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Examination of accelerometer reactivity among children, adolescents, and adults: Implications for influencing physical activity estimates, proportion meeting physical activity guidelines, and associations with health outcomes

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EXAMINATION OF ACCELEROMETER REACTIVITY AMONG CHILDREN, ADOLESCENTS, AND ADULTS: IMPLICATIONS FOR INFLUENCING PHYSICAL ACTIVITY ESTIMATES, PROPORTION MEETING PHYSICAL ACTIVITY GUIDELINES, AND ASSOCIATIONS WITH HEALTH OUTCOMES

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ABSTRACT

The health benefits of regular Physical activity (PA) have been rigorously documented and continue to be investigated from the standpoint of prevention, as well as, treatment of a multitude of adverse health outcomes including cardiovascular disease, obesity, sleep disorders, depressive symptomatology and countless others. In order to minimize subjectivity and more accurately measure PA behavior, researchers often use accelerometers. Although this method is considered valid and reliable a methodological issue that has rarely been addressed is the potential "reactivity" effect of measuring PA with an objective measure, such as accelerometry. Reactivity is a behavior change by the participant due to the fact that he/she is aware that they are being monitored. The implications of accelerometer reactivity are such that, if present, then accelerometer-determined PA estimates as well as associations between PA and health outcomes may be biased. These estimates (i.e., PA estimates and their associations with health) inform the development and implementation of PA-related surveillance systems and intervention studies; thus, identification of whether accelerometry reactivity occurs not only has implications for the validity of an accelerometry study, but also has far reaching implications at the community and policy level. As a result, the purpose of the current study was to examine whether accelerometry reactivity is present in a nationally representative sample of U.S. children, adolescents, and adults. Three specific aims will be addressed in this study. The first aim of our study will examine whether accelerometer reactivity is indeed present, with evaluations considered across a nationally representative U.S. sample of children, adolescents, and adults, as well as, in various demographic and morbidity characteristics. Second, if reactivity is detected, the proportion

meeting physical activity guidelines will be calculated in the original data, then recalculated upon removal of 'reactive' data, in order to determine the extent to which reactivity biased proportional estimates meeting PA guidelines, as well as, weekly aggregative estimates of total physical activity and total activity counts. Similar to the second aim, the last aim will examine the extent to which potential reactivity may influence the association between PA and health.

LIST OF ABBREVIATIONS AND SYMBOLS

PA	Physical Activity
CVD	Cardiovascular Disease
CRP	C-Reactive Protein
MS	Multiple Sclerosis
CHF	Coronary Heart Failure
BMI	Body Mass Index
NHANES	National Health and Nutrition Examination Survey
CDC	Center for Disease Control
MEC	Mobile Examination Center
CPD	Activity Counts per Day
MVPA	Moderate/Vigorous PA

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DEDICATION

I am here by dedicating this thesis to my daughter Ellie who was born during the process of my thesis study on the 25th day of January 2015.

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CHAPTER 1

Physical activity (PA) is often defined as bodily movement eliciting energy expenditure above resting levels.[1] The health benefits of regular PA have been rigorously documented and continue to be investigated from the standpoint of prevention, as well as, treatment of a multitude of adverse health outcomes including cardiovascular disease, obesity, sleep disorders, depressive symptomatology and countless others.[2-6]

The most widely used means of collecting data on PA behavior comes in the form of self-report methodology, due to it being practical and economically advantageous.[7,8] Survey methodology regarding PA assessment requires the participant to fill out a questionnaire, usually from his or her own recollection. This medium of data collection is generally accepted as a viable means, however, concerns arise regarding the validity and reliability of this approach.[9] Numerous published studies demonstrate gross overestimations of PA when self-report data were compared to more objective measures (i.e. accelerometers, heart rate monitors or indirect calorimetry).[10,11] Further, validation studies examining the association between self-report PA and some gold-standard (e.g., accelerometry) typically show a poor correlation in the range of 0.3-0.5.[12] Thus, these 'validated' self-report questionnaires only account for 9-25% of the variance in the explanatory parameter and are therefore likely to result in considerable misclassification.

Possible reasons for this self-report misclassification bias may be a result of biases associated with recall, social desirability, and questions not always being age- and culturally appropriate. In order to minimize subjectivity to more accurately measure PA behavior,

researchers are more often utilizing objective measures, such as, accelerometers and pedometers. [13-16]

Although accelerometry and pedometry are generally accepted as reliable and valid methodologies for measuring PA behavior,[17] they are not without concerns of their own. For example, and with regard to accelerometry, numerous methodological issues need to be considered, such as maximizing compliance with wearing the monitor,[18,19] utilizing appropriate intensity-related activity count cut-points,[20] and selecting an appropriate time interval (epoch) in which to summarize the measured data.[21] Although these methodological areas have garnered attention in the recent years, another methodological issue that has rarely been addressed includes the potential "reactivity" effect of measuring PA with an objective measure, such as accelerometry. Reactivity is a behavior change by the participant due to the fact that he/she is aware that they are being monitored; this phenomenon is also known as the Hawthorn Effect.[22,23] In objectively-measured PA research, reactivity is present when there is a transitory increase in measured PA followed by an observed reduction in activity level over the course of the monitored period,[24,25] which implies that the individual has altered their normal behavioral pattern because of their PA being monitored. Reactivity in pedometer studies has been observed primarily in samples comprised of children and adolescents.[24-27] However, several studies on the same population (children and adolescents) have found conflicting results,[23,28,29] i.e. an absence of reactivity. Pedometer reactivity studies on adult populations are few and also report mixed findings with regard to a reactive presence.[30,31] These mixed findings regarding reactivity may be a result of methodological flaws/inconsistency in the assessment of reactivity or possibly the need for uniformity in the assessment and/or definition of reactivity.

