RELIABLY MEASURING HABITUAL FREE-LIVING PHYSICAL ACTIVITY WITH THE ACTICAL® ACTIVITY MONITOR

by

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ABSTRACT

The purpose of this study was to compare reliability measures between a hip- and wrist-worn Actical® accelerometer. A group of 40 (25 female, 15 male) Montana State University employees wore both monitors for 14 consecutive days. Intraclass correlation coefficients (ICC) were determined for three variables for each monitor wearing location for bouts of one, three, five, eight and ten consecutive minutes over the entire monitoring period and for each single day of monitoring. The three dependent variables were the raw activity count values (CNT_{MV}, counts/day) at or above specified moderate intensity activity thresholds, and the corresponding summation of total time (T_{MV}, mins/day) and activity energy expenditure (AEE_{MV}, kcals/day) spent at or above a moderate intensity. As time bouts increased from one to ten minutes, ICC values decreased for both the hip- and wrist-worn monitors. The number of days for the hip-worn monitor to reach an ICC of 0.80 ranged from 3 to 4, 2 to 5, and 3 to 6 for CNT_{MV}, AEE_{MV}, and T_{MV}, respectively, while the wrist-worn monitor took 10 to 12, 5 to 8, and 3 to 5 days for the same respective variables. No substantial differences in physical activity between weekdays and weekend days were observed. Subjects were divided post-hoc into an Active or Inactive group. Higher ICC values were observed with the hip-worn monitor in the Active group (5, 2 to 9, and 3 to 10 days to reach an ICC of 0.80 for CNT_{MV}, AEE_{MV}, and T_{MV}, respectively), while higher ICC values were observed with the wrist-worn monitor in the Inactive group (3 to 4, 4 to 5, and 3 to 4 days to reach an ICC of 0.80 for CNT_{MV}, AEE_{MV}, and T_{MV}, respectively). No substantial differences in physical activity were seen between weekdays and weekend days for the Active or Inactive group. These findings indicate that a hip-worn Actical® will reach a desired ICC value in fewer monitoring days than a wrist-worn Actical®, except in inactive populations where the wrist-worn Actical® required fewer monitoring days.

CHAPTER ONE

INTRODUCTION

The number of cases of obesity, diabetes, and cardiovascular disease (CVD) is rising in the United States faster than ever before. For example, the 1992-2002 National Health and Nutrition Examination Survey showed that 30% of adults over the age of 20 were obese, and that the percentage of overweight children had tripled to 16% since 1980 (National Center for Health Statistics, 2004). These numbers pale in comparison to heart disease, which is the leading cause of death in the U.S. Twenty-six thousand people die each day (one every 33 seconds) as a result of CVD (National Center for Chronic Disease Prevention and Health Promotion, 2003).

While the association between physical activity and health has been known for decades (Laporte, Montoye, & Casperson, 1985), recent studies have shown that minimal amounts of physical activity can reduce the likelihood of developing obesity, diabetes, and CVD (Pate et al., 1995). Guidelines that define minimal amounts of physical activity have also been established by the Centers for Disease Control and Prevention (CDC) and the American College of Sports Medicine (ACSM) (Pate et al., 1995). These guidelines state that 30 minutes of moderate to vigorous activity accumulated in at least 8-10 minute bouts most days of the week is sufficient for disease prevention and health promotion (Pate et al., 1995). Still, many Americans fail to meet these guidelines. At the crux of the problem is translating these guidelines into specific activities. A common method for overcoming this problem is to provide individuals with electronic physical activity measurement devices, or physical activity monitors. These monitoring devices include heart rate monitors, pedometers, accelerometers, and even global positioning system (GPS) monitors. Other methods include calorimetry, job classifications, surveys, behavioral observation, and dietary measures (LaPorte et al., 1985). However, as technology has improved, physical activity monitors have become smaller, less invasive, and capable of storing more data, making them a desirable choice to study physical activity in free-living activities (Trost, McIver, & Pate, 2005; Welk, Schaben, & Morrow, 2004).

Accelerometers are frequently used as physical activity monitors. These are small, simple devices that measure movement due to the acceleration caused by the body during physical activity. Depending on the type of accelerometer, movement can be measured in one, two, or three dimensions (horizontal movement, vertical movement, and lateral movement). Most commonly, a piezoelectric sensor measures acceleration when a seismic mass deforms a piezoelectric element as a result of acceleration caused by the body (Chen & Bassett, 2005). The resulting changes in voltage of the piezoelectric element are filtered, recorded, and processed by a microprocessor in the unit and are stored as "raw counts." These raw counts are then mathematically manipulated, most commonly through an algorithm, to represent physical activity counts for a given time period, or epoch (Chen & Bassett, 2005).

These physical activity counts can then be used to measure what Heil (2006) calls time-based information (cumulative time spent and different intensity activity) and/or energy expenditure (EE)- based information (energy expended due to physical activity).

Since the CDC and ACSM guidelines are based on duration and intensity of physical activity, time- and EE-based information is clearly crucial to help individuals know if their daily activities are meeting these guidelines.

Several recent studies have used accelerometers in an attempt to more accurately measure physical activity. Topics of study have included various positions of accelerometers on the body, their use in elderly and juvenile populations, and simultaneous use of multiple accelerometers at different locations on the body (Finn & Specker, 2000; Heil, 2002; Heil, 2006; Janz, Witt, & Mahoney, 1995; Kochersberger, McConnell, Kuchibhatla, & Pieper, 1996; Patterson, Krantz, Montogomery, Deuster, Hedges, & Nebel, 1993; Pfeiffer, McIver, Dowda, Almeida, & Pate, 2006; Puyau, Adolph, Vohra, Zakeri & Butte, 2004). However, stability reliability is one of the most important characteristics of accelerometers when they are used to measure physical activity. Stability reliability can be defined as the variability in measurements from day to day (Atkinson & Nevill, 1998). This is an important consideration when measuring habitual amounts of physical activity as it can vary widely from day to day; it may be very high one day and very low the next. If too few days of physical activity are monitored, stability reliability can be very low and habitual physical activity is poorly estimated. Thus, physical activity needs to be monitored over several days for habitual physical activity to be accurately reflected and reliably measured.

The number of monitoring days necessary to reliably measure habitual physical activity depends on the population being studied, the setting, the activity monitor being used, and how generalizable the investigator wishes the findings to be (Ward, Evenson, Vaughn, Rodgers, & Troiano, 2005). Janz et al. (1995) determined that in free-living conditions children needed to wear an accelerometer for a minimum of 4 days to reliably measure habitual physical activity. Trost et al. (2005) reviewed several accelerometer studies and suggested that seven monitoring days are sufficient to obtain reliable measures for children and 3 to 5 monitoring days are needed for adults. However, these studies placed accelerometers on the subjects' hip. The hip has become the most common placement site for accelerometers (Ward et al., 2005), and it has even been recommended that the accelerometer be placed as close to the individual's center of mass as possible (Trost et al., 2005). However, accelerometers worn at the hip do a poor job of reliably measuring physical activity that involves upper-body activity (Swartz, Strath, Bassett, O'Brien, King, & Ainsworth, 2000). Establishing a reliable measure for populations whose primary mode of physical activity is upper-body oriented (e.g., home or gardening activities or wheelchair-bound individuals) may be important (Heil, 2006). Furthermore, establishing such measures could be accomplished by wearing an accelerometer on the wrist. However, these measures may be lower than those from a hip-worn accelerometer as a person's arms can move frequently in activities that are not directly related to whole-body physical activity (e.g., washing dishes, playing video games, etc.). Regardless, no study to date has attempted to access the reliability of free-living physical activity for adults wearing accelerometers on the wrist.

One commercially available physical activity monitor, the Actical® activity monitor (Mini Mitter Co., Inc., Bend, OR, USA), is a versatile unit that can be worn either on the hip, wrist, or ankle (hereafter referred to as hip-worn, wrist-worn, and ankle-worn, respectively). The small size and weight of the Actical® (2.8 x 2.7 x 1.0 cm^3, 17 g, respectively) make it a desirable and relatively non-invasive choice to measure physical activity. Furthermore, the Actical® is capable of measuring acceleration in more than one plane (omnidirectional versus uniaxial or unidirectional), making it more appropriate for detecting the primarily angular accelerations at the wrist or ankle (Heil, 2006). Thus, the wrist-worn Actical® activity monitor may be a good tool for measuring habitual free-living physical activity. However, despite these seemingly desirable traits of the Actical®, it has been worn on the wrist in only one study to measure physical activity and predict energy expenditure (Heil, 2006). Perhaps one reason the Actical® has not been more widely used in field-based studies is the result of previous reliability studies. Welk et al. (2004) reported that a hip-worn Actical® showed lower than expected reliability, and the lowest inter-instrument reliability of four accelerometers tested. It was later found that an experimental version of the Actical® was being used in the study which may have caused the low reliability scores (Welk, 2005). Eslinger and Tremblay (2006) later found the modified and most recent version of the Actical® to have high reliability scores, but some discrepancies in the variability of activity count output. Clearly, further investigation is needed to see how well the Actical® measures habitual free-living physical activity when worn on the wrist.

Statement of Purpose

The purpose of this study was to compare reliability measures between wrist- and hip-worn Actical® accelerometers.

Hypothesis

The reliability measures from the wrist-worn accelerometer will be lower than the hip-worn accelerometer for a given number of monitoring days.

$$\mathbf{H_0: R_w = R_h}$$

$$\mathbf{H_A: R_w < R_h}$$

Where R_w is the mean population reliability for summed movement counts ≥ a moderate intensity (CNT_{MV}), summed minutes ≥ moderate intensity (T_{MV}), and summed activity energy expenditure ≥ moderate intensity (AEE_{MV}) from the wrist-worn accelerometer (dependent variables). Similarly, R_h is the mean population reliability for CNT_{MV}, T_{MV}, and AEE_{MV} from the hip-worn accelerometer, and is compared to R_w with 95% confidence intervals.

Delimitations

1. The scope of this study was delimited to the autumn season and climate of Bozeman, Montana.
2. The study population was delimited to employees of Montana State University in Bozeman, Montana.

Operational Definitions

Free-living:	Completing daily activities in a usual manner with no special instructions or constraints imposed by the investigator.

Physical Activity: Movement caused by contraction of the skeletal muscles that substantially increases energy expenditure.

Energy Expenditure: Total kilocalories expended to complete a task (kcals).

Activity Energy Expenditure (AEE): Relative energy expenditure to perform a task above resting metabolism (kcals/kg/min or kcals/day).

Reliability: The reproducibility or consistency of a measurement.

Stability Reliability: A type of reliability where repeated measures of the same variable are similar.

Monitoring Day: Period of time lasting at least 12 consecutive hours where physical activity is measured with an accelerometer.

Raw Movement Count: Number of times a seismic mass deforms a piezoelectric element as a result of acceleration caused by the body.

Moderate to Vigorous Movement Counts (CNT_{MV}):

The summation of raw movement counts over a 24-hour period at or above a moderate intensity cut point.

