic components of daily energy expenditure: posture allocation, ambulation, and fidgeting.

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CHAPTER I

INTRODUCTION

The Obesity Epidemic

The world is in the grip of an obesity epidemic (Naser, Gruber, & Thomson, 2006). Obesity became widespread in the early 1980's (James, 2008), and was officially recognized by the World Health Organization (WHO) as a major health issue in 1997 (WHO, 2000). World-wide prevalence of obesity nearly doubled from 1980 to 2008, at which time it was estimated to affect over 10% of the global population (WHO, 2011). In the United States (U.S.), 34.9% of adults 20 years or older are obese (Ogden, Carroll, Kit, & Flegal, 2014). This high prevalence is of particular concern because obesity increases the risk of serious morbidity and mortality (Chang, Pollack, & Colditz, 2013). Obese individuals are more likely to develop cardiovascular disease (Gregg et al., 2005), stroke (Curioni, 2008), osteoarthritis (Wang et al., 2009), and specific cancers (A. S. Anderson & Caswell, 2009), and in aggregate, obese individuals experience excess mortality when compared to normal weight individuals (McGee, 2005).

Obesity occurs when an individual maintains a positive energy balance, that is, when energy intake exceeds energy expenditure over time. The body stores excess energy as fat, resulting in weight gain that could progress to obesity. As energy intake and energy expenditure are the primary mechanisms through which one's energy balance is changed, explanations for the obesity epidemic traditionally focused on whether one

one energetic component or the other was to blame. A promising reconceptualization of this issue, however, foregoes the focus on either energetic component in isolation, centering instead on the energy balance itself, e.g., (Hill, Wyatt, & Peters, 2012; Levine & Kotz, 2005). This approach may lend needed perspective when addressing obesity within surroundings that promote excessive energy intake and low energetic expenditure (Hill & Peters, 1998).

Despite constant environmental encouragement of both excessive energy intake and the adoption of a sedentary lifestyle, not all individuals exposed to these conditions are sedentary, gain weight, or become obese. This may be due to biological factors that help resist environmental discouragement of physical activity (Hill & Melanson, 1999; Kotz, Teske, & Billington, 2008), an idea proposed in the 1980's (Ravussin, Lillioja, Anderson, Christin, & Bogardus, 1986). Ravussin et al. (1986) monitored the energetic expenditure of participants in a respiratory chamber and suggested that individual differences in the biologically driven proclivity for movement could explain the differences they observed between participant activity levels. In their study, despite the lack of environmental demand for activity, participant activity levels varied widely. Subsequent studies have confirmed that physical activity levels in a respiratory chamber are significantly associated with free-living physical activity levels (Snitker, Tataranni, & Ravussin, 2001), and that some individuals have higher levels of daily physical activity than others, across repeated measurements on different days (Levine et al., 2008). Persistently high levels of energy expended through physical activity might counteract the environmental influences that promote weight gain. A better understanding of biological mechanisms influencing one's engagement in physical activity, and thus energy expenditure, may clarify why some individuals resist weight gain in an environment that seems to encourage it (Kotz et al., 2008).

Nonexercise Activity Thermogenesis

It is believed that fewer than one quarter (~20%) of U.S. citizens participate in regular exercise (McCrady-Spitzer & Levine, 2012). Therefore, the majority of U.S. citizens' daily physical activity is that which is not devoted to exercise, so called nonexercise activity thermogenesis (NEAT) (Levine, Eberhardt, & Jensen, 1999). NEAT represents the energy expended for everything we do that is not sleeping, eating, or sports-like exercise (Levine, 2002). NEAT is a large component of total daily energy expenditure (TDEE), it is the most variable category, and includes sitting, standing, stepping, shivering, fidgeting, and posture change, among other behaviors (Levine, Melanson, Westerterp, & Hill, 2001; Poehlman, Melby, & Goran, 1991). Shivering is distinguished from fidgeting in that shivering is undertaken to achieve a goal, i.e. to increase bodily warmth. Fidgeting refers to physical activity that is peripheral or nonessential to ongoing focal tasks or events (Mehrabian & Friedman, 1986). Elements responsible for the variability in NEAT can be categorized as environmental or biological (Levine & Kotz, 2005). From a behavioral perspective, NEAT results from carrying out the routines of daily life within a given environment. From an energetic perspective, NEAT represents the sum of all physical activity energetic expenditure devoted to carrying out these routines (Levine et al., 2001).

Accounting for Differences in Nonexercise Activity Thermogenesis

Recent studies have used accelerometers to quantify physical activity during daily life. Accelerometers are small, unobtrusive, body-worn devices that store continuous or aggregated measurements of the acceleration of the body part to which the monitor is affixed. Accelerometers quantify physical activity in terms of acceleration counts, sometimes associated via regression equations to levels of energy expenditure. Newer activity monitors can directly measure posture, number of steps taken, step cadence, and time spent in each activity, in addition to measuring acceleration and estimating energy expenditure (Grant, Dall, Mitchell, & Granat, 2008; Grant, Ryan, Tigbe, & Granat, 2006). Studies using accelerometers to measure daily physical activity typically assess one, or sometimes two, of the energetic components of daily physical activity. To our knowledge, no studies of daily physical activity quantify all three energetic components: that is, posture allocation (e.g., seated, standing), ambulation (e.g., stepping time, number of steps, step cadence), and fidgeting (e.g., the number of instances of fidgeting). Measuring extraneous behavior like fidgeting is important, because fidgeting-like movements have been associated with quantitatively significant changes in energy expenditure, compared to remaining motionless (Levine, Schleusner, & Jensen, 2000).

While several accelerometry-derived activity studies record the physical activity of participants over multiple days, few can account for the environmental conditions faced by participants throughout the recording period. This lack of context is problematic for isolating the variance in individuals' physical activity that is attributable to biological versus environmental factors. For example, Cooper, Page, Fox, and Misson (2000) studied hourly activity counts and found that obese participants were less active than nonobese participants during nearly all waking hours of the week. The persistence of this difference in activity between obese and nonobese individuals strengthens the case for the difference stemming from biological rather than environmental factors. The present study examined individual differences in posture allocation, ambulation, and fidgeting behavior among American first year medical students of different BMI-derived weight classifications (WHO, 2000), whose schedules of activities are known and virtually identical throughout the recording period.

Simultaneous measurement of multiple energetic components of physical activity may yield additional information about the nature of biological control mechanisms for physical activity, as well as how these mechanisms interact with environmental stimuli. Given that levels of certain NEAT behaviors remain intraindividually stable, Levine et al. (2008) suggested that walking is under mechanistic control. Alternatively, it is possible that an intrinsic drive for physical activity is expressed according to environmental conditions. If so, such a drive would likely be expressed as ambulation when an individual's movement is unrestricted by their environment, and they are free to move as desired. Fidgeting should be more likely in the environments that constrain physical activity, such as while attending a lecture. Therefore, we will look to answer questions about the influence of environment on the physical behaviors displayed by individuals from disparate BMI-derived weight groups. Specifically, when compared with those in the normal weight classification, will those in overweight and obese classifications exhibit a quantitatively lesser amount of fidgeting when constrained by their environment? In addition, when compared with those in the normal weight classification, will those in overweight and obese classifications remain sedentary for longer, stand and ambulate for a lesser amount of time, take fewer overall steps, and walk at a slower pace, when environment places no constraint on their activities?

Researcher Position and Study Context

This study involves the reanalysis of data from a study initially conducted in 2009. My involvement with the original study was as a paid research assistant in the Department of Behavioral Sciences of a medical school in the Midwestern United States, and I reported directly to the Principal Investigator (P.I.). At the time of the original study, neither my position nor the study itself were associated with any academic program in which I was a student. My responsibilities for the original study included scheduling and running all participants though the entirety of the research protocol, administering all associated study forms and instruments, collecting all participant physical activity data, and compiling this data into a networked database. I developed and ran syntax protocols to truncate, aggregate, and synchronize multiple formats of the activity data into a unified master file, which I analyzed using parametric split-plot ANOVA tests and trend analysis. I then informally reported the results of these analyses to the P.I. It was determined that the physical activity data collected in the original study did not uniformly lend themselves to analysis by parametric statistical tests. Consequently, I propose to reanalyze the data. My analytic approach, however, will differ from that of the original study, in that I will reassess a subset of the original research questions using data transformations, nonparametric statistical tests, or both. No results from the original study have be published.

Assumptions, Limitations, and Delimitations

Assumptions associated with this study include the following:

- When questioned about whether they attended all scheduled classes, labs, and lectures for their full duration, participants responded accurately.

- When questioned about whether they were experiencing illness or were taking medication known to affect physical activity, participants reported the presence or absence of such factors accurately.
- The activPAL accelerometers employed to record participant activity performed reliably, without appreciable difference in error from their validation field studies.
- To the greatest extent possible, The Hawthorne Effect and experimenter expectancy effects were experimentally controlled for, and had negligible influence upon participant activity.