However, few studies have specifically examined whether accelerometer monitoring induces a reactivity effect. Such an investigation is important as accelerometry is becoming the method of choice for measuring PA in all age populations. Unlike pedometry, accelerometry has the ability to measure not only step duration and frequency, but the frequency, intensity, and duration of physical activity.

The implications of accelerometer reactivity is that, if present, then accelerometer-determined PA estimates, as well as, associations between PA and health outcomes may be biased. These estimates (i.e., PA estimates and their associations with health) inform the development and implementation of PA-related surveillance systems and intervention studies; thus, identification of whether accelerometry reactivity occurs not only has implications for the validity of an accelerometry study, but also has far reaching implications at the community and policy level.

To our knowledge, very few studies[32-34] (N= 3) have evaluated whether reactivity is present with accelerometry monitoring, with these three studies either occurring in children[32] or employing a convenience sample of adults[33,34]. As a result, the purpose of the current study was to examine whether accelerometry reactivity is present in a nationally representative sample of U.S. adults. Three specific aims will be addressed in this study. The first aim of our study will examine whether accelerometer reactivity is indeed present, with evaluations considered across a nationally representative U.S. sample of children, adolescents, and adults, as well as, in various demographic and morbidity characteristics. Second, if reactivity is detected, the proportion meeting physical activity guidelines will be calculated in the original data, then recalculated upon removal of 'reactive' data, in order to determine the extent to which reactivity biased proportional estimates meeting PA guidelines, as well as, weekly aggregative estimates of total

physical activity and total activity counts. Similar to the second aim, the last aim will examine the extent to which potential reactivity may influence the association between PA and health.

CHAPTER 2

An accelerometer is a wireless ambulatory monitoring device that can be used to measure PA. These devices are quickly replacing pedometer use for objective PA assessment because of the more complex data derived. Accelerometers allow for the measure of accelerations in one to three planes (sagittal, transverse, and frontal). Most accelerometers are similar in size to a wristwatch. In most cases the accelerometer is placed on an individual in one of two locations, at the wrist or attached to the hip near the iliac crest and subsequently worn for multiple days. When wrist mounted, the accelerometer is worn in the fashion of a watch. When mounted at the hip, the accelerometer is secured by an elastic belt around the waste and generates activity counts proportional to movement at the center of mass.

An accelerometer measures an individual's frequency, intensity, and duration of physical activity while providing output of these measures in the form of counts. These activity counts are summed over a time period of the researchers preference; this time period is termed an "epoch." Subsequently, intensity-related activity count thresholds are applied to determine time spent at different PA intensity levels.

Although poorly investigated, reactivity may be present with accelerometer use,[35] which would be in accordance with some of the pedometer-related studies.[26,27] The basis of this reactivity could be the result of several psychological components, namely, social desirability, social facilitation, or a basic human need to demonstrate competence in the physical domain. It is also plausible to hypothesize that by giving an individual a device to measure their PA, this may induce a premature shift from a pre-contemplative state to contemplative (or preparation/action)

state among those who are indeed pre-contemplative. If this speculative scenario were indeed to occur, then this may have long-lasting implications on future PA behavior. For example, a premature shift in readiness to change their PA behavior may lead to a lapse or relapse in behavioral engagement, perhaps because of being in a cognitive state less suitable for adherence to PA and/or the limited acquisition of cognitive and behavioral skills to facilitate behavior change.

Regardless of the potential underlying psychosocial mechanism(s), fundamentally, accelerometer reactivity by definition is a change in behavioral pattern due to the knowledge that their PA is being monitored.[23] Thus far, few studies have acknowledged the possibility of reactivity specific to accelerometry[32,33,35] and fewer still have substantiated the presence of this phenomenon.[32,34] The findings of these studies investigating accelerometer reactivity will be discussed in the following pages.

Thus far, there exists only three studies whose purpose was to evaluate potential reactivity to accelerometer-measured PA behavior.[32-34] Among these studies, two identified reactivity,[32,34] while one did not find substantial evidence to report a reactive effect.[33] It is noteworthy that each of these prior studies examined different subpopulations with different age groups and also used different criteria to define reactivity.

The first study to examine accelerometer-specific reactivity was conducted by Behrens & Dinger (2007) who attempted to observe whether reactivity was present in a sample of U.S. undergraduate students (n = 119) aged 18 – 30. An a-priori decision criterion was set to evaluate the presence of reactivity, the criterion being a systematic decline in PA from each study day to the next. This criterion was not met. Through post-hoc analysis, Behrens & Dinger (2007) observed significant differences in daily activity counts to be the result of different behavioral

patterns for weekdays and weekends, i.e., differences occurred between weekdays and weekends, but there was no successive decrease for each day of the week. Consequently, when examining potential accelerometer-specific reactivity, considerations as to which days are being monitored is important.