Moderate to Vigorous Activity Time (T_{MV}):

Sum of minutes within a 24-hour period at or above a moderate intensity cut point.

Moderate to Vigorous Activity Energy Expenditure (AEE_{MV}):

Sum of AEE values within a 24-hour period when AEE is at or above a moderate intensity cut point.

CHAPTER TWO

REVIEW OF THE LITERATURE

Introduction

Accelerometers are non-invasive tools used to measure physical activity. Measuring physical activity, and doing so reliably, is important to help individuals meet the Center for Disease Control and Prevention (CDC) and American College of Sports Medicine (ACSM) guidelines for disease prevention and health promotion. However, because daily physical activity is not consistent, several monitoring days are required to reliably measure free-living physical activity. Additionally, accelerometer placement on the body will yield different measures of physical activity depending on the type of activity accomplished. Thus, accelerometer studies must be concerned with reliability, the number of monitoring days and accelerometer placement.

Types of Reliability

A common concern in any scientific study is the measurement reliability. That is, how consistently a measurement yields similar values and is free from error (Portney & Watkins, 2000). However, reliability is often a point of confusion to readers of scientific literature, possibly because there are various types of reliability and several ways to calculate reliability. In human research, for example, reliability measures can be applied to the behavior of a subject or an instrument itself. Portney & Watkins (2000) explain that, "If a [subject's] behavior is reliable, we can expect consistent responses under given conditions... Similarly, a reliable instrument is one that will perform with predictable consistency under set conditions" (p. 61). With accelerometer studies, these two types of reliability are intrinsically linked and need to be clearly distinguished by the investigator. Often this is done by examining the test-retest reliability of the accelerometer and the stability reliability of the behavior (i.e., physical activity). However, the investigator must first determine how reliability is going to be measured.

Several methods exist for measuring reliability, such as comparing coefficients, or ratios, that take into account the statistical variance between repeated measures of both true and error scores (Portney & Watkins, 2000). The coefficients are often compared through correlation to determine reliability. However, Portney and Watkins (2000) explain that while a correlation coefficient by itself can indicate how scores vary together, they give no information about agreement, or the similarity of observed values. For example, the sets of paired scores 5:5, 4:4, 3:3, 2:2, and 1:1, as well as 5:10, 4:9, 3:8, 2:7, and 1:6 both have perfect correlation, but only the first set shows perfect agreement. Portney & Watkins (2000) also explain that these limitations are often overcome by using additional statistical methods to address agreement, such as a *t*-test. While the addition of a *t*-test accounts for agreement, "it does not provide a single index to describe reliability" (Portney & Watkins, 2000, p. 560). That is, two values must be used to obtain a true sense of reliability, instead of one single value, or index.

Since reliability is based on variance and measurement error, another method of measuring reliability involves looking at the standard deviation of the error scores, or the standard error of measurement (SEM) (Portney & Watkins, 2000). Similar to a standard deviation, the SEM can be interpreted with the same properties of a normal curve. That is, the true score will fall with a 68% likelihood within one SEM of the mean and a 95% likelihood within two SEMs. Thus, a less variable distribution is indicative of greater reliability (i.e., smaller SEM). Similarly, the amount of variability within the responses, Portney & Watkins (2000) state, should also be reflective of the measurement error, and is measured as the standard deviation of the responses. The amount of variation in proportion to the mean can then be compared by using the coefficient of variation (CV), which is simply calculated by dividing the standard deviation by the mean and multiplying by 100. Like SEM, the smaller the CV the greater the reliability. A CV is an advantageous measure of reliability not only because it is independent of units, but it also measures relative variation, which is meaningful when comparing two distributions (Portney & Watkins, 2000). One weakness, however, is that the extent of error in a measurement is difficult to assess with a CV. That is, while measuring the amount of variation, the amount of error in the measurements is not accounted for with a CV (Portney & Watkins, 2000).

Another method of measuring reliability is with an intraclass correlation coefficient (ICC), which accounts for both the correlation and agreement of observed values (Portney & Watkins, 2000). Often used in accelerometer studies, an ICC is statistically calculated using the variance scores from an analysis of variance (ANOVA) table, and expressed as a number between zero and one. A reliability score of 1.00 indicates a measurement that yields the same value consistently 100% of the time with zero error. In addition, a stability reliability ICC can be calculated for each individual trial or monitoring day. In an accelerometer study, for example, suppose physical activity measures were taken over a ten day monitoring period. An ICC could then be calculated for the full ten monitoring days, or for any number of days between one and ten. For example, an investigator may want to know the ICC after only seven monitoring days. Such partitioned values provide useful insight into how many monitoring days are needed to reach acceptable reliability. In addition, having such information provides another way to compare reliability measures. In addition, test-retest reliability and stability reliability can both be measured with an ICC.

Test-retest reliability is measured by subjecting an instrument to numerous, identical tests, by which an investigator can determine the instrument's capability of measuring a variable consistently (Portney & Watkins, 2000). Furthermore, test-retest reliability can be sub-divided into intra-instrument and inter-instrument reliability. Intra-instrument reliability is how consistently *one* accelerometer records similar measures when tested and re-tested repeatedly under identical conditions, whereas inter-instrument reliability is the similarity of values recorded by several like-model accelerometers when they are tested once simultaneously under identical conditions. Clearly, the test-retest reliability of a given accelerometer is important information and has been determined previously in several studies (Esliger & Tremblay, 2006; Welk et al., 2004; Howe, Dock, Camenisch, & Heil, 2007).

A common method by which intra- and inter-instrument reliabilities are measured is to subject one or several accelerometers, respectively, to a controlled, highly repeatable task. This can be accomplished with a mechanical setup, such as a shaker table, or with a human wearer repeating a task, such as treadmill walking at a fixed speed. For example, using a mechanical setup, Esliger and Tremblay (2006) found the inter-model, or inter-instrument, ICC between Actical® and Actigraph model accelerometers ranged from 0.91 to 1.00. Welk et al. (2004) found this inter-instrument reliability ranged from 0.62 to 0.80 between four different accelerometer models (CSA/MTI, Biotrainer Pro, Tritrac-R3D, and Actical) during treadmill walking. Furthermore, Howe et al. (2007) found the intra-instrument reliability of the Actical® monitor when worn on the hip and ankle ranged from 0.97 to 0.99 during treadmill walking. However, Trost et al. (2005) reported that no study has evaluated the validity and reliability of all accelerometers simultaneously. Therefore, there is not sufficient evidence of one accelerometer being more valid or reliable than another (Trost et al., 2005). Simply put, investigators "should select a make and model that has adequate evidence of validity and reliability in their study population" (Trost et al., 2005, p. S532).

While intra- and inter-instrument test-retest reliability indicates how well an accelerometer works as a unit, stability reliability tests the reliability of a task or behavior. When free-living physical activity is the behavior of interest, each monitoring day's accelerometer data are the given conditions by which stability reliability is determined. Additionally, since physical activity is variable from day to day, several monitoring days are needed to achieve high stability reliability.

Reliability Studies: Number of Monitoring Days

Several accelerometer studies have been conducted with hip-worn monitors to identify the number of monitoring days necessary for reliable measures of free-living physical activity (Coleman & Epstein, 1998; Gretebeck & Montoye, 1992; Janz et al., 1995; Matthews, Ainsworth, Thompson, & Bassett, 2002; Treuth, Sherwood, Butte, McClanahan, Obaranek, Zhou, et al., 2003; Trost, Pate, Freedson, Sallis, & Taylor, 2000). Several factors in these studies influenced the number of monitoring days needed. Particularly, the age of the population studied, investigator-defined acceptable levels of reliability, the number of consecutive monitoring days, and the days of the week (weekdays versus weekend days) during which monitoring occurred.

Generally, children require more monitoring days than adults. By comparing several reliability studies, Trost et al. (2005) found that 4 to 9 monitoring days were needed for children versus only 3 to 5 days for adults. This is because of what Trost et al. (2005) called, "the inherent differences in the amount and tempo of physical activity," between adults and children (p. S538). In fact, children only required a similar number of monitoring days (i.e., 4) compared to adults when monitoring occurred during a summer break from school (Janz et al., 1995). This is because "that during the summer, any day (Monday through Sunday) is reflective of [habitual] activity" (Janz et al., 1995, p. 1328-1329).

The range of necessary monitoring days reported by Trost et al. (2005) for both children and adults was often due to different investigator-defined acceptable levels of reliability. That is, stability reliability is usually calculated statistically from each monitoring day's data and defined as an ICC. It is then up to the investigator to determine what ICC value constitutes an acceptable reliability. For example, Janz et al. (1995) chose an ICC of 0.70, or 70% reliability, and found 4 monitoring days necessary for children to reach this level of reliability. Trost et al. (2000) found a range between 2 and 11 monitoring days necessary for children depending if the ICC was chosen to be 0.70, 0.80, or 0.90. Treuth et al. (2002) found 4 days of monitoring yielded an ICC of only 0.37, and concluded that 7 days would be necessary for children to reach an ICC of 0.80. Coleman and Epstein (1998) found 3 to 4 monitoring days necessary to reach an ICC between 0.77 and 0.82 in males who were not regularly active, while Matthews et al. (2002) also found 3 to 4 monitoring days yielded an ICC of 0.80 in adults. Gretebeck and Montoye (1992), using a slightly different statistical method, reported 5 to 6 monitoring days necessary for adults with less than 5% error. A brief summary of these studies can be found in Table 1.

Table 1. Summary of previous free-living physical activity reliability studies.

Population	Lead Author	Year	Activity Monitor	Total Monitoring Days	Desired ICC	Monitoring Days to Reach ICC
Adults	Coleman	1998	TriTrac®	7	0.77-0.82	3 to 4
Adults	Gretebeck	1992	Calcrac	7	*0.95	5 to 6
Adults	Matthews	2002	CSA	21	0.8	3 to 4
Children	Janz	1995	CSA	6	0.7	4
Children	Trost	2000	CSA	7	0.7	†3
			CSA	7	0.8	†5
			CSA	7	0.9	†11
Children	Trueth	2003	MTI/CSA	4	0.8	7

* Different statistical test indicating <5% error. † Rounded to nearest whole day. Actual values equaled 2.7, 4.7, and 10.6 days, respectively.

Another cause for the variable number of monitoring days reported is perhaps a result of a methodological difference in the studies. Most of the studies differed in the number of consecutive monitoring days physical activity was measured. Coleman and Epstein (1998), Gretebeck and Montoye (1992) and Trost et al. (2000) monitored activity for seven consecutive days, while Matthews et al. (2002) monitored for 21 consecutive days, Trueth et al. (2003) for four consecutive days, and Janz et al. (1995) for only three consecutive days (monitoring was repeated after one month for six total monitoring days) (Table 1). Thus, studies that monitored for more days than necessary to reach acceptable reliability were able to directly measure ICC values (Coleman & Epstein, 1998; Gretebeck & Montoye, 1992; Matthews et al., 2002; Trost et al., 2000), rather than calculate the number of necessary monitoring days (Treuth et al., 2003). Rather than rely on calculated ICC values, Trost et al. (2005) suggested that investigators monitor enough days so that the collected data are sufficient to reliably measure free-living physical activity.