Limitations associated with this study include the following:

- Members of the target population (first year students of the 2009 entering class Midwestern United States medical school) were not required to participate in this physical activity study, and therefore did so of their own volition. This may have resulted in students with certain intrinsic traits and beliefs regarding physical activity to participate, potentially resulting in a biased sample. If there were a self-selection effect, it would be unlikely that activity patterns of these participants were representative of the target population as a whole.
- Participants were grouped by BMI-derived weight classifications, and BMI is a simple function of weight for height. The WHO developed BMI categories to represent the graded health risk associated with body mass in adults. As is well known, BMI does not account for the composition of an individual's body mass. Therefore, BMI cannot distinguish between weight associated

with muscle and weight associated with fat. Further, as BMI may not correspond to the same degree of fatness across populations, some Asian countries have developed their own BMI-derived weight classification ranges, to better reflect the relationship between body mass and health risk. This study did assess for participant race.

- Most contemporary physical activity studies last from a few days to a week or longer, in order to gain a representative sample of daily activity. While this study benefits from knowledge of the participant's daily schedule, the resources to record an appropriately sized sample of medical students for a week or more were lacking. Therefore, this cross-sectional study may not have captured physical activity patterns of the participant sample representative of a typical day.

Delimitations associated with this study include the following:

- This study was concerned with the differences in activity between individuals from different weight classifications. It was decided these groups were to be based upon BMI, a commonly used metric for classifying individuals by weight, albeit with known caveats.
- This study only accepted first year medical students pursuing the D.O. degree in a standard fashion; dual degree (D.O./Ph.D., D.O./M.S., & D.O./M.P.H.) and bridge program students were not invited to participate.
- Only participants free from illness or conditions known to affect physical activity were invited to participate in the study. Pregnancy was also among the exclusion criteria.

Term Definitions

The following is a list of definitions for select conceptual terms used in the study:

- **Accelerometer**: “an accelerometer is an electromechanical device that will measure acceleration forces. These forces may be static, like the constant force of gravity pulling at your feet, or they could be dynamic - caused by moving or vibrating the accelerometer” (DimensionEngineering, n.d.).
- **Activity thermogenesis (AT)**: is the production of heat generated by physical movement during purposeful exercise (exercise thermogenesis) and nonexercise activity thermogenesis (NEAT) (Rubin, Strayer, & Rubin, 2012).
- **Ambulation**: the action of walking or moving about freely (Venes, 2009).
- **Basal metabolic rate (BMR)**: the minimal rate of metabolism of an individual at complete rest, at normal body temperature [in a postabsorptive state], and is estimated when an individual is resting quietly in a laboratory under optimal conditions, after at least 8-h sleep and 12-h since the last meal (Kent, 2006).
- **Body Mass Index (BMI)**: an index of weight for height that is commonly used to classify underweight, overweight, and obesity in adults but does not distinguish between weight associated with muscle and weight associated with fat (WHO, 2000). The formula for computing BMI from U.S. customary units is: weight (lbs.) / $[\text{height (in)}]^2 * 703$
- **Energy expenditure**: the amount of energy used, for example, in an activity, most commonly expressed in terms of the kilocalorie (kcal) (Kent, 2006).

- **Energy intake**: a straightforward concept, energy intake is dependent on diet, which is mainly regulated by hunger and calories consumed, including protein, carbohydrate, fat, or alcohol (Rhoades & Bell, 2013).
- **Energy gap**: the discrepancy between energy intake and energy expenditure (James & Leach, 2011).
- **Exercise**: a subset of physical activity that is planned, structured, and repetitive and has as a final or an intermediate objective the improvement or maintenance of physical fitness (Caspersen, Powell, & Christenson, 1985).
- **Exercise thermogenesis (ET)**: the production of heat generated by physical movement during volitional exercise (sports and fitness-related activities) (Levine et al., 1999).
- **Fidgeting**: fidgeting is defined as engaging in manipulations of one's own body parts, such actions being peripheral or nonessential to central ongoing events or tasks (Mehrabian & Friedman, 1986).
    - **Fidgeting computation**: fidgeting behavior (as defined above) was computed by quantifying the number of nonzero consecutive differences in the acceleration signal, indicative of movement in the thigh, during a period of at least 15 consecutive seconds with no posture change and no steps recorded. For the sedentary fidgeting computation, it was further specified that these nonzero consecutive differences occur within at minimum a 15-second period in the sedentary posture. The degree of specificity chosen to compute sedentary fidgeting was not expected to produce meaningful data loss,

as participants were seated in class lectures while this behavior was assessed.

- **Kilocalorie (kcal)**: the amount of heat needed to raise the temperature of 1 liter of water by 1 °C [1kcal = 1000 cal], also used to express energy changes associated with biochemical reactions or the energy content in food (Kent, 2006).
- **Metabolic equivalent (MET)**: the ratio of work metabolic rate to a standard resting metabolic rate of $1.0 \cdot kg^{-1} \cdot h^{-1}$, where 1 MET is considered a resting metabolic rate obtained during quiet sitting (Ainsworth et al., 2000).
- **Metabolism**: the sum total of all the chemical reactions which take place in the body to sustain life (Kent, 2006).
- **Nonexercise activity thermogenesis (NEAT)**: the production of heat that accompanies physical activities other than volitional exercise, such as the activities of daily living, fidgeting, spontaneous muscle contraction, and maintaining posture when not recumbent (Levine et al., 1999).
- **Normal weight**: for [non-Asian] adults, a body mass index between 18.5 and 24.99 kg/m^2 (Westerterp, 2013).
- **Obesity**: for adults, obesity is clinically defined as a weight that is 20% or more above ideal body weight per standard height and weight tables (Stevens et al., 2007), and practically defined as a BMI of 30 kg/m^2 or greater (WHO, 2000).
- **Overweight**: for [non-Asian] adults, a body mass index between 25.00 and 29.99 kg/m^2 (Westerterp, 2013).

- **Physical activity**: body movement produced by skeletal muscles and resulting in energy expenditure (Westerterp, 2013).
- **Physical activity level**: total energy expenditure expressed in multiples of the MET unit (Westerterp, 2013).
- **Postabsorptive state**: complete digestion of the previous meal; the state of having fasted for 12-h in duration (Lieberman, Marks, & Smith, 2009).
- **Thermic effect of food (TEF)**: an increase in metabolic rate (reflected by an increase in oxygen consumption) associated with the digestion, absorption, transport, and assimilation of ingested food (Kent, 2006).
- **Thermogenesis**: the production of body heat, most of which is a by-product of metabolism (Kent, 2006).
- **Total daily energy expenditure (TDEE)**: the sum of energy expended via BMR, TEF, and AT within a given 24-h timeframe (Rubin et al., 2012).
- **Shivering**: involuntary muscular contractions for the purpose of thermoregulation (Rubin et al., 2012).

CHAPTER II

REVIEW OF THE LITERATURE

This review of the literature provides an overview of the evolutionary perspective of human energy balance. First, our ancestral progression from hunter-gatherer to subsistence agriculture lifestyle is presented. Next, the components of human energy balance are introduced, and described. Following this is a description of the manner in which the industrial revolution and urbanization influenced human energy balance. Rationale for the objective assessment of NEAT behaviors with activity monitors sensitive to static and dynamic acceleration is given, as is the potential for closing the existing energy gap by increasing NEAT behaviors. This review concludes by suggesting that a specific range of the NEAT behaviors associated with volitional energetic expenditure may hold the key to simply and affordably closing the energy gap, thereby stemming the incidence of obesity in Western society.

Evolutionary Perspective of Obesity

Several recent articles support a positive relationship between physical activity and positive health outcomes. Physical health, mental health, quality of life, and lifespan each typically improve as an individual becomes more active. The relationship between activity and health should be apparent, however, as our forbearers evolved within a state of near constant physical activity, and it is likely that we are programmed with a genetic need to move (Booth, Chakravarthy, Gordon, & Spangenburg, 2002). Humans could not display the myriad complex behaviors without first developing metabolic systems to support such activity, and a clear selective advantage exists for mammals with enhanced capacity for movement (Bennett & Ruben, 1979). Thus, our biological systems develop and function best when exposed to frequent physical activity, and sedentary lifestyles likely interfere with our bodies' expectation to expend energy through physical movement (Booth, Laye, Lees, Rector, & Thyfault, 2008). The observation that physical inactivity is an "actual" cause of chronic disease further supports this position (Blair et al., 1993; Mokdad, Marks, Stroup, & Gerberding, 2004).