Motl et al. (2012) looked at data from two previous studies on individuals with diagnosed Multiple Sclerosis (MS) who enrolled in an intervention to increase their PA. The combined study participants produced a sample size of N=38. Mean age for study group 1 and 2 was 45.4 and 48.3 years, respectively. The groups also consisted of a female majority (≥ 80%). In order to evaluate whether accelerometer reactivity was present, they measured the PA behavior of the two groups at two time periods: one week prior to the start of the intervention and then again during week one of the study. They concluded that reactivity was present based on a significant paired difference in PA levels between baseline week and week 1 of the study. This equated to roughly a 30% drop in steps per day from baseline to study week 1, which is the opposite effect we would expect to see from and intervention designed to increase PA. Significant differences were observed for both groups 1,822 ± 3,265; $t(17) = 2.37$, $p = .03$, $d = .56$ and 2,338 ± 1,716 $t(19) = 6.09$, $p = .0001$, $d = 1.36$, respectively. This equated to a reduction in PA of 29% for study group 1 and 32% for study group 2.

The most recent study to examine reactivity to accelerometer-measured PA was conducted by Dossegger et al. (2014). This study examined data collected from 8 previous Swiss studies, which provided a large sample size (N = 2,081). The target population was children and adolescents aged 3 – 18. A statistically significant decrease in activity counts was identified moving from day 1 to 2-6 of wear time, however, day 7 counts increased showing no difference

from day 1. Age-adjusted mean differences in daily counts per minute (cpm) ranged from 3.6% - 7.1%. The author's accepted these results as sufficient evidence of a reactive effect.

The limited research focused on accelerometer reactivity makes it difficult to form any definitive basis for the identification of a reactive presence in data derived from accelerometry. Each study dedicated to the evaluation of reactivity established different criteria by which to judge their data. This highlights the need for a standard definition of accelerometer reactivity. It is evident that the reactivity studies conducted on adults utilized a convenience sampling method, by which limiting their generalizability. This reactive phenomena will be better understood when examined among a large representative population. There is also a need to investigate whether reactivity is present in specific demographic and morbid subpopulations. One could postulate that an individual living with a, to some extent, weakening illness may be more inclined to demonstrate themselves competent within a domain such as PA, thus resulting in a more prominent reactive effect to accelerometer measure.

Thus, the specific aims of this study are as follows. The first aim of our study will be to identify whether an accelerometer-reactive effect is present among a nationally representative sample of children, adolescents, and adults, as well as, in various demographic and morbid subpopulations. Second, if reactivity is detected, we will evaluate the extent to which reactivity biases estimates of PA and proportion meeting PA guidelines. Thirdly, if reactivity is observed, we will evaluate the extent to which reactivity influences the relationship between PA and health.

CHAPTER 3

Study Design

Data will be obtained from the 2003-2006 National Health and Nutrition Examination Survey (NHANES), which was approved by the National Center for Health Statistics ethics committee. Notably, at the time of this writing, these are the only NHANES cycles with accelerometry data. The NHANES is an ongoing survey conducted by the Center for Disease Control (CDC), which uses a multistage, complex clustered probability design to select a representative sample of non-institutionalized United States civilians. The multistage design consists of 4 stages, including the identification of counties, segments (city blocks), random selection of households within the segments, and random selection of individuals within the households. In the 2003-2006 cycles, participants were sampled across 15 different U.S. geographic areas during each 2-year cycle. Participants were interviewed in their homes and then subsequently examined in a mobile examination center (MEC) by NHANES personnel.

Measurement of Accelerometry

In the 2003-2006 NHANES, objectively-measured PA was assessed via accelerometer, with details provided elsewhere.[20] Briefly, at the MEC, participants who were not prevented by impairments of walking or wearing an accelerometer were issued an ActiGraph 7164

accelerometer. Participants were asked to wear the accelerometer on the right hip for 7 days following their examination. The accelerometer was affixed to an elastic belt worn around the waist. The output of an accelerometer is *activity counts*, which are proportional to measured acceleration. The ActiGraph 7164 accelerometer measures accelerations in the vertical axis using a piezoelectric plate. The accelerometer output is digitized using an analog-to-digital converter, and once digitized, the signal passes through a digital filter that detects accelerations ranging from 0.05 to 2.00 g in magnitude with frequency responses ranging from 0.25 to 2.5 Hz to filter motion outside normal human movement. The filtered signal is then rectified and summed over a pre-determined epoch period. After the activity count is sorted into an epoch, it is stored in the internal memory and then the integrator is reset to zero. In NHANES, activity counts were summarized in 1-min epoch intervals. To determine the amount of time the monitor was worn, nonwear will be defined by a period of a minimum of 60 consecutive minutes of zero activity counts, with the allowance of 1-2 minutes of activity counts between 0 and 100.

Given the noted issues with applying an absolute accelerometer-determined activity count threshold,[17,20] we will examine associations using the accelerometer's output parameter (i.e., activity counts).[36,37] A variable, activity counts per day (CPD), will be created to reflect the amount of physical activity each individual engages in daily. In addition to CPD we will also investigate time spent in moderate or vigorous PA (MVPA).

Thus, accelerometer reactivity will be evaluated with the consideration of two accelerometer metrics: CPD and MVPA. Given the noted differences between weekday and weekend physical activity estimates,[32,33]our analyses will exclude data from the weekend. Only participants with

valid (i.e., at least 10 hrs/day of monitoring) data for all 5 days of the week (Mon-Fri) will be included. As noted below, we will further restrict the sample to those whose first day of accelerometer monitoring occurred on a Monday.