The days of the week during which monitoring takes place are also important to consider. Several studies have found that habitual physical activity differs on weekend days (Saturday and Sunday) versus weekdays (Monday through Friday) in both adults and children (Gretebeck & Montoye, 1992; Matthews et al., 2002; Trost et al., 2000). Trost et al. (2000) found that in children (grades 1-6 or ages 6-12) physical activity was significantly higher on weekend days than weekdays, but significantly lower in adolescents (grades 7-12 or ages 13-18). Matthews et al. (2002) found that physical inactivity was less on weekend days (i.e., physical activity was greater on the weekends) in healthy adults. However, Gretebeck and Montoye (1992) found that physical activity was lower on weekend days in adult males with varying occupations. How physical activity varies from weekend days to weekdays is not so much of importance, but rather knowing that habitual physical activity can vary on weekend days. Taking this into consideration, Trost et al. (2005) made the sound recommendation that weekend days be included in any study attempting to reliably measure free-living physical activity.

Taking the above considerations to mind, Trost et al. (2005) have also proposed conservative ranges of monitoring days rather than a specific number of monitoring days for accelerometer studies. These ranges are 3 to 5 monitoring days for adults and 4 to 9 for children. However, all of the above studies used hip-worn accelerometers. No studies have determined the number of days necessary to reliably measure habitual free-living physical activity with wrist-worn accelerometers.

Monitor Placement

A number of studies have placed accelerometers on various body locations, such as the wrist, rather than the hip for various reasons (Heil, 2002; Heil, 2006; Melanson & Freedson, 1995; Patterson et al., 1993; Swartz et al., 2000). Patterson et al. (1993) used wrist-worn accelerometers to determine how well different levels of physical activity could be assessed. Because the wrist can move rapidly while the individual remains primarily physically inactive (such as playing video games), Patterson et al. (1993) found that wrist-worn accelerometers did a poor job of accurately estimating true levels of physical activity.

Swartz et al. (2000) used one accelerometer on the hip and one on the wrist to determine if the additional wrist accelerometer could improve estimates of energy expenditure in tasks that require upper-body movement. These tasks were categorized as yard work, occupation, housework, family care, conditioning, and recreation, and included tasks such as ironing, washing dishes, raking leaves, vacuuming, tennis, golf, walking, and walking carrying a load. While statistically significant, the addition of the wrist-worn accelerometer had only slight improvements in predicting energy expenditure when compared to using the hip monitor alone.

Melanson and Freedson (1995) also used accelerometers on the wrist, hip, and ankle to improve estimates of energy expenditure during treadmill walking and running. While the additional use of accelerometers at the ankle and wrist resulted in more accurate estimates of energy expenditure, Trost et al. (2005) pointed out that the differences were not physiologically significant.

For these reasons, placement of accelerometers on the hip or lower back are considered the best and are the most common placement sites (Ward et al., 2005; Trost et al., 2005). However, the studies of Patterson et al. (1993), Swartz et al. (2000), and Melanson and Freedson (1995) all used an accelerometer that only measures acceleration in one plane, or uniaxially. A commercially available accelerometer, the Actical® activity monitor (Mini Mitter Co., Inc., Bend, OR, USA), is capable of measuring acceleration in more than one plane, or omnidirectional, making it more appropriate for detecting acceleration at the wrist or ankle (Heil, 2006). Heil (2006) found his algorithm valid for predicting energy expenditure in a lab-based setting with the Actical®, but the

Actical® has not yet been tested in field-based research of free-living activity. Welk et al. (2004) originally found the Actical® to have low reliability compared to other accelerometers, but Welk (2005) later found that this could have likely been the result of an experimental version of the Actical® being used.

While the use of wrist-worn accelerometers has not improved estimates of energy expenditure, no studies have been conducted which attempt to obtain a reliable measure of habitual physical activity using a wrist-worn accelerometer.

Summary

The number of monitoring days necessary to reliably measure habitual free-living physical activity depends on the age of the population of study, the investigator-defined ICC value, the days of the week that monitoring occurs, the activity monitor being used, and how many consecutive days are monitored. It has also been found that adults require fewer monitoring days than children, an ICC of 0.80 is a commonly accepted level of reliability, and weekends should be included in monitoring days.

While the standard practice in accelerometry research is to place accelerometers on the hip, addition of accelerometers to the wrist have only been used to predict energy expenditure. In such studies the wrist-worn accelerometer has done little to improve predictions of energy expenditure. No studies have used wrist-worn accelerometers as the criterion measure to assess the reliability of habitual free-living physical activity. Omnidirectional accelerometers have been validated in lab-based research, but have not been used in field-based research.

CHAPTER THREE

METHODOLOGY

Subjects

Forty-four adults employed in various departments at Montana State University in Bozeman, Montana, volunteered to participate in this study. Subjects read and signed an informed consent form (Appendix A), approved by the Montana State University Human Subjects Review Committee, explaining the requirements and potential risks of participating in the study. Subjects were given an activity questionnaire (Appendix B) to determine their activity level and means of habitual physical activity. Subjects were excluded from the study if they habitually (at least once per week) participated in physical activities that could not be measured by the Actical® (Mini Mitter Co., Inc., Bend, OR, USA) activity monitor (e.g., swimming, bicycling, roller skating, rollerblading, roller skiing, rock climbing, weight lifting, etc.). In addition, all subjects were given the Physical Activity Readiness Questionnaire (PAR-Q) health screening questionnaire (Appendix C). Subjects needed to pass the PAR-Q to be included in the study.

Procedures

Participation in this study required two visits to the Montana State University Movement Science Laboratory in Bozeman, Montana, in addition to at least one face-to-face meeting with the investigator. During the first lab visit, subjects' descriptive and personal information (age, height, weight, and contact information) were recorded. Subjects were then given two Actical® activity monitors to be worn on the wrist and hip. The wrist-worn monitor was secured on the dorsal side of the subject's nondominant wrist (dominant was defined as the hand the subject preferred for writing) just proximal to the ulnar styloid via a plastic band and secured by a locking button. Once locked, wristbands could only be removed by cutting the plastic. Subjects were instructed to place the hip-worn monitor on the beltline just anterior to the right iliac crest via a plastic clip. The hip-worn monitors were thus removable, and subjects were instructed to only remove them during showering, swimming or sleeping. With the exception of those three activities, subjects were instructed to keep the hip-worn monitor attached for a minimum of 12 consecutive hours each day (i.e., one monitoring day). In addition, for each monitoring day subjects were instructed to record the times at which the hip-worn monitor was donned and doffed and for what purpose (i.e., waking, sleeping, showering or swimming). One notebook was provided to each subject for this purpose.

Compliance issues with the hip-worn monitor were also addressed during the first lab visit. High compliance was viewed as wearing the hip-worn monitor exactly as instructed by the investigator or as closely as possible. Conversely, low compliance was wearing the hip-worn monitor infrequently or not as instructed. Each subject was then shown two sets of sample Actical® data. These data illustrated the difference between high and low compliance with the hip-worn monitor for a full monitoring day. This showed the subjects that the investigator could determine each subject's compliance and served as an attempt to elicit higher compliance rates among subjects.

The first lab visit took place on a weekday (Monday through Friday), and subjects were instructed to return to the lab 15 days later for their second lab visit, which allowed for 14 consecutive monitoring days including four weekend days (Saturday and Sunday). For the 14 monitoring days subjects were instructed to carry out their daily free-living activities, occupational and recreational, as usual. During the second lab visit, both monitors were collected and the data were downloaded to an IBM-compatible personal computer using software supplied by the Actical ® manufacturer.

Subjects were contacted via phone and e-mail on the morning following the first lab visit to remind them to wear the hip-worn monitor. A face-to-face meeting was also arranged during the first week of monitoring to determine any problems subjects had encountered. Secondarily, this meeting served as another attempt to raise subject compliance rates. Subsequent phone calls and e-mails followed every two to three days for the duration of the 14 monitoring days. If low compliance issues existed, a second face-to-face meeting was arranged during the second week of monitoring.

Instrumentation

The Actical® activity monitor (Mini Mitter Co., Inc., Bend, OR, USA) is a small, lightweight (2.8 x 2.7 x 1.0 cm^3, 17 g, respectively), water resistant, accelerometer used to measure physical activity. Capable of measuring acceleration due to bodily movement in three planes, the Actical® is an omnidirectional accelerometer. Unlike other triaxial accelerometers, the manufacturer claims that the Actical® is more sensitive to acceleration along one axis. A blue arrow on the face of each monitor indicates this axis.

The wrist-worn monitors were positioned with the blue arrow pointed proximally towards the elbow, while the hip-worn monitors were positioned with the blue arrow pointed superiorly towards the head. Fifty-four Actical® monitors were used in this study. Furthermore, before distribution to the subjects, monitors were set to sample in one-minute epochs and the resulting raw data were reported in counts/min.

Subjects' height and mass were recorded during the first lab visit with a Health o meter® PRO Series (Health o meter, Inc., Bridgeview, IL, USA) Balance Beam Scale to the nearest 0.1 cm and 0.1 kg, respectively.

Accelerometer Data Screening and Processing

The raw accelerometer data files were visually inspected for wearing compliance and data integrity using the monitors' software (Actical V2.0, Mini Mitter Co., Inc., Bend, OR, USA). Each accelerometer file had to satisfy the following criteria prior to further processing: 1) The subject must have worn the monitor at least 14 full monitoring days (including four weekend days) during the specified wearing period; 2) A "full monitoring day" was defined as at least 12 hours of continuous monitoring from the first to last bursts of activity data; 3) The 12-hour minimum could include a single one-hour period of unaccounted-for activity. Partial days (<12 hrs) were counted in the analyses if they were reflective of the subject's behavior pattern that day and were accounted for in the notebook provided during the first visit. Actual wearing time was inferred by the mild burst of activity associated with donning and doffing the monitor in the morning and evenings, respectively, and verified by the times recorded in each subject's notebook.

The accelerometers were initialized to record continuously using one minute epochs. The raw activity data for each subject were imported into a custom Visual Basic (Version 6.0) program for conversion to minute-by-minute activity energy expenditure (AEE, kcals/kg/min) using previously validated hip and wrist "2R" (i.e., double regression modeling) algorithms for adults (Heil, 2006). These algorithms were validated in a lab-based setting for both whole- and upper-body activities, such as sweeping, vacuuming, and treadmill walking.