Our human ancestors lived as hunter-gatherers until the agricultural revolution 10,000 years ago, at which time subsistence agriculture was adopted as the predominant lifestyle (Cordain, Gotschall, Eaton, & Eaton, 1998). Cordain et al. (1998) estimate that modern hunter gatherers expend the energetic equivalent of walking 19 km each day, and Bassett, Schneider, and Huntington (2004) found that Old Order Amish men and women walk more than 18,000 and 14,000 steps per day, respectively. Benedetti et al. (2009) found that obese adults walked an average of 5,870 steps per day while nonobese adults took 7,859 steps per day. Though these values are short of the recommended 10,000 steps per day figure, they are significantly greater than the 1,000 to 3,000 steps managed by sedentary individuals. Approximately 150 years ago, 90% of the world's population lived in agricultural regions, and the work and transportation of the time was largely characterized by physical exertion (Habitat, 2005). Like those before them, our more recent ancestors walked to and from jobs that required them to be active, and this routine was complementary of the activity patterns that shaped our development (Levine, 2007). It is possible that the obesity-promoting environment we currently live in is simply the result of our ancestors' desire to engineer a less demanding existence, with accessible and inexpensive food, and a reduced physical workload (Hill, Wyatt, Reed, & Peters, 2003).

During the last 150 years, the world has experienced a fundamental demographic transition (Levine, 2007); half of the world's population moved to cities (Habitat, 2005). This urban shift helped stem the need for physical exertion, and the increased prevalence of labor saving devices at work and at home, as well as the entry of more affordable cars into market, greatly reduced physical demands of daily life (James, 2008). Thus, in this transition, physical activity declined (Richards et al., 2000). It was assumed that technology and increased productivity would leave individuals with more time for pursuits of leisure, but ironically, they have created a faster and more stressful pace of life (Gleick, 1999). Former U.S. Department of Labor secretary Robert Reich, in his book *The Future of Success* (Reich, 2001), states "… work is organized and rewarded in America in a manner that induces harder work." Such conditions result in a more fast paced lifestyle, and with less time in the day for traditional food preparation, the consumer market is driven to offer prepackaged and fast food (Hill et al., 2003). Women are now ubiquitous in the workforce, and single-parent families are much more common. In conjunction, these recent changes have placed a premium on convenience (Hill et al., 2003). As developing countries become wealthier and more Westernized, lifestyles characterized by positive energy balance and urbanization have become a precursor for subsequent obesity (Ford & Mokdad, 2008).

Components of Human Energy Balance

When applied to living organisms, the first law of thermodynamics holds that when energy is added to a system, it is either stored, or used to perform work. A positive energy balance can therefore only occur when energy intake exceeds expenditure. Negative energy balance is only possible when energy expenditure exceeds energy intake. Therefore, obesity can only develop in the state of a prolonged positive energy balance. Energy intake occurs through diet in the form of protein, carbohydrate, fat, and alcohol, and these energy sources provide the fuel for TDEE. There are three main components of human energy balance: basal metabolic rate (BMR), thermic effect of food (TEF), and activity thermogenesis (AT) [physical activity] (Levine, 2002). See Figure 2.1 for an illustration of these components and their relation to TDEE.

Figure 2.1. Major Components of Human Energy Balance

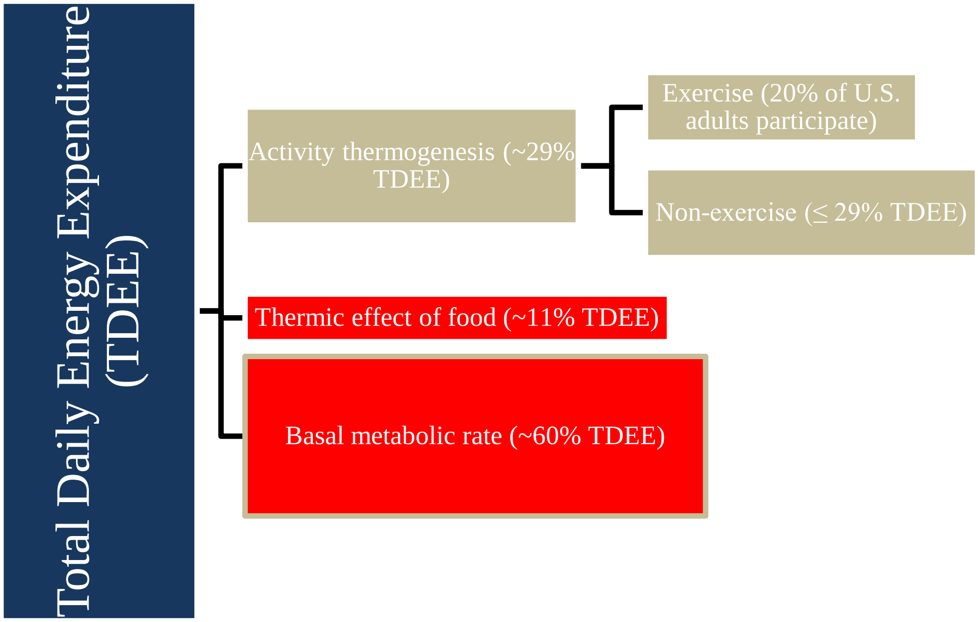

Figure 2.1. Figure 2.1 models the major components of human energy balance. Each of the three major components is expressed in terms of its contribution to the overall total daily energy expenditure in a sedentary individual (Levine, 2002, 2004). The BMR and

TEF elements of energy balance remain stable, while AT, and its subcomponents, can vary broadly (Church et al., 2011).

BMR is the energy required by one's body to carry out the daily functions of life, including respiration, blood circulation, cell division, and others. This rate of energy consumption is relatively stable over time, but varies widely as a function of body composition between individuals, and accounts for approximately 60% of TDEE in a sedentary individual (McCrady-Spitzer & Levine, 2012). TEF is the energy required by one's body to ingest and digest food, and absorb associated nutrients. TEF accounts for about 11% of TDEE, is fairly stable over time, but does fluctuate as a function of body mass between individuals (McCrady-Spitzer & Levine, 2012). The remainder (~29%) of one's TDEE is attributed to energy expended through activity thermogenesis (AT), which describes the heat associated with energy burned during locomotion and posture maintenance (McCrady-Spitzer & Levine, 2012). AT is partitioned into exercise thermogenesis (ET) and nonexercise activity thermogenesis (NEAT). As only 20% of Americans exercise regularly, the majority of U.S. citizens' AT comes in the form of NEAT (Levine, 2004).

NEAT is the energy expenditure of all physical activity other than purposeful exercise (Levine & Kotz, 2005), and is the focus of the majority of nonexercise physical activity research, due in part to its variable nature. For instance, TDEE can vary by as much as 1500 kcal/day between two similarly sized adults, and the variance in NEAT accounts for nearly all the variance in AT (Levine & Kotz, 2005). NEAT is the only modifiable variable contributing to TDEE, and can be divided into occupational and non-occupational/leisure time physical activity (Church et al., 2011). Non-occupational NEAT represents a fairly small amount of the total hours in a week, while occupational

NEAT has a greater potential to significantly impact overall energy expenditure (Church et al., 2011). Indeed, from 1960 to 2008, occupation-related daily energy expenditure dropped by approximately 140 calories and 124 calories for men and women respectively (Church et al., 2011). The influence of occupation upon NEAT is difficult to explicate, because this effect is also influenced by one's society and biology (Levine, 2007).

Gene/Environment Interactions May Affect Energy Balance

An individual's body weight and body composition are determined by interactions between the environment and genetics (Hill et al., 1994). Therefore, the influence of the environment upon obesity is best thought of in terms of how it increases the likelihood of behaviors that contribute to risk of positive energy balance (Hill & Peters, 1998). It is widely held that aside from discouraging energetic expenditure, the modern environment promotes excessive energy intake. In fact, by employing various modeling techniques, several have concluded that increased food intake is predominantly responsible for the obesity epidemic (Katan & Ludwig, 2010; Swinburn, Sacks, & Ravussin, 2009; K. R. Westerterp & Plasqui, 2009). Others believed differently, and a validated differential equation model was used to propose a lower bound figure representative of the food waste in the U.S. (Hall, Guo, Dore, & Chow, 2009). With the aid of this model, it was determined that previous figures related to national food waste were substantially misjudged. The national average calorie intake was found to be lower than previously estimated. Data collected over the past 150 years from several studies show food intake has remained fairly constant (McCrady-Spitzer & Levine, 2012), and data from the U.K. suggest caloric intake has actually declined (Smith, Shipley, Batty, Morris, & Marmot, 2000).