Analysis

All statistical analyses was performed using procedures from sample survey data using Stata (version 12.0, College Station, TX) to account for the complex survey design used in NHANES. To account for oversampling, non-response, non-coverage, and to provide nationally representative estimates, all analyses included the use of survey sample weights, clustering and primary sampling units. A sample weight for each person is generated. This sample weight is created using three steps: first, the base weight is calculated for each person which takes into consideration the participant's probability that their county, city block, household, and then her/himself is selected; second, the sample weight is adjusted for non-response (i.e., whether they were a non-respondent to either the interview portion and/or the exam portion) and noncoverage (i.e., not sampled in the NHANES population); and third, post-stratification adjustment is made to the sample weights to match the 2000 U.S. Census population. Prior to any analyses, the following Stata command will be used to define the survey design: svyset [w = weight, psu (psu variable) strara (strata variable). Then, "svy" commands will be used for each analysis to ensure the complex survey design of NHANES is accounted for when determining variance estimates, which will be computed via Taylor linearization method.

The specific analyses for each of the three aims are noted as follows.

AIM 1: Identify whether an accelerometer reactive effect is present among various demographic and morbid subpopulations.

Herein, accelerometer "reactivity" is defined as a statistically significantly ($p<0.05$) reduction (from day 1) in the physical activity metric (either activity counts per day or MVPA in days 2 or 3 of monitoring, with days 4 and 5 not being higher than days 1 and 2. Paired sample t-tests will be used to evaluate statistically significant differences across days. In addition to restricting the analyses to weekdays of accelerometer monitoring, analyses will be restricted to participants whose first day of monitoring occurred on a Monday. This standardization will minimize any misclassification of reactivity as a result of the day the monitoring started. Potentially reactivity will be evaluated across a nationally representative sample, as well as, various demographic and morbid subpopulations, which include: age, gender, race-ethnicity, education level, body mass index (BMI), poverty-to-income ratio, congestive heart failure (CHF), coronary artery disease (CAD), stroke, cancer, diabetes, depression, kidney disease, and hypertension.

AIM 2: Evaluate the extent to which potential reactivity biases estimates of PA (i.e., CPD and MVPA) and proportion meeting PA guidelines.

This aim examines the extent to which reactivity has the potential to bias estimates of individuals adhering to PA guidelines. PA guidelines considered by this study will be those recommended by the U.S. Department of Health and Human Services. Those who

meet guidelines will accrue a minimum of 150 minutes of moderate PA (activity counts/min between 2020 and 5999) per week or at least 75 minutes of vigorous intensity (activity counts/min ≥ 5999) PA per week. A dichotomous variable will be created to identify those who meet versus those who do not meet PA guidelines. Given that our analytic sample will include those with valid accelerometer day during all days of the week (Mon-Fri), we will specifically calculate whether they meet PA guidelines by averaging their 5-day moderate-intensity PA estimate and multiplying it by 7, and similarly, averaging their 5-day vigorous-intensity PA estimate and multiplying it by 7. If their 'weekly' moderate-intensity PA estimate is greater than or equal to 150 min/week, or if their 'weekly' vigorous-intensity PA estimate is greater than or equal to 75 min/week, they will be classified as meeting PA guidelines. We will then, for the entire sample, calculate the proportion meeting PA guidelines. Subsequently, for participants with an observed reactivity effect (i.e., day 2 is less than day 1), their "day 1" data will be removed. With this "removed" data, we will then re-calculate the proportion meeting PA guidelines and compare this with the first proportional estimate to determine the extent to which reactivity influences proportional estimates for meeting PA guidelines.

Comparisons will be made for all groups; children, adolescents, and adults.

AIM 3: Evaluate the extent to which reactivity influences the relationship between PA and health.

In order to investigate the possibility of reactivity altering the relationship between PA and health outcomes we have chosen to examine the relationship between PA and blood concentrations of high sensitivity C – reactive protein (CRP). CRP was chosen as it represents a biomarker for systemic inflammation and a substantial indicator of chronic disease. High levels of inflammation have been linked with the development of numerous chronic diseases, including cardiovascular disease[38], diabetes[39], chronic kidney disease[40], a host mental disorders[41], and poorer prognosis in cancer recovery.[42]. Blood samples were obtained to assess high sensitivity CRP, using latex-enhanced nephelometry. For the 2003-2006 NHANES cycles, the coefficients of variation (CV) ranged from 3.1% to 9.9%. A multivariable linear regression model will be used to examine the association between the two PA metrics and CRP (outcome variable). Covariates will include age, race, gender, BMI, poverty-to-income ratio, and education. Similar to the approach mentioned for Aim 2, a separate model will be evaluated upon removal of reactivity from the PA estimates. From the two regression models (1 with all data and the other with the "reactive" data removed), we will compare the beta coefficient to determine the extent to which reactivity influenced the association between PA and CRP.

CHAPTER 4

Results

After excluding individuals who began their 7-day PA monitoring period on a day other than Monday the 2003-2006 NHANES data set produced 674 individuals for analytic purposes; Monday was selected because the majority of participants started their first day of monitoring on Monday. This population was divided into three subcategories; children, adolescents, and adults. Children (n = 106) were comprised of 59% boys and 41% girls. The sample of adolescents (n = 128) was more equally distributed regarding gender with boys encompassing 51% and girls 49%. The adult sample (n = 440) was much larger with men representing 48% and women 52% of the sample. Mexican Americans accounted for the ethnic majority for both children and adolescents groups at 49% and 38.3%, respectively, with the adult group comprised largely of Non-Hispanic Whites at 47.5% of the sample. Mean ages for children, adolescents and adults were (8.6 ± 1.8), (14.4 ± 1.7), and (49.4 ± 16.6) years, respectively. Notably, these are unweighted estimates (means and proportions). Additional demographic information can be found in Table 1.