Each algorithm determined AEE by a four-step process based on predefined cut points of raw activity data. If raw activity output was below 50 counts/min, AEE was determined to be zero kcals/kg/min for both the hip and wrist monitors. If the raw activity monitor output was between 50 and 350 counts/min for the hip monitor or between 50 and 600 counts/min for the wrist monitor, AEE was given a constant value of 0.007565 kcals/kg/min. If the activity output fell between lower and upper cut points (350 to 1,200 and 600 to 2,000 counts/min for the hip and wrist monitors, respectively) a prediction equation was used to estimate AEE. Finally, if the raw activity data were above the upper cut point (1,200 and 2,000 counts/min for the hip and wrist, respectively) a second prediction equation was used. These algorithms are summarized in Table 2.

Table 2. Summary of Heil's (2006) 2R algorithms for converting raw activity monitor output to activity energy expenditure (AEE) in adults.

Location	CP1	CP2	AEE constant when 50 < AC < CP1	Predicted AEE when CP1 ≤ AC ≤ CP2	Predicted AEE when AC ≥ CP2
Hip	350	1,200	0.007565	AEE = 0.01217 + (5.268E-5) x AC	AEE = 0.02663 + (1.107E-5) x AC
Wrist	600	2,000	0.007565	AEE = 0.008006 + (2.355E-5)	AEE = 0.04184 + (3.960E-6) x AC

Note. AC = activity monitor output (counts/min); CP1 = lower AC cut point; CP2 = upper AC cut point; AEE = activity energy expenditure (kcals/kg/min).

After conversion to AEE, the program then searched each AEE file for predetermined bouts (minimum one, three, five, eight and ten consecutive minutes) of activity that met or exceeded a moderate intensity. The AEE cut points corresponding to moderate intensity (≥3.0 METs and <6.0 METs) were 0.0310 kcals/kg/min ≤ moderate intensity < 0.0832 kcals/kg/min (Heil, 2006). The outcome of this search was the total time spent at or above the specified threshold intensity (T_{MV}), as well as the corresponding summation of AEE (AEE_{MV}) and activity counts (CNT_{MV}) for each bout duration and monitoring day. Figures 1 and 2 show "dummy" raw activity output from a hip-worn monitor, and the corresponding AEE values from the 2R algorithm, respectively, to illustrate bouts of moderate or vigorous intensity activity for one, three, five, eight and ten consecutive minutes.

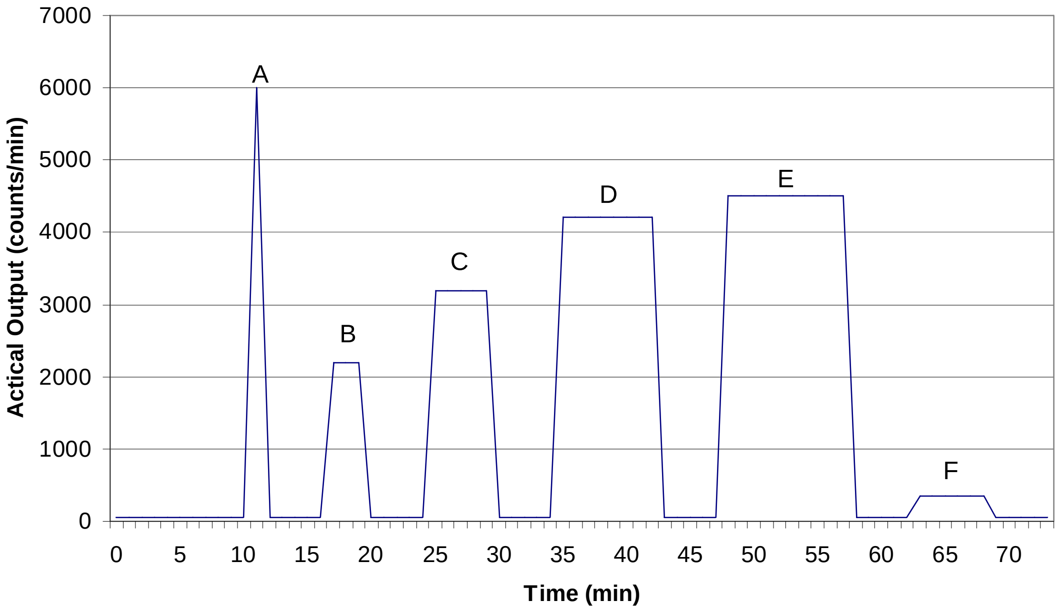

Figure 1. Sample Actical® monitor output from a dummy file demonstrating 1- through 10-minute bouts of moderate to vigorous intensity and a bout of sedentary/light intensity activity. A = 1-minute bout. B = 3-minute bout. C = 5-minute bout. D = 8-minute bout. E = 10-minute bout. F = Sedentary/light bout.

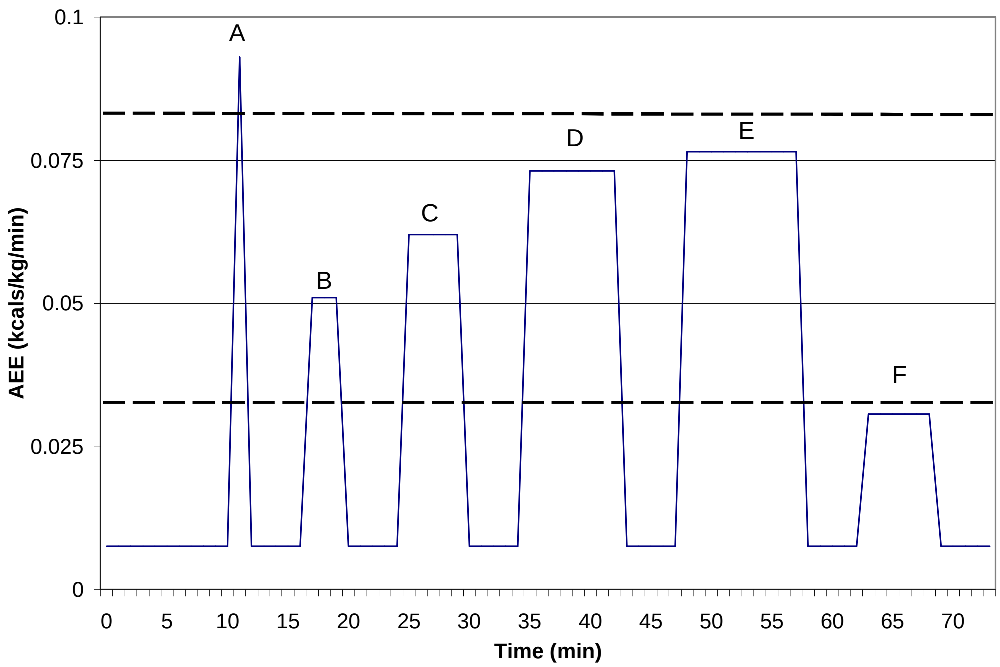

Figure 2. Sample activity energy expenditure (AEE) from a dummy file demonstrating 1-, 5-, 8-, and 10-minute bouts of moderate to vigorous activity and one bout of sedentary/light intensity activity. *Note*. A = 1-minute vigorous bout; B = 3-minute moderate bout; C = 5-minute moderate bout; D = 8-minute moderate bout; E = 10-minute moderate bout; F = Sedentary/light bout. Lines at 0.0310 and 0.0832 kcals/kg/min represent the lower and upper cut points for moderate intensity activity, respectively.

A search of the data presented in Figure 2 for one-minute bouts of moderate or greater intensity activity would yield five different activity bouts; that is, bouts A-E. Similarly, a search for three-minute bouts would yield four different activity bouts (sum of bouts B-E), a search for five-minute bouts, three (sum of bouts C-E), etc. Thus, the resulting T_{MV} from Figure 2 for a search of one-minute bouts at or above a moderate intensity would be 27 minutes (sum of bouts A-E). The T_{MV} for a search of three-minute bouts would be 26 minutes (sum of bouts B-E), while T_{MV} for a search of five-minute bouts would be 23 minutes (sum of bouts C-E), etc.

The resulting summation of AEE_{MV} is similarly calculated. The sum of AEE values from each activity bout at or above a moderate intensity are summed and multiplied by the subject's body mass to yield the total AEE_{MV} for each monitoring day. For example, the AEE values from Figure 2 for bouts A-E are 0.0931, 0.0510, 0.0621, 0.0731 and 0.0764 kcals/kg/min, respectively, for each minute of duration. For bout A, the total AEE_{MV} is thus 0.0931 kcals/kg/min time body mass, while for bout B, AEE_{MV} is 0.1529 kcals/kg/min (0.0510+0.0510+0.0510) times body mass, for bout C, AEE_{MV} is 0.3103 kcals/kg/min (0.0621+0.0621+0.0621+0.0621+0.0621) times body mass, etc. Thus, the AEE_{MV} value for one-minute bouts would once again be the sum of AEE_{MV} values from bouts A-E, the AEE_{MV} for three-minute bouts the sum AEE_{MV} of bouts B-E, etc. While searching for multi-minute bouts decreases precision, the resulting values were more consistent with the guidelines set by Pate et al. (1995), which state that physical activity should be accumulated in eight- to ten-minutes.

Lastly, CNT_{MV} values are determined by first converting the activity monitor output to AEE, and then determining if those AEE values fall above the moderate cut point (lower dotted line in Figure 2). If so, the CNT value used in the 2R algorithm is determined to be in the moderate range. Those values are then summed in the same way T_{MV} and AEE_{MV} are summed for each time bout of interest.

Data Analyses

Mean and standard deviation of subjects' demographic characteristics were first calculated. Mean and standard error values of summed activity counts, the time and AEE at or above a moderate intensity activity (dependent variables) were also calculated. Intraclass correlation coefficients (ICC) for the dependent variables were then determined using a two-factor (Subjects x Days) repeated measures analysis of variance (RMANOVA). The RMANOVA was conducted for each monitoring location (hip and wrist) for minimum bout durations of one, three, five, eight and ten consecutive minutes. The resulting ANOVA tables were used to calculate an average ICC for each variable over the entire monitoring period as:

$$ICC = \frac{\sigma_w^2 - \sigma_b^2}{\sigma_w^2} \quad (1)$$

where σ_w^2 is within-subject variance and σ_b^2 is between-subject variance calculated as:

$$\sigma_b^2 = \frac{SS_{DAY} + SS_{ERROR}}{DF_{DAY} + DF_{ERROR}} \quad (2)$$

Where SS_{DAY} , SS_{ERROR} and DF_{DAY} , DF_{ERROR} are sum of squares and degrees of freedom values, respectively, from the resulting ANOVA tables. Thus, these average ICC values represented the stability reliability for each dependent variable across 14 days of monitoring. The same variance scores were then used to calculate the reliability for each dependent variable for both monitor wearing locations across one to 14 days:

$$ICC_{DAY} = \frac{\sigma_w^2 - \sigma_b^2}{\sigma_w^2 + [(N/N') - 1)] \cdot (\sigma_b^2)} \quad (3)$$

where N is the total number of monitoring days (i.e., 14) and N' is the number of days of monitoring between one and 14 for which ICC is estimated (Baumgartner & Jackson, 1995). For each pair of ICC_{DAY} values (one dependent variable across two monitor wearing locations), 95% confidence intervals were calculated as described by Morrow and Jackson (1993). This was done to determine whether the calculated reliability values were significantly different for N days of monitoring (i.e., the calculated 95% confidence intervals do not overlap).