It is worth mentioning that the energy gap required to explain the increased prevalence of obesity is only 100 to 200 kcal/day (Hill et al., 2003), suggesting that a small adjustment to either component of energy balance would be sufficient to prevent obesity. Therefore, the difference in NEAT observed between obese and lean individuals is significant and implies that obesity might be prevented through simply limiting sedentary activities, or increasing behaviors such as standing, walking, and fidgeting (Ravussin, 2005). Indeed, a half-century ago, Widdowson, Edholm, and McCance (1954) found that fidgeting is important for energy expenditure, and Ravussin et al. (1986) found that [NEAT] measured within a respiratory chamber accounted for an average energy expenditure of 348 kcal/day. These values are nearly equivalent to the difference (352 kcal/day) reported between lean and obese groups of self-described “couch potatoes” (Levine et al., 2005), and 89% of the total body movement across the two groups was devoted to ambulation. Further, an energy expenditure discrepancy between these groups is equivalent to a difference of over 30 lbs. in the course of a year (Levine et al., 2005). Church et al. (2011) used NHANES data spanning five decades to predict weight change stemming from diminished occupational physical activity. For all but the 2003-2006 period in men’s data, and for all but the 1976-1980 period in women’s data, the prediction model could theoretically account for the observed weight changes, as NHANES figures were within the confidence intervals of the model’s estimate (Church et al., 2011). These cumulative findings implicate the importance of walking to maintain energy balance, and apparently health, as Lee et al. (2013) observed that for non-exercising people, the number of steps walked is more strongly associated with health than time spent walking.

Assessing Nonexercise Activity Thermogenesis

Distracted, and unable to hear the speaker at a meeting, Sir Francis Galton once undertook to quantify the relationship between a bored audience and their corresponding fidget behaviors (Galton, 1885). Sir Galton's approach included estimating the frequency, amplitude, and duration of fidget in his peers, across conditions of interest and indifference (Galton, 1885). These features of physical movement were well chosen, as they reflect the four dimensions by which physical activity is currently described: frequency, intensity [amplitude], duration, and activity type (Haskell et al., 2007). Three of these dimensions, frequency, intensity, and duration, are fundamental because they allow for equating physical activity with energetic expenditure (Warren et al., 2010). It is possible to enumerate these three dimensions of certain physical activities (NEAT) through direct observation, but a different approach is needed to quantify long-term free-living physical activity. Attempts to record free-living physical activity have typically pooled into two broad categories: self-report and objective methods.

Self-report of human physical activity occurs when the individuals of interest provide information about their own activity. The degree of sophistication for self-reporting one's physical activity is quite variable, ranging from the prompted completion of an ecological momentary assessment at random or predetermined intervals, to at-once recalling the entirety of the previous week's physical activity behaviors. Intuitively, these forms of self-reporting one's physical activity vary in their precision and ease of administration. In terms of validity, self-report surveys lack a gold standard of comparison, and therefore rely upon face-validity, criterion validity, or discriminant validity (Sternfeld & Goldman-Rosas, 2012).

Objective methods for determining one’s free-living physical activity have improved dramatically over the past ten years. Body-worn physical activity monitors, or accelerometers, are typically the preferred method for objectively assessing one’s free-living physical activity. Early accelerometer models were only capable of indirectly measuring an individual’s physical activity. These models set a minimum threshold for the amplitude of acceleration deemed meaningful and simply counted the number of times this threshold was exceeded. Therefore, the output of these devices was the number of threshold crossings, which came to be known as “counts.” Counts could be aggregated and expressed as a rate per given unit of time, providing an index of an individual’s activity intensity. Rate thresholds were subsequently developed to categorize the intensity level of activity, e.g., low, moderate, or vigorous physical activity.

This approach to measuring physical activity is imperfect, however, in that it provided an incomplete picture of participant activity at a given point in time; such count-based accelerometers could only detect dynamic movement, meaning they could not account for posture, variations in which significantly contribute to TDEE. Classifying physical activity by the accumulation of counts can lead to imperfect conclusions about the physical activity patterns of a given participant, and this error is compounded over time. For example, when a researcher records an individual’s physical activity using count-based accelerometers, they are only able to relate the data to an estimate of energy expenditure. Yet, quite often, the conclusions of such research are discussed in terms of posture (e.g., sedentary), something their chosen instrument is incapable of measuring. The advantage of directly measuring posture in addition to the magnitude of movement over time should therefore become clear. Recent advances in the design of accelerometers now allow researchers to measure activity in each manner simultaneously.

The Current Study

The purpose of the current study is to examine the individual differences in posture allocation, ambulation, and fidgeting behavior (NEAT) of American first year medical students of disparate weight classification, whose schedules of activities are known and virtually identical throughout the recording period. Specifically, the following research questions are to be examined:

1. When compared with those in the normal weight classification, will those in overweight and obese classifications exhibit a quantitatively lesser amount of fidgeting, when activity is constrained by their environment?
2. When compared with those in the normal weight classification, will those in overweight and obese classifications remain sedentary for longer, take fewer steps, ambulate for a shorter amount of time, and walk at a slower pace, when activity is unconstrained they their environment?

CHAPTER III

METHODOLOGY

Participants

Data collection occurred during the participants' first semester on campus, from August to October 2009. Participants were recruited from among the 99 first-year medical students of the Entering Class of 2009. Of these 99 students, 46 (46% participation rate) completed the study in its entirety. Data from five students were excluded from analysis due to a lack of adherence to study protocol. This resulted in a sample size of 41 (46% female) in the final analyses.

Sampling Procedure

First-year students were recruited for participation in the study during their morning lectures at the beginning of the fall semester, and were included in the study if they gave informed consent, met the study inclusion criteria, and agreed to attend all of their scheduled classes, laboratories, and lectures during the activity-recording period. Students were excluded from participation if they were subject to one or more of the following conditions: if they were a dual-degree or bridge student; if they had a physical injury or disability that limited their mobility or physical activity during the recording period; if they had a medical condition with known influence on physical activity (e.g., attention-deficit hyperactivity disorder (ADHD), anxiety, depression, thyroid disorder); if they took a medication known to affect motor activity or mood; or if they were pregnant. Students were notified during informed consent that their decision to participate in the study would have no bearing on their progress in medical school.

As the purpose of the study was to compare the individual differences in physical activity of a wide range of physical activity levels, the study accepted all students who met the inclusion criteria. The limiting factors on participation were the number of available monitors (6) and recording days from the beginning of the semester through the end of the participant recording period (approximately 15). This allowed for a theoretical sample of 90 participants, though we considered approximately half this amount to be realistic.

Participant Compensation

Participants who completed the study in full were compensated $10.00, issued by check from the University Office of the Bursar. Participants were advised that they could withdraw from the study at any time for any reason, and that they would still receive compensation accrued up to the point of their withdrawal. Every participant completed the study in its entirety.

Measures

Participants self-reported age, and were measured for height and weight by a medical-grade column scale. Participant height was recorded in inches to the nearest quarter inch, participant weight was recorded in pounds, and these measurements were used to compute each participant's BMI. Participants were administered a health-screening questionnaire developed by the P.I., referred to in the study as the *Physical*

Activity Study Health Checklist, to gauge their well-being immediately prior to the recording period. The PALtechnologies activPAL^{TM} physical activity logger (PAL Technologies Ltd, Glasgow, Scotland, www.paltechnologies.com) objectively assessed participant physical activity during the recording period.

Physical Activity Study Health Checklist

Participants were administered a health assessment form referred to as the *Physical Activity Study Health Checklist*. This checklist asked participants about how they felt before their recording session, and whether they were experiencing illness. The checklist asked how many hours the participant slept the previous night, and assessed for the presence of nonobvious factors that may have influenced their activity during the recording period. The checklist also re-affirmed the participant's intention to attend all scheduled school obligations throughout the recording period, a prompt to record the serial number of the monitor used during the session, the leg upon which the participant wore the monitor, and participant height and weight. Finally, the checklist prompted the research assistant to record the participant's university I.D. number. The University's Office of the Bursar required this number to authorize and process the payment each participant received.

PALtechnologies activPAL^{TM} Physical Activity Logger

The PAL*technologies* activPAL^{TM} physical activity logger (PAL Technologies Ltd, Glasgow, Scotland, www.paltechnologies.com), which interfaced with Version 5.8.3.4 Research Edition of the activPAL^{TM} proprietary software program, was used to record participant physical activity. The PALDock USB Charging Station (PAL Technologies Ltd.) allowed the PC operated software to program and download data from the activPAL monitors. The activPAL is small (53 X 35 X 7 mm), unobtrusive, and worn on the midline of the anterior aspect of the thigh, halfway between the hip and knee. The device adheres to the bare skin with hypoallergenic and commercially available adhesive patches, and is capable of storing more than 7 days of consecutive activity. It is the researcher's experience that participants who have worn this device in past studies report they forget they are wearing it, so it can be assumed they are exhibiting natural patterns of activity.