Table 1. Descriptive Statistics (N = 674)

		Children (6-11)	**Adolescents** (12-17)	**Adults** (20-85)
Sample size		106	128	440
Male (%)		59	51	48
Mean age (years)		8.6	14.4	49.4
Race/Ethnicity (%)	Mexican American	49	38.3	26.4
	Other Hispanic	1.9	2.3	2.7
	Non-Hispanic White	19	19.5	47.5
	Non-Hispanic Black	21	34.4	16.6
	Multiracial	7.6	5.5	6.8

Reactivity

To investigate a potential reactive presence among the accelerometer data, two metrics were produced and analyzed. These metrics were time spent in MVPA and CPD. Children engaged in the greatest amounts of PA followed by adolescents and subsequently the adult group. These findings are evidenced both by CPD (Table 2) and time spent in MVPA (Table 3).

Table 2. Total activity counts/day (CPD) by measurement day with first the day of monitoring being Monday, NHANES 2003-2006 (N = 674).

CPD		Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Children (6-11yrs) (n = 106)	Total	541449.2 (25542.2)	525709.5 (24122.2)	537814.8 (24657.3)	499485.4 (22235.1)	557859.3 (23665.4)	566628.1 (36965.4)	***466281.5 (21307.9)**
	Male	580588.3 (38605.4)	548996.5 (34135.2)	591360.5 (30570.5)	508169.4 (27592.8)	575080.8 (29453.0)	619906.8 (50273.4)	526866.9 (29158.0)
	Female	484105.9 (25797.5)	491591.4 (31926.0)	459364.1 (38458.7)	486762.4 (37332.8)	532627.8 (39367.4)	488568.7 (52064.7)	***377516.7 (25369.9)**
Adolescents (12-17yrs) (n = 128)	Total	379819.8 (16409.8)	387759.8 (16974.1)	361598.9 (15976.2)	394777.4 (19732.5)	395060.4 (20315.4)	348735.8 (18274.9)	***297453.5 (17185.1)**
	Male	442768.7 (24709.4)	451840.2 (25806.9)	424285.2 (24956.1)	452953.4 (29467.8)	437985.9 (27963.6)	388451.8 (23199.3)	***359166.4 (29148.9)**
	Female	312809.5 (17947.4)	319544.9 (18303.4)	294868.5 (15781.2)	332848.0 (23805.5)	349365.4 (28645.6)	306457.5 (27715.9)	***231759.1 (12976.8)**
Adults (20-85yrs) (n = 440)	Total	309611.5 (9134.9)	***297140.6 (7920.3)**	***295812.9 (8364.9)**	297339.3 (7825.3)	298567.2 (8012.4)	***276846.7 (8100.7)**	***253652.1 (8863.8)**
	Male	353349.4 (15470.3)	***329589.1 (13193.1)**	336238.8 (14105.9)	331377.3 (13028.1)	331250.5 (13040.0)	***304016.4 (13750.5)**	**275488.0 (15780.4)**
	Female	268942.9 (9458.5)	266969.1 (8680.9)	258223.9 (8732.0)	265690.0 (8525.4)	268177.5 (9175.3)	***251583.7 (8698.1)**	***233348.6 (8615.3)**

Values represent total activity counts per day (CPD), with the values in parentheses being the standard error Bold values (and those with an *) indicates a significant difference ($p < 0.05$) in CPD when compared to day 1 (Monday).

We identified, *a-priori*, that reactivity would be evidenced by an initial decline in either CPD or MVPA, demonstrated by a significant ($p \leq 0.05$) difference between day one and days two or three of monitoring. Suggestion of reactivity was observed only for the adult population (Table 2) where CPD from days two and three (297140.6 ± 7920.3 and 295812.9 ± 8364.9),

respectively, differed significantly from day one (309611.5 ± 9134.9) over the monitoring period, equating to a 4.0 – 4.5% change in activity levels. A graphic representation of the CPD findings can be seen in Figure 1. Notably, and although there appeared to be some evidence of reactivity among adults when considering the CPD metric, there was no evidence of reactivity for adults when considering the MVPA metric (Table 3).

Table 3. Time spent in MVPA (min/day) by measurement day with first the day of monitoring being Monday, NHANES 2003-2006 (N = 674).

MVPA		**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**
Children (6-11yrs) (n = 106)	Total	89.2 (5.3)	86.3 (5.2)	88.4 (5.0)	83.5 (4.9)	93.7 (5.2)	92.6 (7.0)	77.9 (5.1)
	Male	97.1 (7.6)	93.9 (7.6)	100.4 (6.9)	86.2 (6.5)	101.0 (7.3)	107.3 (9.8)	92.4 (7.0)
	Female	77.5 (6.4)	75.3 (6.0)	70.8 (6.2)	79.5 (7.4)	83.1 (6.9)	70.9 (8.9)	***56.7 (5.9)**
Adolescents (12-17yrs) (n = 128)	Total	32.6 (2.9)	36.0 (3.1)	30.6 (2.6)	34.9 (3.2)	32.5 (3.1)	***25.2 (2.8)**	***22.4 (3.1)**
	Male	43.5 (4.7)	47.7 (4.7)	40.7 (4.2)	46.4 (4.9)	42.2 (5.0)	***33.1 (4.1)**	33.2 (5.3)
	Female	21.0 (2.5)	23.6 (3.2)	19.2 (2.4)	22.7 (3.4)	22.1 (3.0)	16.8 (3.4)	***10.9 (1.7)**
Adults (20-85yrs) (n = 440)	Total	26.2 (1.6)	24.7 (1.4)	25.3 (1.5)	25.7 (1.4)	24.4 (1.4)	***23.0 (1.5)**	***21.1 (1.6)**
	Male	34.5 (2.8)	31.1 (2.5)	33.8 (2.7)	32.6 (2.5)	31.4 (2.4)	30.0 (2.6)	***26.9 (2.9)**
	Female	18.4 (1.4)	18.8 (1.3)	17.4 (1.4)	19.2 (1.4)	17.8 (1.4)	16.5 (1.3)	15.6 (1.3)