Intraclass correlation coefficient values for each variable and time bout after 14 monitoring days were then compared between monitor wearing locations. In addition, the number of days to reach an ICC of 0.80 for each variable and time bout was compared between wearing locations. This provided a second way to view the ICC data, and to determine the minimum number of monitoring days necessary for future studies to reach an acceptable ICC value.

CHAPTER FOUR

RESULTS

The purpose of this study was to compare intraclass correlation coefficients (ICC) values of habitual free-living physical activity between wrist- and hip-worn Actical® accelerometers through 14 consecutive days of monitoring. The ICC values were determined using a two-factor (Subjects x Days) repeated measures analysis of variance (RMANOVA). The RMANOVA was conducted for each monitor wearing location (hip and wrist) for bouts of one, three, five, eight and ten consecutive minutes. The variance scores from the resulting ANOVA tables were used to calculate an average ICC for three variables over the entire monitoring period (14 days) and for each single day of monitoring. The three dependent variables of interest in this study were as follows: the raw activity count values (CNT_{MV}, counts/day) at or above specified moderate intensity activity thresholds, and the corresponding summation of total time (T_{MV}, mins/day) and activity energy expenditure (AEE_{MV}, kcals/day) spent at or above a moderate intensity. Before any data analysis occurred, subjects' raw data were reordered so that the first Monday of the monitoring period became the first monitoring day for all subjects. Monitoring days prior to the first Monday were placed sequentially as the last monitoring days. Since not all subjects began their monitoring period on the same day of the week, this served to make the test order of days within the ANOVA analysis consistent for all subjects.

Forty-four subjects (28 female, 16 male) volunteered to wear both monitors for the full 14 monitoring days. However, data from only 40 subjects (25 female, 15 male) were used in the final calculations. Four subjects' data were dropped for one of each of the following four reasons: monitor malfunction, hardware errors during data download, low compliance, and non-habitual activity (i.e., an asthma-induced overnight hospital visit and an automobile accident). Demographic measures for the 40 subjects are summarized in Table 3.

Table 3. Subject demographic characteristics (Mean ± SD).

	N	Age (years)	Height (cm)	Weight (kg)	BMI (kg/m^2)
Men	15	31.7 ± 12.3	180.0 ± 7.9	87.5 ± 18.4	26.9 ± 4.7
Women	25	40.9 ± 12.2	165.8 ± 5.7	70.2 ± 14.2	25.6 ± 5.2
All Subjects	40	39.5 ± 12.2	171.1 ± 9.5	76.7 ± 18.4	26.1 ± 5.0

Initial Intraclass Correlation Coefficient Caluculations

Intraclass correlation coefficients were calculated to determine the stability reliability for all three dependent variables (CNT_{MV}, counts/day, T_{MV}, mins/day, AEE_{MV}, kcals/day) and time bouts for both the wrist- and hip-worn monitors. Mean and standard error values for each variable, time bout, and monitor location are shown in Tables 4 and 5 while the ICC values are shown in Tables 6-11.

Table 4. Dependent variable values (Mean±SE) from the hip-worn monitor by minimum time bout (n = 40).

Time Bout (min)	CNT_{MV} (counts/day)	T_{MV} (min/day)	AEE_{MV} (kcals/day)
1	193,032 ± 5,894	154.5 ± 3.5	587.5 ± 16.2
3	148,761 ± 5,600	96.7 ± 3.1	392.1 ± 14.0
5	114,996 ± 5,150	64.5 ± 2.5	272.4 ± 11.6
8	82,467 ± 4,610	40.2 ± 2.0	177.5 ± 9.3
10	67,183 ± 4,305	30.6 ± 1.7	139.7 ± 8.3

CNT_{MV} = Raw activity monitor counts at or above a moderate intensity activity.
T_{MV} = Time at or above a moderate intensity activity.
AEE_{MV} = Activity energy expenditure at or above a moderate intensity activity.

Table 5. Descriptive variable values (Mean±SE) from the wrist-worn monitor by minimum time bout (n = 40).

Time Bout (min)	CNT_{MV} (counts/day)	T_{MV} (min/day)	AEE_{MV} (kcals/day)
1	543,157 ± 25,176	255.2 ± 5.5	915.6 ± 30.1
3	443,287 ± 25,290	187.7 ± 5.1	697.9 ± 26.6
5	353,907 ± 22,259	141.6 ± 4.6	539.3 ± 23.8
8	262,301 ± 17,990	98.6 ± 3.9	386.0 ± 20.4
10	220,964 ± 16,762	80.3 ± 3.6	319.4 ± 18.9

CNT_{MV} = Raw activity monitor counts at or above a moderate intensity activity.
T_{MV} = Time at or above a moderate intensity activity.
AEE_{MV} = Activity energy expenditure at or above a moderate intensity activity.

Table 6. Intraclass correlation coefficients (ICC) with 95% confidence intervals (CI) for hip-worn raw counts per minute at or above a moderate intensity (CNT_{MV}). Boxed ICC values indicate desired reliability of ≥ 0.80 (n = 40).

		Day													
Time Bout (min)		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	ICC	0.57	0.73	0.80	0.84	0.87	0.89	0.90	0.92	0.92	0.93	0.94	0.94	0.95	0.95
	Upper 95% CI	0.75	0.85	0.89	0.92	0.93	0.94	0.95	0.96	0.96	0.96	0.97	0.97	0.97	0.97
	Lower 95% CI	0.32	0.54	0.65	0.72	0.77	0.80	0.83	0.85	0.86	0.87	0.88	0.89	0.90	0.91
3	ICC	0.57	0.73	0.80	0.84	0.87	0.89	0.90	0.92	0.92	0.93	0.94	0.94	0.95	0.95
	Upper 95% CI	0.75	0.85	0.89	0.92	0.93	0.94	0.95	0.96	0.96	0.96	0.97	0.97	0.97	0.97
	Lower 95% CI	0.32	0.54	0.65	0.72	0.77	0.80	0.83	0.85	0.86	0.87	0.88	0.89	0.90	0.91
5	ICC	0.58	0.73	0.80	0.84	0.87	0.89	0.90	0.92	0.92	0.93	0.94	0.94	0.95	0.95
	Upper 95% CI	0.75	0.85	0.89	0.92	0.93	0.94	0.95	0.96	0.96	0.96	0.97	0.97	0.97	0.97
	Lower 95% CI	0.32	0.54	0.66	0.72	0.77	0.80	0.83	0.85	0.86	0.87	0.88	0.89	0.90	0.91
8	ICC	0.56	0.71	0.79	0.83	0.86	0.88	0.90	0.91	0.92	0.93	0.93	0.94	0.94	0.95
	Upper 95% CI	0.74	0.84	0.88	0.91	0.93	0.94	0.95	0.95	0.96	0.96	0.96	0.97	0.97	0.97
	Lower 95% CI	0.30	0.52	0.63	0.71	0.75	0.79	0.81	0.83	0.85	0.86	0.88	0.88	0.89	0.90
10	ICC	0.56	0.72	0.79	0.83	0.86	0.88	0.90	0.91	0.92	0.93	0.93	0.94	0.94	0.95
	Upper 95% CI	0.74	0.84	0.88	0.91	0.93	0.94	0.95	0.95	0.96	0.96	0.96	0.97	0.97	0.97
	Lower 95% CI	0.30	0.52	0.64	0.71	0.75	0.79	0.81	0.83	0.85	0.86	0.88	0.89	0.89	0.90

Table 7. Intraclass correlation coefficients (ICC) with 95% confidence intervals (CI) for wrist-worn raw counts per minute at or above a moderate intensity (CNT_{MV}). Boxed ICC values indicate desired reliability of ≥ 0.80 (n = 40).

		Day													
Time Bout (min)		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	ICC	0.29	0.45	0.55	0.62	0.67	0.71	0.74	0.77	0.79	**0.81**	0.82	0.83	0.84	0.85
	Upper 95% CI	0.55	0.67	0.74	0.78	0.82	0.84	0.86	0.87	0.88	0.89	0.90	0.91	0.92	0.92
	Lower 95% CI	-0.02	0.17	0.29	0.39	0.46	0.52	0.56	0.60	0.63	0.66	0.68	0.70	0.72	0.74
3	ICC	0.29	0.45	0.55	0.62	0.67	0.71	0.74	0.77	0.79	**0.80**	0.82	0.83	0.84	0.85
	Upper 95% CI	0.55	0.67	0.74	0.78	0.81	0.84	0.86	0.87	0.88	0.89	0.90	0.91	0.91	0.92
	Lower 95% CI	-0.02	0.16	0.29	0.39	0.46	0.51	0.56	0.60	0.63	0.66	0.68	0.70	0.72	0.74
5	ICC	0.28	0.43	0.54	0.61	0.66	0.70	0.73	0.75	0.78	0.79	**0.81**	0.82	0.83	0.84
	Upper 95% CI	0.54	0.66	0.73	0.77	0.80	0.83	0.85	0.86	0.88	0.89	0.90	0.90	0.92	0.92
	Lower 95% CI	-0.04	0.14	0.27	0.36	0.44	0.49	0.54	0.58	0.61	0.64	0.66	0.69	0.71	0.72
8	ICC	0.28	0.44	0.54	0.61	0.66	0.70	0.73	0.76	0.78	**0.80**	0.81	0.83	0.84	0.85
	Upper 95% CI	0.55	0.66	0.73	0.78	0.81	0.83	0.85	0.87	0.88	0.89	0.90	0.90	0.91	0.92
	Lower 95% CI	-0.03	0.15	0.28	0.37	0.44	0.50	0.55	0.59	0.62	0.65	0.67	0.69	0.71	0.73
10	ICC	0.26	0.41	0.51	0.58	0.64	0.68	0.71	0.74	0.76	0.78	0.79	**0.81**	0.82	0.83
	Upper 95% CI	0.53	0.64	0.71	0.76	0.79	0.82	0.84	0.85	0.87	0.88	0.89	0.90	0.90	0.91
	Lower 95% CI	-0.06	0.12	0.24	0.33	0.41	0.47	0.51	0.55	0.59	0.62	0.64	0.66	0.67	0.70

Table 8. Intraclass correlation coefficients (ICC) with 95% confidence intervals (CI) for hip-worn time at or above a moderate intensity (T_{MV}). Boxed ICC values indicate desired reliability of ≥ 0.80 (n = 40).