The activPAL detects postures and movement with a uniaxial accelerometer that is sensitive to both static and dynamic accelerations (Hart, McClain, & Tudor-Locke, 2011). Detection of static acceleration, coupled with the device's location on the front of the thigh, allow for determining posture and posture transitions of the wearer (Hart, McClain, et al., 2011). The device detects acceleration related to body movement with a sensitivity of 0.01 *g* to 2.00 *g* (Hart, McClain, et al., 2011). The activPAL samples acceleration at a rate of 10 times per second, and proprietary algorithms use this signal to compute variables representing posture (stand vs. sit/lie), step count, step cadence, directional posture transition, and an estimate of energy expenditure, over time periods of varying length (Grant et al., 2006; Ryan, Grant, Tigbe, & Granat, 2006). The output from this device is therefore a classification of events (Granat, 2012).

Support for the validity of the activPAL to measure stepping and posture-change behaviors has been demonstrated (Dahlgren, Carlsson, Moorhead, Häger-Ross, & McDonough, 2010; Grant et al., 2008; Oliver, Badland, Shepherd, & Schofield, 2011). Support also exists for the activPAL to accurately identify bouts of walking, sitting, and standing (Grant et al., 2006), step count (Aminian & Hinckson, 2012), step cadence

(Harrington, Welk, & Donnelly, 2011), and measure the relative magnitude of movement of the lower extremities in real time. The activPAL is validated for use with the obese clinical population (Kozey-Keadle, Libertine, Lyden, Staudenmayer, & Freedson, 2011). Further, it has been suggested that this monitor could be used as the gold standard for classifying sedentary events (Hart, Ainsworth, & Tudor-Locke, 2011; Kozey-Keadle et al., 2011). Recently, the activPAL was validated against direct observation for free-living breaks in sedentary time where break rate was calculated by dividing the absolute number of breaks by total hours spent sedentary (Breaks per sedentary hour) (Lyden, Keadle, Staudenmayer, & Freedson, 2012). Detection of static and dynamic activity by the activPAL showed approximately a 98% agreement with a proven dual sensor accelerometer-based postural detection monitor in a free-living situation (Godfrey, Culhane, & Lyons, 2007).

Study Protocol

The P.I. and the research assistant recruited participants from the students' initial morning lecture course on the first day of the semester. The P.I. conceptualized and designed the study, and the research assistant scheduled all participants, obtained informed consent before each recording session, administered all requisite forms, assessments, and questionnaires, and ran all study protocols. The research assistant imported activity data into a networked database, developed syntax programming to facilitate the synchronization of multiple formats of activity data, and ran parametric repeated measures analyses on the data.

Before each participant recording session, the research assistant charged and programmed each activPAL prior to the participant's arrival. At the start of each participant recording session, the requirements of the participant's role in the study were detailed, and participant informed consent was obtained. A medical-grade column scale measured the participant's height and weight, and then participants self-reported their age and responded to items on the *Physical Activity Study Health Checklist*, administered by the research assistant. Participants were then given an overview of the activPAL, its function, and how to affix it to the thigh of their choosing. After adhering the monitor to their leg, participants were asked to make evident the location of the monitor beneath their clothing by pointing to it, ensuring that it was placed correctly. The research assistant recorded participant height and weight, administered a brief health checklist, and recorded the participant's university I.D. number to facilitate compensation for their involvement in the study. A time was scheduled for the participant to return the activity monitor on the following day, questions about study participation were answered, and then the participant was free to go about their day.

At the conclusion of each recording session, the participant returned their assigned activity monitor to the office of the research assistant. During this post-session meeting, each participant verified they had worn the monitor throughout the recording period, and attended all scheduled classes, labs, and lectures, in their entirety. The participant was asked to express any concerns regarding their participation in the study, and following this, the participant was formally debriefed. At the conclusion of each debriefing session, and prior to docking the monitor with the charging cradle, changes to two default settings within the activPAL^{TM} proprietary software program were confirmed. Minimum sitting and minimum upright periods were verified to have been changed from the default value of 10 seconds to 1 second, the shortest-duration setting possible. The effect of these changes was a finer grained depiction of participant posture during the recording period.

After verifying these settings, each monitor was placed into the docking cradle connected by USB cable to a networked PC, which downloaded all raw physical activity data into a networked database repository. Each raw data file was retrieved from the repository via the activPAL^{TM} data management software, and a summary of the recorded activity period is presented graphically, by default. Proprietary data management software provided by PAL*technologies* Ltd. retrieved the raw data files from the repository, and algorithms contained within the software program performed on these raw data, creating several time stamped activity variables. The activPAL software is capable of creating four distinct output formats, and these formats present the activity data using different variables displayed across different timeframes. After processing the raw data, each monitor's memory bank was erased, and the monitor was recharged. Each of the four file formats generated from an individual participant's activity data were subsequently imported into PASW 18 (SPSS).

Primary Data Analysis

This study was intended to assess the working day physical activity of first-year medical students, defined as 9:00 am through 9:00 pm. The activPAL program used in this study did not provide utility to schedule an end time for activity recording, consequently, activity monitors in every recording session continued to record until the participant's return on the following morning. SPSS syntax programming that truncated participant data files to reflect only the 12-hour recording period of interest was developed. Additional SPSS syntax programming was developed to compile individual activity files into a master file. Finally, aggregation syntax programming was developed to assemble the data according to seven unique activity periods common to all participants throughout their recording period. For an overview of these activity periods, see Table 3.1.

Table 3.1
Workday Activity Periods

Timeperiod	Description	Timeframe
1	Histology (Lecture)	9:00 am to 9:50 am
2	Medical Biochemistry (Lecture)	10:00 am to 10:50 am
3	Gross Anatomy (Lecture)	11:00 am to 11:50 am
4	Lunch	12:00 pm to 12:50 pm
5	Anatomy (Lab)	1:00 pm to 2:50 pm
6	Histology (Lab)	3:00 pm to 4:50 pm
7	Evening	5:00 pm to 9:00 pm

Note. Data from periods 1-3 were used to address Research question #1. Data from period 7 were used to address Research question #2.

After these aggregations were saved, the master file was restructured to wide data-file format to facilitate the performance of split-plot ANOVA tests. In this final configuration, each case in the master file represented the activity data from an individual participant, and outcome variables represent the values of a given activity type during each activity period. As noted in Chapter 1, this study is a reanalysis of the original data collected in 2009. Those data were analyzed using parametric split-plot ANOVA and trend analysis, and the original findings were not statistically significant. It was determined that the activity data were in violation of the normality assumption required by parametric statistical tests. Therefore, a secondary data analysis that utilized analytic techniques more appropriate for these extant data was required. All programming development and primary data analyses were conducted through PASW 18 Statistics for

Windows (Chicago: SPSS Inc.). A description of the analytic processes in this secondary analysis are described in the Secondary Data Analysis section.

Secondary Data Analysis

This study began by examining the data structure as it existed during the Primary Data Analysis. Sedentary fidgeting volume, sedentary time^{sec}, stepping time^{sec}, number of steps taken, stepping time^{sec}, and number of steps taken^{min} (steps^{min}) [number of steps taken/(stepping time^{sec}/60)] were subjected to assessment for violation of the assumptions of parametric ANOVA models, including the presence of outliers, normality of distribution, and homogeneity of variance. Outliers were initially assessed by boxplot with extreme values labelled by participant ID, and by standardized residuals. Normality of distribution was assessed by histogram and Shapiro-Wilk tests of normality. Results of the test statistics of the Shapiro-Wilk tests were confirmed with Normal Q-Q plots. Homogeneity of variance was assessed by scatterplot of each outcome variable grouped by level of between-subjects factor, and by Levene's Test of Equality of Variance.

After these preliminary analyses were conducted, activity variables found to have significantly violated one of more of the assumptions of parametric ANOVA were analyzed by nonparametric statistical models, and by modified parametric ANOVA models, when appropriate. Performance of the models from each approach was compared, and the better performing approach for each activity variable was reported. Details of these processes are presented in the Results chapter.

A directional relationship between each activity variable and the BMI-derived weight group was predicted. For those activity data determined to be unfit for analysis by traditional parametric ANOVA, the nonparametric Jonckheere-Terpstra test for ordered alternatives was used (Jonckheere, 1954; Terpstra, 1952). The Jonckheere-Terpstra is a one-tailed test that assesses for the presence of *a priori* trends among the levels of the between-groups factor and their respective median value for each activity variable, and this test was appropriate because it made no assumptions about the underlying distribution of the data. This test also allowed for a reference level of the between-subjects factor to be set for the directional comparison. In the event of a significant trend, pairwise comparisons among the levels of the between-subjects factor followed. The second approach for analysis utilized parametric ANOVA tests on statistically corrected data (data transformations, etc.) with planned contrasts, when such an approach was appropriate.