Values represent mean minutes of Moderate to Vigorous Physical Activity (MVPA) per day and standard error*Indicates a significant difference ($p < 0.05$) in MVPA when compared to day 1 (Monday).

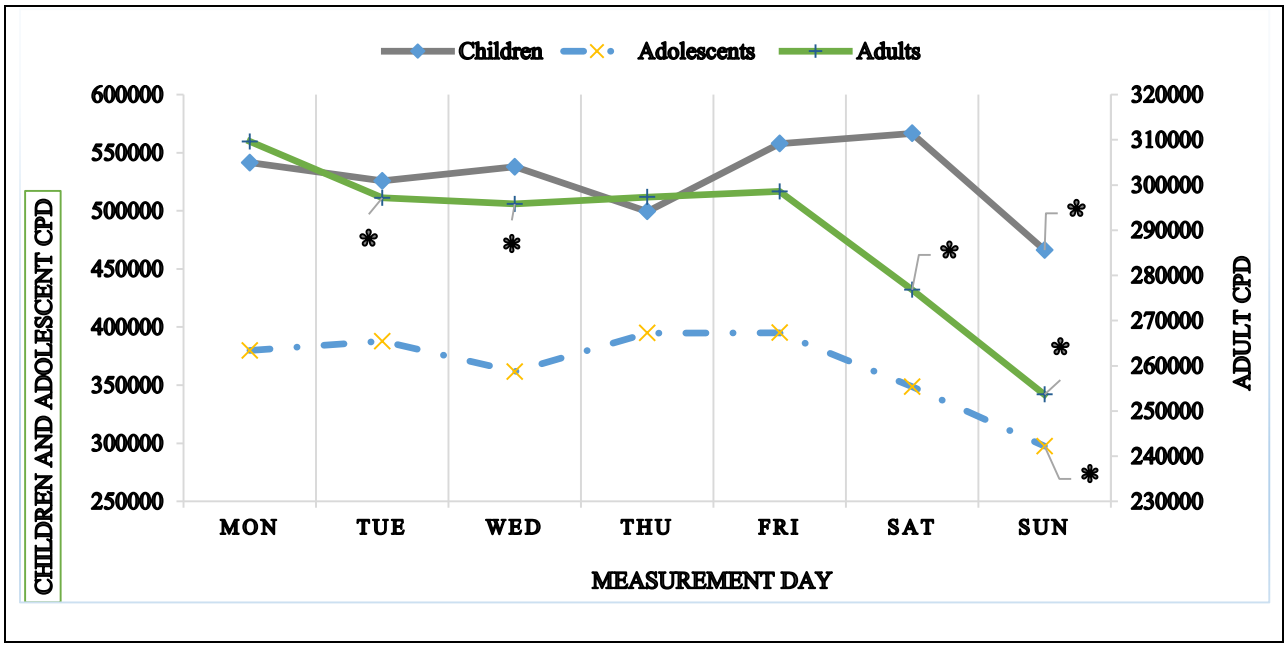

Figure 1. CPD (counts per day) by measurement day. Data represents only those participants who began monitoring period on Monday. Significant differences ($p \leq 0.05$) are identified by an asterisk and represent significant differences between the evaluated day compared to the start day (Monday).

Due to the potential reactivity findings observed in the adult population, the analysis was conducted 2 additional times with differing start days (Tuesday and Wednesday) as opposed to Monday; this was not possible with the child and adolescent samples due to sample size considerations (i.e., too few children/adolescents started their first day of monitoring on a Monday or Tuesday). Had there truly been a reactive phenomenon occurring in the adult population, theoretically, we should have observed it among those who began monitoring periods on Tuesday and Wednesday (Table 4). As shown in Table 4, there was some evidence of adult reactivity (with regard to CPD) among those starting on Monday (same results as shown in Table 2); however, we observed little reactivity presence among adults who started their first day of monitoring on Tuesday or Wednesday. The reduction in activity levels on weekends vs week days was the only finding substantiated by replicating the analysis by start day (Tuesday & Wednesday).

Table 4. Total activity counts/day (CPD) by measurement day with first the day of monitoring being Monday, Tuesday or Wednesday, NHANES 2003-2006.