		Day													
Time Bout (min)		1	2	3	4	5	6	7	8	9	10	11	12	13	14
	ICC	0.62	0.77	0.83	0.87	0.89	0.91	0.92	0.93	0.94	0.94	0.95	0.95	0.95	0.96
1	Upper 95% CI	0.78	0.87	0.91	0.93	0.94	0.95	0.96	0.96	0.97	0.97	0.97	0.97	0.98	0.98
	Lower 95% CI	0.38	0.60	0.70	0.76	0.80	0.83	0.85	0.87	0.88	0.89	0.90	0.91	0.92	0.92
	ICC	0.60	0.75	0.82	0.85	0.88	0.90	0.91	0.92	0.93	0.94	0.94	0.95	0.95	0.95
3	Upper 95% CI	0.77	0.86	0.90	0.92	0.94	0.95	0.95	0.96	0.96	0.97	0.97	0.97	0.97	0.98
	Lower 95% CI	0.35	0.57	0.68	0.74	0.78	0.82	0.84	0.86	0.87	0.88	0.89	0.90	0.91	0.91
	ICC	0.55	0.71	0.78	0.83	0.86	0.88	0.89	0.91	0.92	0.92	0.93	0.93	0.94	0.94
5	Upper 95% CI	0.73	0.83	0.88	0.91	0.92	0.93	0.94	0.95	0.96	0.96	0.96	0.97	0.97	0.97
	Lower 95% CI	0.28	0.51	0.62	0.70	0.74	0.78	0.81	0.83	0.84	0.86	0.87	0.88	0.89	0.90
	ICC	0.45	0.62	0.71	0.76	0.80	0.83	0.85	0.87	0.88	0.89	0.90	0.91	0.91	0.92
8	Upper 95% CI	0.67	0.78	0.84	0.87	0.89	0.91	0.92	0.93	0.94	0.94	0.95	0.95	0.95	0.96
	Lower 95% CI	0.16	0.38	0.51	0.59	0.65	0.70	0.73	0.76	0.78	0.80	0.82	0.83	0.84	0.85
	ICC	0.42	0.59	0.69	0.75	0.79	0.81	0.84	0.85	0.87	0.88	0.89	0.90	0.90	0.91
10	Upper 95% CI	0.65	0.76	0.82	0.86	0.88	0.90	0.91	0.92	0.93	0.94	0.94	0.95	0.95	0.95
	Lower 95% CI	0.13	0.35	0.48	0.57	0.63	0.67	0.71	0.74	0.76	0.78	0.80	0.81	0.83	0.84

Table 9. Intraclass correlation coefficients (ICC) with 95% confidence intervals (CI) for wrist-worn time at or above a moderate intensity (T_{MV}). Boxed ICC values indicate desired reliability of ≥ 0.80 (n = 40).

Time Bout (min)		Day 1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	ICC	0.57	0.72	0.80	0.84	0.87	0.89	0.90	0.91	0.92	0.93	0.94	0.94	0.94	0.95
	Upper 95% CI	0.75	0.85	0.89	0.91	0.93	0.94	0.95	0.95	0.96	0.96	0.97	0.97	0.97	0.97
	Lower 95% CI	0.31	0.53	0.65	0.72	0.76	0.80	0.82	0.84	0.86	0.87	0.88	0.89	0.90	0.90
3	ICC	0.58	0.73	0.80	0.85	0.87	0.89	0.91	0.92	0.92	0.93	0.94	0.94	0.95	0.95
	Upper 95% CI	0.75	0.85	0.89	0.92	0.93	0.94	0.95	0.96	0.96	0.96	0.97	0.97	0.97	0.97
	Lower 95% CI	0.33	0.55	0.66	0.73	0.77	0.80	0.83	0.85	0.86	0.87	0.88	0.89	0.90	0.91
5	ICC	0.56	0.71	0.79	0.83	0.86	0.88	0.90	0.91	0.92	0.93	0.93	0.94	0.94	0.95
	Upper 95% CI	0.74	0.84	0.88	0.91	0.93	0.94	0.95	0.95	0.96	0.96	0.96	0.97	0.97	0.97
	Lower 95% CI	0.30	0.52	0.63	0.71	0.75	0.79	0.81	0.83	0.85	0.86	0.88	0.88	0.89	0.90
8	ICC	0.52	0.69	0.77	0.81	0.85	0.87	0.88	0.90	0.91	0.92	0.92	0.93	0.93	0.94
	Upper 95% CI	0.72	0.82	0.87	0.90	0.92	0.93	0.94	0.95	0.95	0.96	0.96	0.96	0.97	0.97
	Lower 95% CI	0.25	0.48	0.60	0.67	0.73	0.76	0.79	0.81	0.83	0.85	0.86	0.87	0.88	0.89
10	ICC	0.49	0.66	0.74	0.79	0.83	0.85	0.87	0.88	0.90	0.91	0.91	0.92	0.93	0.93
	Upper 95% CI	0.69	0.72	0.86	0.89	0.91	0.92	0.93	0.94	0.94	0.95	0.95	0.96	0.96	0.96
	Lower 95% CI	0.21	0.25	0.56	0.64	0.69	0.74	0.77	0.79	0.81	0.83	0.84	0.85	0.86	0.87

Table 10. Intraclass correlation coefficients (ICC) with 95% confidence intervals (CI) for hip-worn activity energy expenditure at or above a moderate intensity (AEE_{MV}). Boxed ICC values indicate desired reliability of ≥ 0.80 (n = 40).

Time Bout (min)		Day 1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	ICC	0.71	0.83	0.88	0.91	0.93	0.94	0.95	0.95	0.96	0.96	0.96	0.97	0.97	0.97
	Upper 95% CI	0.84	0.91	0.94	0.95	0.96	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.98	0.99
	Lower 95% CI	0.52	0.70	0.79	0.83	0.86	0.88	0.90	0.91	0.92	0.93	0.93	0.94	0.94	0.95
3	ICC	0.66	0.80	0.85	0.89	0.91	0.92	0.93	0.94	0.95	0.95	0.96	0.96	0.96	0.96
	Upper 95% CI	0.81	0.89	0.92	0.94	0.95	0.96	0.96	0.97	0.97	0.97	0.98	0.98	0.98	0.98
	Lower 95% CI	0.44	0.64	0.71	0.79	0.83	0.86	0.87	0.89	0.90	0.91	0.92	0.92	0.93	0.93
5	ICC	0.59	0.75	0.81	0.85	0.88	0.90	0.91	0.92	0.93	0.94	0.94	0.95	0.95	0.95
	Upper 95% CI	0.76	0.86	0.90	0.92	0.94	0.95	0.95	0.96	0.96	0.97	0.97	0.97	0.97	0.98
	Lower 95% CI	0.35	0.57	0.67	0.74	0.78	0.81	0.84	0.86	0.87	0.88	0.83	0.90	0.91	0.91
8	ICC	0.49	0.65	0.74	0.79	0.83	0.85	0.87	0.88	0.89	0.90	0.91	0.92	0.92	0.93
	Upper 95% CI	0.69	0.80	0.85	0.89	0.90	0.92	0.93	0.94	0.94	0.95	0.95	0.96	0.96	0.96
	Lower 95% CI	0.21	0.43	0.56	0.64	0.69	0.73	0.76	0.79	0.81	0.83	0.84	0.85	0.86	0.87
10	ICC	0.46	0.63	0.72	0.77	0.81	0.84	0.86	0.87	0.89	0.90	0.90	0.91	0.92	0.92
	Upper 95% CI	0.68	0.79	0.84	0.88	0.90	0.91	0.92	0.93	0.94	0.94	0.95	0.95	0.96	0.96
	Lower 95% CI	0.18	0.40	0.53	0.61	0.67	0.71	0.75	0.77	0.79	0.81	0.83	0.84	0.85	0.86

Table 11. Intraclass correlation coefficients (ICC) with 95% confidence intervals (CI) for wrist-worn activity energy expenditure at or above a moderate intensity (AEE_{MV}). Boxed ICC values indicate desired reliability of ≥ 0.80 (n = 40).

		Day													
Time Bout (min)		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	ICC	0.45	0.62	0.71	0.76	0.80	0.83	0.85	0.87	0.88	0.89	0.90	0.91	0.91	0.92
	Upper 95% CI	0.67	0.78	0.84	0.87	0.89	0.91	0.92	0.93	0.94	0.94	0.95	0.95	0.95	0.96
	Lower 95% CI	0.16	0.38	0.51	0.59	0.65	0.70	0.73	0.76	0.78	0.80	0.82	0.83	0.84	0.85
3	ICC	0.43	0.60	0.70	0.75	0.79	0.82	0.84	0.86	0.87	0.88	0.89	0.90	0.91	0.91
	Upper 95% CI	0.66	0.77	0.83	0.86	0.89	0.90	0.91	0.92	0.93	0.94	0.94	0.95	0.95	0.95
	Lower 95% CI	0.14	0.36	0.49	0.58	0.64	0.69	0.72	0.75	0.77	0.79	0.81	0.82	0.83	0.84
5	ICC	0.40	0.58	0.67	0.73	0.77	0.80	0.83	0.84	0.86	0.87	0.88	0.89	0.90	0.90
	Upper 95% CI	0.64	0.75	0.81	0.85	0.87	0.89	0.91	0.92	0.92	0.93	0.94	0.94	0.95	0.95
	Lower 95% CI	0.11	0.32	0.46	0.54	0.61	0.66	0.69	0.72	0.75	0.77	0.79	0.80	0.82	0.83
8	ICC	0.37	0.54	0.64	0.70	0.74	0.78	0.80	0.82	0.84	0.85	0.87	0.88	0.88	0.89
	Upper 95% CI	0.07	0.27	0.41	0.50	0.57	0.62	0.66	0.69	0.72	0.74	0.46	0.78	0.79	0.80
	Lower 95% CI	0.07	0.27	0.41	0.50	0.57	0.62	0.66	0.69	0.72	0.74	0.76	0.78	0.79	0.80
10	ICC	0.33	0.50	0.60	0.67	0.71	0.75	0.78	0.80	0.82	0.83	0.85	0.86	0.87	0.88
	Upper 95% CI	0.58	0.70	0.77	0.81	0.84	0.86	0.88	0.89	0.90	0.91	0.92	0.92	0.93	0.93
	Lower 95% CI	0.03	0.22	0.36	0.45	0.52	0.57	0.62	0.65	0.68	0.71	0.73	0.75	0.76	0.78

While there were no significant differences in ICC values (i.e., 95% confidence intervals overlapped), substantial differences were observed between the hip- and wrist-worn monitors for two dependent variables. Tables 6 and 7 (hip- and wrist-worn CNT_{MV}, respectively), and Tables 10 and 11 (hip- and wrist-worn AEE_{MV}, respectively), show the wrist monitor ICC's were lower than the hip monitor ICC's for any given number of days for CNT_{MV} and AEE_{MV}. Across all time bouts for CNT_{MV}, 3 to 4 monitoring days were necessary for the hip-worn monitor to reach an ICC of 0.80 while the wrist-worn monitor required 10 to 12 monitoring days. Similarly, the hip-worn monitor required 2 to 5 monitoring days to reach an ICC of 0.80 for AEE_{MV} while the wrist-worn monitor required 5 to 8 monitoring days. However, Tables 8 and 9 (hip- and wrist-worn T_{MV}, respectively) show that for all time bouts, T_{MV} ICC for the wrist- and hip-worn monitors were almost identical, requiring only 3 to 5 and 3 to 6 monitoring days, respectively, to reach an ICC of 0.80. Tables 6 through 11 also show a clear trend for ICC values to decrease as bout length increased for any given number of days. That is, it took between 1 and 3 days longer for a given variable to reach the same ICC as bout length increase from one to ten minutes. The findings from Tables 6-11 are summarized in Table 12.