CHAPTER IV

FINDINGS

Introduction

The purpose of the current study was to explore the individual differences in posture allocation, ambulation, and fidgeting behavior (NEAT) of American first year medical students whose daily schedules are known and virtually identical. Participants who met the inclusion criteria were recruited from among the entering class of 2009 at a medical school in the Midwestern United States. Forty-six students completed the study in its entirety (46% participation rate), and 41 participants' data were included in the final analysis. The activity data of all participants were recorded between August and October of their first year of medical school. A Chi-square goodness-of fit model was used to test for significant differences in the distribution of gender, and results indicated no difference between the expected number of males and females, $\chi^2(1, N = 41) = .22, p = .639$. Table 4.1 further displays a summary of demographic data for participants by gender, in aggregate, and by BMI-derived weight group. These data indicate general similarity in age and gender distribution, with the exception of the obese-classified weight group. Individuals from the obese-classified group were notably older than peers from lower-weight groups, a finding that reflects the nearly universal positive relationship between BMI and age, across populations, e.g., (Gostynski et al., 2004).

BMI was calculated for all participants via the formula given in Table 4.1, who were then categorized on this basis according to standard WHO weight classifications, with these weight groups serving as the between-subjects factor in both research questions. The dependent variable in the environmentally constrained activity period was volume of sedentary fidgeting. The dependent variables in the evening free period were sedentary time^{sec}, stepping time^{sec}, number of steps taken, and steps^{min}. Participant activity data are summarized by BMI-category in Table 4.2.

Table 4.1

Participant Demographics

Gender	Age (years)	Height (in.)	Weight (lbs.)	BMI	BMI Category		
					Normal	Overweight	Obese
Men (*n* = 22)	24.27 ± 3.69	70.47 ± 2.65	179.27 ± 24.39	25.38 ± 3.19	23.17 ± 2.01 (11)	26.88 ± 1.20 (11)	N/A (1)
Women (*n* = 19)	25.63 ± 6.41	65.37 ± 2.29	154.79 ± 39.08	25.34 ± 5.63	21.93 ± 1.35 (12)	28.19 ± 1.78 (5)	N/A (2)
Total (*N* = 41)	24.90 ± 5.11	68.10 ± 3.56	167.93 ± 33.95	25.36 ± 4.43	22.52 ± 1.77 (23)	27.32 ± 1.50 (15)	37.32 ± 2.41 (3)

Note. Figures are presented as Mean ± SD (*n* of given BMI category). Summary data for obese category by gender are omitted to prevent participant identification. BMI was calculated by the given formula: [lbs. / inches^2] * 703.

Table 4.2

Activity Variable by BMI Category

BMI Category	*n*	Sedentary fidgeting volume	Sedentary time^{min}	Number of steps	Stepping time^{min}	Steps/min
Normal	23	405.61 (286.67) ± 443.19	160.20 (179.80) ± 44.99	2059.30 (1600.0) ± 1307.05	25.16 (20.70) ± 16.47	82.56 (83.17) ± 10.37
Overweight	15	734.33 (598.0) ± 608.74	170.05 (169.93) ± 35.59	1774.13 (1254.0) ± 1013.89	23.76 (17.57) ± 14.15	76.48 (78.31) ± 8.72
Obese	3	763.67 (566.67) ± 456.88	180.70 (189.27) ± 18.95	1159.33 (1080.0) ± 188.0	14.70 (13.20) ± 3.44	79.68 (81.82) ± 5.21
All Groups	41	552.07 (351.0) ± 525.66	165.31 (179.80) ± 40.23	1889.12 (1404.0) ± 1167.36	23.88 (18.20) ± 15.07	80.12 (79.33) ± 9.77

Note. Figures are presented as Mean (Median) ± SD; *n* = BMI-category sample size. Sedentary time^{sec} and stepping time^{sec} were converted to minutes to aid interpretation.

Tests of Assumptions

Outliers

Compared with the general population, medical students may be acutely aware of the benefits of good health habits, an example of which could include the positive relationship between exercise and cognitive performance, e.g., (Ratey & Hagerman, 2008). Coupled with such awareness is the responsibility for an extensive amount of basic and clinical science knowledge, which necessitates studying for long hours. Conventional thought holds that medical students curtail health behaviors (including physical activity) during their training to keep abreast of didactic instruction, a position which has some support (Wolf & Kissling, 1984). Conversely, there is evidence suggesting first year medical students are more fit than age & gender-specific reference populations (Licciardone & Hagan, 1992). Given this contradiction, large variation in the activity level of first year medical students may exist, and awareness of this potential variation conditioned the treatment of outliers in the physical activity data.

For sedentary fidgeting volume, three outliers were detected, z = 3.20, 3.12, and 1.99. For sedentary time^{sec}, four outliers were detected, z = -2.48, -2.27, -2.02, and -2.00. For stepping time^{sec}, two outliers were detected, z = 2.90, and 2.85. For number of steps taken, one outlier was detected, z = 3.33. For steps^{min}, two outliers were detected, z = 2.24, and -2.48. Because the potential for outliers in these activity data was anticipated on the basis of the preceding discussion, it was decided that these extreme values were representative of the variation likely to occur within the sample, and were therefore included in final analyses.

Normality

The distributions of sedentary fidgeting volume, sedentary time$^{\text{sec}}$, number of steps, stepping time$^{\text{sec}}$, and steps$^{\text{min}}$ were examined to determine the extent to which the assumption of normality was met. Shapiro-Wilk tests suggested potential violation for this assumption for sedentary fidgeting volume ($S\text{-}W = .685$, $df = 41$, $p = <.001$), sedentary time$^{\text{sec}}$ ($S\text{-}W = .860$, $df = 41$, $p = <.001$), stepping time$^{\text{sec}}$ ($S\text{-}W = .857$, $df = 41$, $p = <.001$), and number of steps taken ($S\text{-}W = .862$, $df = 41$, $p = <.001$), and these results were confirmed through visual inspection by Normal Q-Q plots. A Shapiro-Wilk test of normality for steps taken$^{\text{min}}$ ($S\text{-}W = .991$, $df = 41$, $p = .984$) suggested the assumption of normality was upheld, a position supported by visual inspection via Normal Q-Q plots.

Homogeneity of Variance

The assumption of homogeneity of variance was first assessed by scatterplot of each activity variable grouped by level of the between-subjects factor, which indicated moderate homogeneity of variance. Levene's Tests for equality of variance were subsequently performed, indicating that for sedentary fidgeting volume ($F = .743$, $df = 2, 38$, $p = .483$), sedentary time$^{\text{sec}}$ ($F = 1.08$, $df = 2, 38$, $p = .351$), stepping time$^{\text{sec}}$ ($F = 1.50$, $df = 2, 38$, $p = .236$), number of steps taken ($F = 2.15$, $df = 2, 38$, $p = .130$), and steps taken$^{\text{min}}$ ($F = .722$, $df = 2, 38$, $p = .492$) homogeneity of variance was a reasonable assumption.

Research Question 1

The initial research question sought to discover if, when compared with those in the normal weight classification, if those in the overweight and obese classifications exhibit a quantitatively lesser amount of fidgeting, when activity is constrained by their environment. Participants attended a series of three consecutive lectures, 50 minutes in length: Histology, Medical Biochemistry, and Gross Anatomy. Participants were seated, and remained in the same auditorium, for each of the three morning lectures. Programming was developed to systematically truncate the activity sample from each lecture to 35 minutes in length, in order to exclude all extraneous behaviors not related to lecture attendance. This resulted in a total activity sample of 105 minutes for the environmentally constrained condition (Seated Time Percentage: Mean = 98.4%; Median = 99.9%). The amount of sedentary fidgeting volume from each of the three lecture periods was averaged, and it was this value that was included in the final analysis.

Relationship of BMI and Sedentary Fidgeting Volume

The relationship between sedentary fidgeting volume and BMI-derived weight categories was analyzed by the Jonckheere-Terpstra test for ordered alternatives. Results indicated that sedentary fidgeting volume was significantly associated with BMI-derived weight classification (Median = 351.0, SD ± 525.66), $J = 337$, $z = 2.76$, $p = .006$. This significant result was followed by pairwise comparisons using adjusted p-values, to account for the accumulating error from multiple comparisons. Results of these comparisons showed that sedentary fidgeting volume by individuals in the normal weight group differed significantly from individuals in the overweight group ($z = 2.43$, $p = .022$, $r = .38$), though not from those in the obese weight group ($z = 1.89$, $p = .089$, $r = .30$). Further, there was no difference in the amount of sedentary fidgeting between the overweight and obese weight groups ($z = .30$, $p = 1.00$, $r = .05$). While the magnitude of difference between the normal and obese weight groups was greater than between the normal and overweight groups, the small sample size ($n = 3$) of the obese weight group resulted in an underpowered comparison between the normal and obese weight groups, preventing it from reaching statistical significance. These results indicate that, while there was a significant overall trend between levels of BMI-category with sedentary fidgeting volume, the direction of this trend was in the opposite direction from that which was predicted, indicating that fidgeting volume was greater among the students with higher BMI.