CPD		Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Adults Mon. Start (n = 440)	Total	309611.5 (9134.9)	***297140.6 (7920.3)**	***295812.9 (8364.9)**	297339.3 (7825.3)	298567.2 (8012.4)	***276846.7 (8100.7)**	***253652.1 (8863.8)**
	Male	353349.4 (15470.3)	***329589.1 (13193.1)**	336238.8 (14105.9)	331377.3 (13028.1)	331250.5 (13040.0)	***304016.4 (13750.5)**	***275488.0 (15780.4)**
	Female	268942.9 (9458.5)	266969.1 (8680.9)	258223.9 (8732.0)	265690.0 (8525.4)	268177.5 (9175.3)	***251583.7 (8698.1)**	***233348.6 (8615.3)**
Adults Tue. Start (n = 423)	Total	255965.8 (7686.9)	266361.4 (7868.32)	264096.9 (7599.9)	256310.9 (7892.0)	265516.5 (7528.2)	***248496.7 (7437.3)**	***216189.7 (6867.6)**
	Male	278249.1 (11290.7)	294353.5 (12278.2)	284272.9 (11454.6)	289925.9 (12130.9)	286658.7 (10975.3)	***268521.3 (10867.3)**	***229367.0 (10173.4)**
	Female	229156.2 (9800.0)	232683.4 (8489.5)	239822.6 (9241.9)	***215867.9 (8619.3)**	240079.7 (9754.6)	224404.6 (9621.8)	***200335.9 (8787.6)**
Adults Wed. Start (n = 202)	Total	249631.0 (12502.7)	240925.4 (10824.6)	257288.9 (11942.9)	260668.4 (11911.6)	269929.5 (13697.9)	***223962.6 (10827.8)**	***209452.5 (10106.4)**
	Male	264507.2 (18752.7)	***247645.9 (16456.8)**	275468.0 (18155.5)	285489.4 (19016.3)	292555.8 (21131.2)	***244391.3 (17446.7)**	***224129.0 (15384.6)**
	Female	233844.1 (16321.4)	233793.4 (13937.7)	237996.8 (15176.5)	234327.8 (13587.9)	245918.8 (16932.1)	***202283.2 (12179.8)**	***193877.5 (12832.9)**

Values represent total activity counts per day and standard error (in parentheses). *Indicates a significant difference ($p \leq 0.05$) in CPD when compared to day 1. The cells in a square bracket indicate CPD for the first day of monitoring (i.e., either Monday, Tuesday, or Wednesday).

CHAPTER 5

Discussion

Past literature has demonstrated evidence of a reactive phenomenon in the use of accelerometer derived PA assessment[32,34], however, the few number of studies, the differing methods of assessing reactivity and the convenience sampling approach have left questions regarding whether or not reactivity should be of concern when drawing conclusions from accelerometer derived data. The aims of the current study were to investigate the presence of a potential reactive effect in the assessment of PA behavior by accelerometry among an unbiased nationally representative sample of noninstitutionalized U.S. individuals, as well as, a proposed threat to the validity of results derived (e.g. does the removal of reactive data change the estimates of adherence to PA guidelines, or associations with health outcomes?). Due to the rapid increase in the selection of accelerometers as an instrument of choice in the objective monitoring of PA behavior[43], the exploration of potential accelerometer reactivity is of critical importance. Our main findings were that accelerometer reactivity does not appear to be present in this nationally representative U.S. sample, subsequently the secondary purposes (i.e., does reactivity influence PA estimates and associations with health outcomes) of this study were not investigated. The findings of this study should serve to build confidence in the conclusions drawn from PA assessment through accelerometry.

To our knowledge, ours was the first study to examine accelerometer reactivity in a representative U.S. population of children, adolescents and adults. Though our initial analysis in the adult population provided some evidence of a reactive effect (day one CPD were

significantly larger than days two or three, 4.0 – 4.5%), we ultimately determined this not to be a reactive effect. Upon replicating the analysis a second and third time (start days on Tuesday and Wednesday) the data failed to produce the reactive effect, which theoretically should have remained present regardless of start day had the phenomenon truly been present. Replicating the analysis by differing start days eliminated the possibility of individual daily routines producing behavioral patterns evident of reactivity.

Much of the previous literature on reactivity to PA measurement has been conducted utilizing pedometers with few studies using accelerometry. The findings, however, are mixed regarding pedometer reactivity[23,26,27,29,44]. Many pedometer studies which identify reactivity utilize sealed versus unsealed pedometers, meaning in some instances the individual can view their accumulated step counts. This is less evident of reactivity and more of the intervention's ability for the pedometer to encourage individual self-monitoring and goal setting of PA behavior[45]. Because of this, caution should be taken when comparing pedometer reactivity studies to those conducted with accelerometers. Similar to pedometer studies, the little research[32-34] devoted to investigating reactivity to accelerometry measured PA also produces ambiguous conclusions, as findings, populations and methodologies differ. Due to the nature of pedometer reactivity studies and the lack of studies utilizing accelerometers, investigation must continue regarding the topic of reactivity to objectively measured PA behavior.

Concerning accelerometer reactivity in children and adolescents, Dossegger and colleagues[32] examined data collected form 8 previous studies, collectively on 2,081 children and adolescents. Their main findings reflect reactivity in that day one counts per minute (CPM) exceeded subsequent days by 3.6%-7.1% with the exclusion of day 7, citing the reason for this rebound of PA as compensatory behavior (i.e., make up for low levels of PA during the

monitoring period). These findings are in conflict with our study results which showed there to be no significant declines in CPD of the child and adolescent age groups across the first 6 study days (Table 2). The reason for the discrepancy in findings could be due to population differences. For instance, the nature of daily activity for Swiss children may consist of more free-play situations than that of their American counterparts, as unrestricted free-play situations have been shown more conducive to reactivity in child populations[27]. It is also plausible that the methods of sampling employed by the original 8 studies utilized by Dossegger and colleagues could have biased their findings, as some of their data was collected from PA intervention studies, thus changes in PA patterns could have been the product of the intervention and not reactivity.