Table 12. Number of days to reach desired ICC of ≥ 0.80 for each dependent variable and wearing location across all bout durations (n = 40).

	Dependent Variable		
Monitor Location	CNT_{MV}	AEE_{MV}	T_{MV}
Hip	3-4 days	2-5 days	3-6 days
Wrist	10-12 days	5-8 days	3-5 days

CNT_{MV} = Raw activity monitor counts at or above a moderate intensity activity (counts/day).
T_{MV} = Time at or above a moderate intensity activity (min/day).
AEE_{MV} = Activity energy expenditure at or above a moderate intensity activity (kcal/day).

Activity Differences by Day Type

Differences in physical activity between weekdays (Monday through Friday) and weekend days (Saturday and Sunday) as expressed by each dependent variable (CNT_{MV}, counts/day, T_{MV}, mins/day, AEE_{MV}, kcals/day) were also examined. Each monitoring day for each subject was classified as either a weekday or a weekend day. A RMANOVA with a Sheffe's post-hoc all-pairwise comparison ($\alpha = 0.05$) was then used to compare differences between day type (weekday vs. weekend) for each dependent variable, bout length and monitor wearing location. Tables 13 and 14 show the mean values and standard error for each dependent variable and monitor wearing location.

Overall, there was no substantial difference in physical activity between day type for all subjects within a given time bout. Higher values were observed from the wrist-worn monitor than the hip-worn monitor across all variables and time bouts. Furthermore, as time bouts increased, mean values of all variables for both the hip- and wrist-worn monitors decreased. For the hip-worn monitor, significant differences in mean values between time bouts and day types for all three variables were generally limited between one- and three-minute and three- and five-minute bouts. Fewer significant differences were present with mean values from the wrist-worn monitor.

Differences in mean wearing time for the hip-worn monitor were next examined. The overall group mean wear time was 15.3 ± 1.0 hours/day. These values were similar when just weekdays were examined (15.6 ± 1.1 hours/day). However, wearing time was less on weekend days with wearing time equal to 14.4 ± 1.3 hours/day.

Table 13. Summary statistics of dependent variables (Mean±SE) for weekdays (Mon.-Fri.) and weekends (Sat. & Sun.) from the hip-worn monitor (n = 40).

	CNT_{MV} (counts/day)		T_{MV} (mins/day)		AEE_{MV} (kcals/day)	
Time Bout (min)	Weekdays	Weekends	Weekdays	Weekends	Weekdays	Weekends
1	205,755 ± 16,978	175,072 ± 20,605	159.1 ± 11.1	150.3 ± 11.7	611.0 ± 535.1	561.8 ± 54.8
3	157,928 ± 16,587[a]	125,844 ± 19,758[a,b]	99.6 ± 9.5[a,b]	89.5 ± 10.8[a,b]	406.0 ± 44.4[a,b]	357.1 ± 50.2[a,b]
5	122,746 ± 15,459	95,622 ± 17,399[b]	66.9 ± 7.5[a]	58.3 ± 8.9[a,b]	283.0 ± 34.4[a]	245.8 ± 42.4[b]
8	86,019 ± 13,484	73,586 ± 15,342[b]	41.0 ± 5.1	38.0 ± 7.0[b]	180.7 ± 24.3	169.7 ± 34.2
10	69,570 ± 12,674	61,214 ± 14,025	30.8 ± 4.2	30.2 ± 6.4	140.1 ± 20.9	138.67 ± 31.0

a = statistically different ($p < 0.05$) than previous time bout. **b** = statistically different ($p < 0.05$) than previous time bout and opposite day type. CNT_{MV} = Raw activity monitor counts at or above a moderate intensity activity. T_{MV} = Time at or above a moderate intensity activity. AEE_{MV} = Activity energy expenditure at or above a moderate intensity activity. While not significant, all mean values tend to be lower on weekend days than weekdays.

Table 14. Summary statistics of dependent variables (Mean±SE) for weekdays (Mon.-Fri.) and weekends (Sat. & Sun.) from the wrist-worn monitor.

	CNT_{MV} (counts/day)		T_{MV} (min/day)		AEE_{MV} (kcals/day)	
Time Bout (min)	Weekdays	Weekends	Weekdays	Weekends	Weekdays	Weekends
1	557,268 ± 53,051	580,112 ± 74,449	257.1 ± 16.5	257.0 ± 18.3	948.1 ± 85.2	909.5 ± 73.2
3	446,501 ± 57,797	427,752 ± 55,693[a]	188.5 ± 15.1[a]	185.6 ± 18.2[a]	713.5 ± 74.2	658.9 ± 66.3
5	358,941 ± 49,838	341,323 ± 49,070	142.2 ± 13.0[a]	140.1 ± 16.8[a]	552.3 ± 64.0	506.6 ± 60.6
8	263,697 ± 40,677	258,811 ± 40,832	97.9 ± 10.4[a]	100.56 ± 14.9	391.9 ± 52.0	371.0 ± 53.5
10	221,562 ± 37,693	219,469 ± 36,069	78.5 ± 9.0	84.8 ± 13.8	321.4 ± 46.3	314.6 ± 50.0

a = statistically different ($p < 0.05$) than previous time bout. CNT_{MV} = Raw activity monitor counts at or above a moderate intensity activity. T_{MV} = Time at or above a moderate intensity activity. AEE_{MV} = Activity energy expenditure at or above a moderate intensity activity. No clear pattern in mean values between weekend days and weekdays.

Activity Differences by Physical Activity Level

Inter-subject differences in physical activity were also examined. Subjects were divided post-hoc into either an Active or an Inactive group by their mean hip-worn T_{MV} value from the 10-minute time bout. Subjects with mean values above the group median (22.9 mins/day) were placed into the Active group and the remaining subjects were placed in the Inactive group. Demographic measures of the two groups are shown in Table 15.

Table 15. Subject demographic characteristics and time above moderate intensity activity for ten-minute bout (T_{MV}) values from the hip-worn monitor by group (Mean ± SD).

Group	N	Male	Female	Height (cm)	Weight (kg)	BMI (kg/m^2)	T_{MV} (min/day)
Active	20	9	11	174.0 ± 9.6	80.8 ± 19.6	26.5 ± 5.0	49.6 ± 28.3
Inactive	20	6	14	168.1 ± 8.7	72.6 ± 15.3	25.7 ± 5.1	11.6 ± 5.9
All Subjects	40	15	25	171.1 ± 9.5	76.7 ± 18.9	26.1 ± 5.0	30.6 ± 27.9

Activity differences between the Active and Inactive groups were most clearly seen when raw activity monitor output was graphed by the monitors' software (Actical V2.0, Mini Mitter Co., Inc., Bend, OR, USA). Figures 3 and 4 show graphs of raw hip-worn activity monitor output from one subject in the Active group and one subject in the Inactive group, respectively. Clear bouts of activity lasting approximately one hour in the morning and approximately one half hour in the evenings can be seen on each

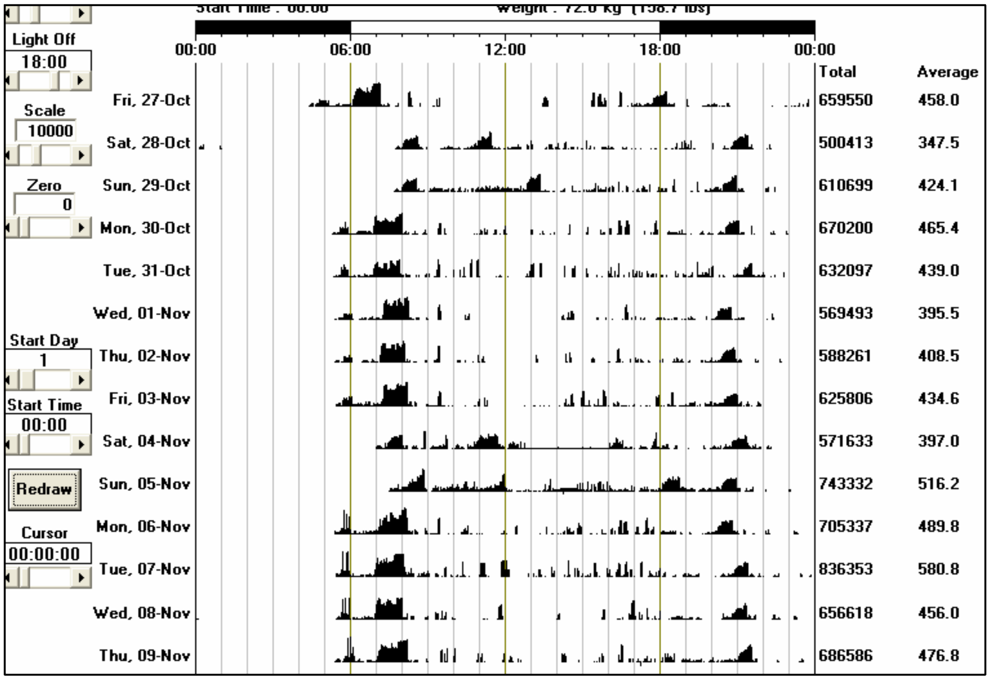

Figure 3. Actical V2.0 graph of raw hip-worn activity monitor output for all 14 monitoring days from a subject in the Active group.