Research Question 2

The second research question examined differences between individuals in normal, overweight, and obese weight categories when the environment placed no constraint on their physical activity. Specifically, are those in overweight and obese categories more likely to remain sedentary, take fewer steps, ambulate for a shorter amount of time, and walk at a slower pace than peers in the normal weight category, when their activity was not constrained by their environment?

Relationship of BMI and Sedentary Time

The relationship between BMI and the amount of time individuals spent either seated or lying down [sedentary] was predicted to be positive. Results of the Jonckheere-Terpstra test for ordered alternatives demonstrated a relationship in this direction, though it did not reach statistical significance (Median = 10788.0, SD ± 2413.69), $J = 253$, $z = .60$, $p = .547$. On this basis, it was concluded that sedentary time did not differ between individuals of different BMI categories

Relationship of BMI and Number of Steps Taken

The relationship between BMI and the number of steps taken was predicted to be negative. Results of the Jonckheere-Terpstra test for ordered alternatives demonstrated a relationship in this direction, though it did not reach statistical significance (Median = 1404.0, SD ± 1167.36), *J* = 195, *z* = -.89, *p* = .376. On this basis, it was concluded that the number of steps taken by individuals did not vary according to their BMI weight classification.

Relationship of BMI to Ambulation Time

The relationship between BMI and the amount of ambulatory time was predicted to be negative. Results of the Jonckheere-Terpstra test of this relationship did, again, demonstrate a negative association, but this relationship did not reach statistical significance (Median = 1092.0, SD ± 90), *J* = 204, *z* = -.65, *p* = .513. On this basis, it was concluded that the time spent walking did not differ between individuals of different BMI weight categories.

Relationship of BMI and Walking Cadence

The relationship between BMI and individuals' pace of ambulation in terms of $\text{steps}^{\text{min}}$ was predicted to be negative. As indicated in the Tests of Assumptions section, $\text{steps}^{\text{min}}$ data did not significantly violate the assumptions of the parametric ANOVA, and were therefore analyzed by such a model. Planned contrasts tested for interrelationships among the levels of BMI-category with $\text{steps}^{\text{min}}$. Results of the planned contrasts revealed that individuals in the normal-weight group (Mean = 82.56, SD ± 10.37) nearly, but not statistically significantly, differed in terms of $\text{steps}^{\text{min}}$ from those in the overweight group (Mean = 76.48, SD ± 8.72), *t*(38) = 1.92, *p* = .063. Individuals in the normal-weight group (Mean = 82.56, SD ± 10.37) and obese weight group (Mean = 79.68, SD ± 5.21) were not found to be statistically significantly different, *t*(38) = .49, *p* = .627. Finally, no main effect was found for the overall relationship between BMI and steps^{min}, $F(2) = 1.83$, $p = .173$, $\omega^2 = .04$. On this basis, it was concluded that BMI was unrelated to steps^{min}.

Summary

The purpose of this study was to record the physical activity patterns of American first-year medical students whose daily schedules were known and virtually identical, and to examine the relationship of these activity patterns and BMI-derived weight classifications, among conditions of environmental influence on individual physical activity. Forty-six of 99 potential (46% participation rate) first year medical students completed the activity study in full, and 41 participants' data were included in the final analysis. Participant activity was recorded for a continuous 12-hour period, from 9:00 am through 9:00 pm, across a span of 11 weeks from August to October. The relationships of five activity variables and BMI-derived weight categories were examined across conditions of environmental influence. Based on the assumption that an underlying biological drive for activity found greater expression in lean individuals, directional trend tests were conducted between BMI-category and sedentary fidgeting volume, sedentary time^{sec}, number of steps taken, stepping time^{sec}. An additional outcome variable of interest, steps taken^{min}, did not violate assumptions of parametric ANOVA, and was therefore analyzed by this model, and by additional planned contrasts. Each relationship under investigation was in the predicted direction, except for sedentary fidgeting volume, which was observed to display a positive relationship with BMI. Implications of these results are presented in the Discussion chapter.

CHAPTER V

DISCUSSION

Introduction

The purpose of this study was examine the physical activity patterns of American first-year medical students whose daily schedules were known and virtually identical, and to examine the relationship of these activity patterns and BMI-derived weight classifications, across conditions of environmental influence on individual physical activity. The goal of this study was to simultaneously quantify and compare individual differences among the three energetic components of daily physical activity, and draw conclusions about their relationship with individuals from disparate BMI-derived weight categories.

As far as is known, no study currently exists which directly measures these three energetic components of participant free-living physical activity. Knowledge of the interrelationships of these components among BMI-derived weight categories may provide insight into why some individuals are more or less susceptible to weight gain in an environment that seems to promote it.

Humans possess an inborn mechanism to match energy expenditure to energy intake, e.g., (Payne & Dugdale, 1977). This system is quite precise, but may become overwhelmed through prolonged exposure to environmental influences. However, individuals vary considerably in their resistance to weight gain when facing a positive energy balance (Dulloo & Jacquet, 2003). It has been suggested that differences in the biological drive for movement could explain observed variation in the level of activity between individuals, and this idea is well supported, e.g., (Ravussin et al., 1986). Indeed, among a sedentary sample of lean and obese individuals, it was found that lean individuals stood and walked a combined 152 minutes longer each day than their obese counterparts (Levine et al., 2005). Further evidence for this biological link exists in the observation that individuals who were previously weight stable exhibit increased NEAT in response to positive energy balance, and for negative energy balance, NEAT briefly increases, assumedly in the search for food, and then decreases as energy reserves diminish (Jones, Bellingham, & Ward, 1990; Levine & Kotz, 2005). Therefore, it appears that NEAT is biologically regulated and genetically determined (Thorburn & Proietto, 2000).

Research Question 1

In this study, fidgeting was defined as engaging in manipulations of one's own body parts (e.g., shaking one's legs), such actions being peripheral or nonessential to central ongoing events or tasks (Mehrabian & Friedman, 1986). Based on prior knowledge of the daily schedules of the participant sample, it was assumed that fidgeting would most likely occur when participants were required to remain stationary for long periods. It was assumed that individuals with a lower BMI would be more active due to an internal drive for movement. Additionally, it was assumed that while environmental constraint on activity was present, a biological drive for movement would be more fully expressed by individuals of lower BMI, resulting in a greater volume of sedentary fidgeting behavior. Interestingly, the analysis revealed a relationship in the opposite direction, with those from higher BMI-derived weight groups exhibiting greater sedentary fidgeting volume.

The significant contribution of fidgeting to energy expenditure is well-documented (S. E. Anderson, Bandini, Dietz, & Must, 2004; Brooks, Butte, Rand, Flatt, & Caballero, 2004; Castaneda et al., 2005; DeLany & Lovejoy, 1996; Johannsen & Ravussin, 2008; Levine et al., 2000; Ravussin, 2005; Ravussin & Bogardus, 1985; Ravussin et al., 1986; Widdowson et al., 1954). It was predicted that individuals in the normal BMI-group would fidget more than their overweight and obese weight-grouped peers, while seated. Examining similar relationships, Levine et al. (2008) found that lean individuals, when compared to obese individuals, were less active while seated, though this difference was not statistically significant. Correcting for the number of minutes each respective group was seated changed the direction of the relationship between body composition and seated fidgeting activity, though the difference remained nonsignificant (Levine et al., 2008). Participants in the present study were seated a virtually identical amount of time, making this correction unnecessary. To our knowledge, a validated method for quantifying fidgeting behavior via accelerometry does not exist. It may be that the true nature of fidgeting is simply complex, with no apparent relationship between quantity of the behavior and body mass.

Alternatively, it may be that environmental contingencies that affect fidgeting are unknown, and uncontrolled for, obscuring this relationship. The potential exists that participants of this study were grouped in a way that was unrelated to fidgeting. Due to the lack of a universally accepted operational definition of fidgeting in physical activity research, and the lack of a validated method for assessing this behavior through accelerometry, we cannot be sure of how completely or appropriately fidgeting was measured in this study. Sample size may have also been an issue, as the small size of the obese group weight group (*n* = 3) may have influenced the results of the analyses, rendering statistics indicative of central tendency of sedentary fidgeting volume susceptible to the outlier value of the group (Outlier Value = 1285.0, Median = 566.67, Mean = 763.67, SD ± 456.88). Therefore, the true relationship of body composition to sedentary fidgeting volume may be less straightforward.

Research Question 2

The relationship of BMI with posture allocation and with stepping behaviors was examined while participant activity was not subject to environmental constraint. In this condition, it was assumed that a hypothesized internal drive for movement would be more fully expressed by individuals of lower BMI, resulting in greater activity and lesser sedentary behavior. Specifically, a positive relationship was predicted between BMI and sedentary time^{sec}, and a negative relationship between BMI and stepping time^{sec}, number of steps taken, and steps^{min}.