In accordance with previous PA reactivity studies,[30,32,33] our data showed week day physical activity behavior to be different (higher) than that accrued on weekends (Table 2). For the children and adolescent groups, Sunday was found to be the only day whose activity counts significantly differed from start day (Monday). Among the adult population, week day PA counts were found to be significantly different than PA accrued on both Saturday and Sunday. These findings were replicated when the start day was changed (Table 4). It stands to reason that children's between day variability regarding weekends versus week days would be less than that of an adult. Adult PA behavior, whether product of vocation or intentional exercise, tends to be more structured whereas children accrue PA largely through unrestricted free-play opportunities[27] not necessarily produced by the structured school day. For the majority of Americans adults Monday through Friday represents the traditional work week. In this population, whether PA results from the nature of their employment or of exercise behavior,

weekend behavior appears to be a lessor contributor to total physical activity than that accrued Monday through Friday.

The strength of this study is that it is the first study to examine accelerometer reactivity from a non-convenience, nationally representative sample of U.S. individuals. Further, our systematic approach to detecting a reactive presence in the data have gone beyond previous methods of detection. A limitation of our study is its non-experimental design. Though our study utilized a robust methodology to assess the existence of accelerometer reactivity, it does not elevate all doubt as to the existence of reactivity. In order to better examine the reactive phenomena future studies would benefit more from an experimental design where the researcher could blind participants to the nature of the device (accelerometer) rendering them unaware their activity levels were being evaluated. By definition, reactivity is the change in behavior due to the fact the individual is aware their PA is being monitored[23]. In essence, the researcher must mislead the participant not only to the nature of the device placed upon them but also as to the purpose of the experiment, as PA in the presence of others could itself elicit a reactive effect[46]. One can speculate as to the problems this methodology would create with an institutional review board. An experimental investigation into PA reactivity attributed to pedometers in children has been previously attempted[27], however, further investigation among differing populations and more robust methodology is necessary to perfect such a design.

Though we did not discover a reactive presence in the national sample, further investigation is warranted into particular demographic and morbid subpopulations. Initially, this investigation was an aim of our study, however, because of our delimitation to a Monday start of the monitoring period, the sample of morbid subpopulations was drastically reduced and insufficient for analysis. Because of the psychological mechanisms triggering the reactive effect

one could, nonetheless, hypothesize as to why an individual from such a population could, theoretically, be more likely to display reactivity than those from a healthier sample. For instance, Self-Determination Theory[47] states that individuals possess an innate psychological need to demonstrate competence in achievement domains of life (which included exercise). Someone who lives with some form of disability or handicap may be more inclined to present themselves fully functional when undergoing PA monitoring. Similarly, an obese individual, due to subjective normative beliefs[48] (stigma) may feel the need to display themselves as less affected by activity-related phenotypical characteristics of their body. To fully improve our understanding of this topic, future experimental work is needed to establish what an expected between-day PA would be among all age populations. Once this is determined, this should be the criteria to determine if reactivity is truly observable in a particular study. For example, rather than relying on a statistically significant between-day change in PA, if it is established that an expected between-day PA change is 1-7%, then a change of 8% or more from the first day of monitoring to next may be more indicative of a reactive effect. At this point, we have little understanding of expected between-day PA variability. In a meta-analysis of 21 studies, Black and Cole reported that the mean within-individual coefficient of variation for daily energy expenditure (via doubly labeled water) was 11.8%, but the range was from 6.5-24.3%. Given the relatively large range, coupled with the minimal sample sizes among these 21 studies (N's ranged from 1-17), additional confirmatory studies are needed.

In conclusion, in this national sample of U.S. children, adolescents and adults, we did not observe evidence of accelerometer reactivity. Although future carefully designed experimental studies on this topic are needed, our findings among the populations evaluated should serve to build confidence in the conclusions drawn from PA assessment through accelerometry.

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Research & Publications

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Published Abstracts:

1. Vinayak K. Nahar, M. Allison Ford, Martha A. Bass, Robert E. Davis, Amanda Hutcheson. 2013. Osteoporosis Health Beliefs, Knowledge, Preventive Behaviors, and Bone Mineral Density in Asian Indian Populations.

Articles Under Review:

1. Loprinzi P.D., Davis, R.E. Secular Trends in Television Viewing Among Children in the United States, 2001-2012.

2. Loprinzi, P.D., Davis, R.E. Effects of Individual, Combined, and Isolated Movement-Based Behaviors on All-Cause Mortality and CVD-Specific Mortality: Prospective Cohort Study Among U.S. Adults

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ES 440 - Behavioral Aspects of Exercise (Exercise Psychology)
HP 191- Personal and Community Health
EL 124 - Racquetball
EL 147 - Tennis
EL 151 - Weight Lifting
EL 156 - Jogging
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Academic Advising

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Professional Qualifications & Continuing Education

CPR & First Aid (May 2011)
University of Mississippi
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Nutrition Environment Measures Survey (NEMS) (July 2012)
The University of Pennsylvania School of Medicine
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Environmental Systems Research Institute (ESRI) (July 2012)
ArcGIS Desktop Training Course
Geographic Information 24 hour Course

Geographic Support System Initiative (US Census Bureau) (October 2012)
Workshop focused on the use of Census data with GIS software
Geographic Information Systems 4 hour Course

Assessing the Built Environment for Physical Activity (December 2012)
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Certificate of Training Completion

Community Service

2010 - Volunteer: Habitat for Humanity

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Psychological Determinants of Physical Activity
Human Behavior
Human Behavior Modification
The "Built Environment's" Impact on Health