When environment placed no constraint on participant activity, evidence of a positive relationship between BMI-derived weight group and sedentary time^{sec} was found. was found, though this relationship did not reach statistical significance. Similarly, during a period free of environmental constraint on activity, evidence of a negative relationship between BMI-derived weight groups and number of steps taken, stepping time^{sec}, and steps^{min} was found. Each of the relationships examined for this condition of environmental influence was in the predicted direction, though none reached statistical significance. This could be due to the presence of a seasonal effect that adulterated the true nature of the examined relationships. If so, seasonal influence could be expected to increase the amount of time that participants were sedentary, and potentially decrease stepping time^{sec}, and number of steps taken. Too little is known about the mechanisms regulating stepping cadence to speculate on how this behavior might be influenced by seasonal variation. The effect of seasonal influence upon participant activity may have stemmed from either climate (Katzmarzyk, Craig, & Bouchard, 2001; Pivarnik, Reeves, & Rafferty, 2003; Uitenbroek, 1993), or simply from a greater workload facing them in the middle of the semester than at the beginning. If students were busier, it is likely that they would be exhibited less active behaviors while completing this additional work.

The additional power of the parametric ANOVA for the main effect of BMI-derived category on number of steps taken^{min} was evident, given $\omega^2 = .04$, which approaches a medium sized effect. While there exists the possibility for this relationship to be confounded by the effects of recording week, the biological processes thought to control walking cadence may be the most complex and interactive of those included in this study. There is evidence suggesting that, while the daily number and duration of walking bouts are fixed, energy balance is modulated through ambulatory activity in terms of walking pace, as a variable means for weight regulation (Levine et al., 2008).

Finally, the assignment of participants to categories intended to represent their degree of overweight based on BMI is thought to have interfered with predicted relationships in this participant sample, as BMI is unable to distinguish between individuals of a given body mass composition. This means that BMI is unable to detect whether a given individual classified as overweight is at that weight due to body fat, or muscle mass (WHO, 1995). BMI may be an appropriate metric for determining the degree of overweight and relative health risk at the population level (WHO, 2000), as the majority (~80%) of U.S. adults do not regularly participate in exercise, which reduces the risk for misclassification by BMI (McCrady-Spitzer & Levine, 2012). However, as 73% of the participant sample performed at least moderate-intensity exercise in the week prior to their recording period, it is possible that body composition of participants in this study was misclassified on the basis of BMI.

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APPENDICES

APPENDIX A

Physical Activity Study Health Checklist

Participant I.D. # __________ Return Time __________ Monitor # __________

To Participant:

1. How are you feeling today? ____
2. Are you ill at all today? ____
3. Show & demonstrate monitor, read monitor description script.
4. Take height and weight. Height: __________ Weight: __________
    a. ^^^^^ **No Shoes, light clothing**^^^^^
5. About how many hours did you sleep last night?
   ____
6. Is there any factor that may affect your physical activity today?
   ____
7. “For the purpose of our study, it’s important that you attend all scheduled lectures/labs/classes today. Do you agree to do so?” ________________________
8. Instruct participant on how to orient and affix monitor.
9. Record which leg the participant chooses.
   ____
10. Take CWID number for Bursar credit (record on paper roster). ☐
11. Ask participant if there are any questions, thank them, and prepare for next participant.

APPENDIX B

FALL SEMESTER 2009 - MS I CLASS
WEEKS 1-16
COURSE SCHEDULE

CLASS: First Year
SEMESTER: Fall 2009
WEEKS: 1-16
DATE: August 17 - December 4, 2009

TIME	MONDAY	TUESDAY		WEDNESDAY	THURSDAY		FRIDAY
8:00-8:50 A.M.							
9:00-9:50 A.M.		Histology Dunlap Auditorium			Histology Dunlap Auditorium		
10:00-10:50 A.M.		Medical Biochemistry Dunlap Auditorium			Medical Biochemistry Dunlap Auditorium		
11:00-11:50 A.M.		Gross Anatomy Dunlap Auditorium			Gross Anatomy Dunlap Auditorium		
12:00-12:50 P.M.		Lunch			Lunch		
1:00-1:50 P.M.		Anatomy Lab (Dissecting Group) G-04	Histology Lab D007		Anatomy Lab (Dissecting Group) G-04	Histology Lab D007	
2:00-2:50 P.M.							
3:00-3:50 P.M.		Anatomy Lab (Observing Group) G-04	Histology Lab D007		Anatomy Lab (Observing Group) G-04	Histology Lab D007	
4:00-4:50 P.M.							

APPENDIX C

Informed Consent Form

Project:	Individual differences in physical activity during daily life in medical students (PACT 1 Study)

Investigator: Michael H. Pollak, Ph.D. Telephone: (918) 561-8426
Professor of Behavioral Sciences
Department of Behavioral Sciences
Oklahoma State University College of Osteopathic Medicine

The purpose of this study is to study individual differences in physical activity during a typical workday in medical students. You are invited to participate because you are a student in the Entering Class of 2009 at OSU-COM. All students in your class in general good health who have no medical disorders and use no medications that affect physical activity are invited to participate.

In order to determine eligibility to participate, you will be asked to answer questions about aspects of your medical history, such as medical disorders or medication use, that might affect your physical activity during the recording period.

Participation in this study involves wearing a small and unobtrusive physical activity recorder from 9 am to 9 pm on one weekday during the 2009 fall semester. The recorder will be attached to your thigh by a double-sided adhesive pad. The recording day will be a Tuesday or Thursday during which you have no exam scheduled. You will be asked to agree to attend all scheduled classes, including lectures and laboratories, on the recording day.

Participants may experience a minor and temporary skin irritation caused by the adhesive used to attach the recorder to the thigh. Participation in this study will involve no other risk or discomfort to you.

You will receive $10 as compensation for your participation in this study.

Information obtained from or about you will be kept confidential. Personal information will not be released or revealed to anyone not directly involved with this research without your written consent, except that the information may be used for scientific purposes in ways, including oral and written reports and publications, which do not identify you personally.

The procedures of this study are not intended to be used to diagnose or treat any medical or psychological disorder and should not be used as substitutes for consultations with appropriate medical or psychological professionals.

You are free to refuse without penalty to participate in this study or any part of this study, and to answer any question. Also, you are free to withdraw your consent and withdraw from this study without penalty. In particular, **your participation or nonparticipation in this study will have no effect on your progress in medical school**. You will receive no academic reward or benefit for participation and no academic penalty for nonparticipation or early withdrawal from the study.

Participants in this study may be asked to participate in future studies. If so, they will receive descriptions of those studies and be provided an opportunity to agree or refuse to participate in those studies via appropriate informed consent procedures.

By agreeing to participate in this research study and by signing this form, you do not waive any of your legal rights nor is the investigator(s), the institution or its agents free from liability for negligence.

If you have any questions about the procedures of this study, please contact the Principal Investigator, Michael Pollak, Ph.D. at 918.561.8426. If you have any questions about your rights as a participant in a research study, please contact the chair of the OSU-CHS Institutional Review Board, Johnny Stephens, PharmD. at 918.382.3527 .

I have read the foregoing and my questions about this study have been answered to my satisfaction. I hereby agree to participate as a volunteer in this research study. My participation in this study will depend on my meeting eligibility criteria with regard to health and medication use and on availability of time slots for wearing the recorder.

______________________	______________________	__________
Participant signature	Participant name (printed)	Date

Contact information:	______________________	______________________
	Email address (print legibly)	Telephone Number

Please provide the following information to assist in determining order of participation.

Age: ______________

Sex: M F

Height: ______________

Weight: ______________

VITA

Joseph Ryan Hart

Candidate for the Degree of

Master of Science

Thesis: ANALYSIS OF OBJECTIVELY ASSESSED PHYSICAL ACTIVITY IN AMERICAN FIRST-YEAR MEDICAL STUDENTS, DURING A TYPICAL WORKDAY

Major Field: Educational Psychology

Biographical:

Personal: Born in Tulsa, Oklahoma, January 19, 1985, to Dr. Leonard D. Hart and Pamela J. Hart, brother to Valerie J. Hart.

Education: Graduated from Collinsville High School, Collinsville, Oklahoma, May, 2004. Received Bachelor of Arts degree in Psychology from Oklahoma State University, Stillwater, Oklahoma in December, 2009. Completed the requirements for the Master of Science degree in Educational Psychology at Oklahoma State University, Stillwater, Oklahoma in July, 2014.

Experience: Teaching Assistant, Introduction to Psychology, Oklahoma State University, Stillwater, Oklahoma (2007 – 2008); Research Assistant, Psychobiology Lab: Stress, Peer Relations, & Health, Oklahoma State University, Stillwater, Oklahoma (2008 – 2009); Research Assistant, Department of Behavioral Sciences, Oklahoma State University Center for Health Sciences, Tulsa, Oklahoma (2009 – 2014).