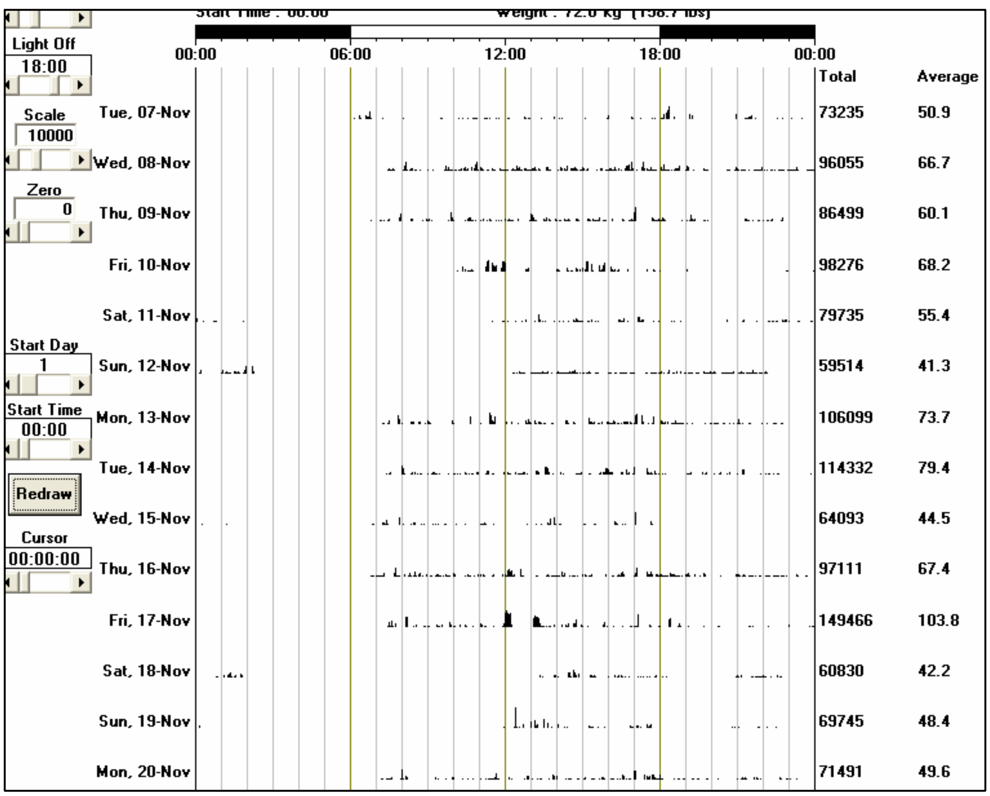

Figure 4. Actical V2.0 graph of raw hip-worn activity monitor output for all 14 monitoring days from a subject in the Inactive group.

monitoring day in Figure 3. However, activity bouts in Figure 4 are much more sporadic and shorter in duration and magnitude. This greater amount of activity is also shown numerically by the total number of raw counts for each day, as seen in the column to the right of each monitoring day's activity graph.

Intraclass correlation coefficients were calculated for Active and Inactive groups for all three dependent variables for both the wrist- and hip-worn monitors. However, with the trend for reliability to increase as bout duration increases (Table 12), only one- and ten-minute bouts were analyzed. The mean and standard error of the raw values for each group and monitor location are shown in Tables 16 and 17, while the complete ICC tables are shown in Appendix D. When 14 monitoring days failed to yield an ICC ≥ 0.80, the Spearman-Brown prophecy formula was used to calculate the number of days necessary to reach an ICC = 0.80, as defined by Treuth et al. (2003).

Table 16. Descriptive statistics of dependent variables (Mean±SE) for Active and Inactive groups from the hip-worn monitor (n = 20 for each group).

	CNT_{MV} (counts/day)		T_{MV} (mins/day)		AEE_{MV} (kcals/day)	
Time Bout (min)	Active	Inactive	Active	Inactive	Active	Inactive
1	265,016 ± 9,462	121,049 ± 3,541	187.4 ± 5.5	121.5 ± 3.4	769.3 ± 26.0	405.7 ± 11.7
10	114,967 ± 7,362	19,399 ± 1,928	49.6 ± 2.9	11.6 ± 1.1	234.9 ± 14.0	44.5 ± 4.1

CNT_{MV} = Raw activity monitor counts at or above a moderate intensity activity. T_{MV} = Time at or above a moderate intensity activity.
AEE_{MV} = Activity energy expenditure at or above a moderate intensity activity.

Table 17. Descriptive statistics of dependent variables (Mean±SE) for Active and Inactive groups from the wrist-worn monitor (n = 20 for each group).

	CNT_{MV} (counts/day)		T_{MV} (mins/day)		AEE_{MV} (kcals/day)	
Time Bout (min)	Active	Inactive	Active	Inactive	Active	Inactive
1	694,722 ± 46,647	391,592 ± 14,114	288.8 ± 8.0	221.7 ± 6.9	1148.8 ± 52.8	682.5 ± 21.1
10	322,094 ± 30,961	119,834 ± 9,694	105.5 ± 5.2	55.1 ± 4.4	463.3 ± 33.5	175.5 ± 12.8

CNT_{MV} = Raw activity monitor counts at or above a moderate intensity activity. T_{MV} = Time at or above a moderate intensity activity.
AEE_{MV} = Activity energy expenditure at or above a moderate intensity activity.

The Active group had similar ICC results with the hip-worn monitor compared to the results from all subjects (Table 12). That is, it took a similar number of monitoring days to reach an ICC = 0.80. For example, it took 5 days to reach an ICC of 0.80 for CNT_{MV}, 2 to 9 days for AEE_{MV} and 3 to 10 days for T_{MV}. However, the Active group had much lower ICC results from the wrist-worn monitor compared to the results from all subjects. An ICC of 0.80 took 15-19 days to reach for CNT_{MV}, 7 to 14 days for AEE_{MV}, and 4 to 7 days for T_{MV}.

The Inactive group showed an opposite trend to that of the Active group, with far higher ICC values for the wrist-worn monitor. The hip-worn monitor took 15-42 days to reach an ICC of 0.80 for CNT_{MV}, 6 to 70 days for AEE_{MV}, and 6 to 102 days for T_{MV}. The wrist-worn monitor took only 3 to 4, 4 to 5, and 3 to 4 days, respectively, to reach an ICC of 0.80 for the same respective variables. The ICC results of the Active and Inactive groups are summarized in Table 18.

Table 18. Number of days for all groups to reach desired ICC of 0.80 for each dependent variable and monitor (n = 20 for Active & Inactive groups and 40 for All Subjects).

	Days to reach ICC = 0.80					
Group	Active		Inactive		All Subjects	
Monitor	Hip	Wrist	Hip	Wrist	Hip	Wrist
CNT_{MV} (counts/day)	5	15-19	15-42	3-4	3-4	10-12
AEE_{MV} (kcals/day)	2-9	7-14	6-70	4-5	2-5	6-9
T_{MV} (mins/day)	3-10	4-7	6-102	3-4	3-6	3-5

CNT_{MV} = Raw activity monitor counts at or above a moderate intensity activity. T_{MV} = Time at or above a moderate intensity activity. AEE_{MV} = Activity energy expenditure at or above a moderate intensity activity.

Activity Differences by Physical Activity Level and Day Type

With subjects divided by activity level, differences in physical activity between weekdays and weekend days were once again examined. The mean and standard error values for each variable and wearing location for one- and ten-minute bouts are shown in Tables 19 and 20. Both the Active and Inactive groups showed little difference in physical activity between weekday and weekend days. However, while no pattern in mean values was observed in the Active group, mean values from the Inactive group wrist-worn monitor increased slightly on weekend days. For example, hip-worn AEE_{MV} values for 10-minute bouts among the Active group were (Mean ± SE) 236.5 ± 27.8 kcals/day on weekdays and 230.9 ± 54.0 kcals/day on weekend days. Similarly, hip-worn AEE_{MV} values for 10-minute bouts amoung the Inactive group were 43.7 ± 7.1 and 46.4 ± 11.7 kcals/day for weekdays and weekend days, respectively.

Differences in mean wearing time for the hip-worn monitor for each activity group were next examined. Wearing times were (Mean ± SD) 15.3 ± 1.2 and 15.2 ± 0.8 hours/day for the Active and Inactive group, respectiviely. When wearing time was split between activity group and day type (weekday versus weekend), overall group means were still similar, despite approximately one less hour/day of wearing time on weekend days versus weekdays. Wearing times for the Active group were 15.6 ± 1.4 hours/day for weekdays and 14.6 ± 1.3 hours/day on weekend days. Similarly, wearing times for the Inactive group were 15.7 ± 0.9 hours/day for weekdays and 14.2 ± 1.3 hours/day on weekend days. These results are summarized in Table 21.

Table 19. Weekday versus Weekend dependent variable values (Mean±SE) by activity group from the hip-worn monitor (n = 20 for each group).

Active Group	CNT_{MV} (counts/day)		T_{MV} (mins/day)		AEE_{MV} (kcals/day)	
Time Bout (min)	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend
1	276,051 ± 24,699	237,428 ± 34,742	192.6 ± 17.8	174.2 ± 18.8	794.2 ± 85.0	707.2 ± 92.9
10	118,802 ± 19,740	105,377 ± 24,114	50.5 ± 5.4	47.5 ± 11.1	236.5 ± 27.8	230.9 ± 54.0
Inactive Group	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend
1	135,459 ± 7,289	112,716 ± 11,252	125.6 ± 8.2	126.4 ± 12.3	427.8 ± 29.0	416.4 ± 38.5
10	20,338 ± 3,821	17,050 ± 4,553	11.0 ± 1.7	12.9 ± 3.4	43.7 ± 7.1	46.4 ± 11.7

CNT_{MV} = Raw activity monitor counts at or above a moderate intensity activity. T_{MV} = Time at or above a moderate intensity activity. AEE_{MV} = Activity energy expenditure at or above a moderate intensity activity. Mean values tended to be lower on weekend days than weekdays.

Table 20. Weekday versus Weekend dependent variable values (Mean±SE) by activity group from the wrist-worn monitor (n = 20 for each group).

Active Group	CNT_{MV} (counts/day)		T_{MV} (mins/day)		AEE_{MV} (kcals/day)	
Time Bout (min)	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend
1	684,990 ± 81,979	719,052 ± 123,226	290.8 ± 23.9	283.9 ± 22.6	1175.1 ± 138.2	1083.1 ± 108.3
10	328,412 ± 63,890	306,300 ± 48,663	105.8 ± 12.5	105.0 ± 16.8	475.6 ± 73.4	432.5 ± 72.9
Inactive Group	Weekday	Weekend	Weekday	Weekend	Weekday	Weekend
1	429,546 ± 55,825	441,172 ± 74,414	223.4 ± 20.6	230.1 ± 27.9	721.0 ± 72.6	735.8 ± 84.2
10	114,712 ± 23,427	132,637 ± 46,680	51.3 ± 9.9	64.6 ± 21.4	167.1 ± 29.9	196.6 ± 58.6

CNT_{MV} = Raw activity monitor counts at or above a moderate intensity activity. T_{MV} = Time at or above a moderate intensity activity. AEE_{MV} = Activity energy expenditure at or above a moderate intensity activity. While all mean values are similar, all mean values increased on weekend days for the Inactive group. No clear pattern in mean values between weekday and weekend day in the Active group.

Table 21. Hip-worn monitor wearing times (Mean ± SD) by group (Active versus Inactive) and day type (Weekday versus Weekend).

Group	N	All days (hours/day)	Weekdays (hours/day)	Weekend days (hour/day)
Active	20	15.3 ± 1.2	15.6 ± 1.4	14.6 ± 1.3
Inactive	20	15.2 ± 0.8	15.7 ± 0.9	14.2 ± 1.3

<u>Intraclass Correlation Coefficients for All Activity Intensities</u>

To further investigate the differences in ICC values between the Active and Inactive groups, various activity intensity variables were examined. Raw activity counts, time, and AEE for sedentary to light intensity activity were next examined. When summed with CNT_{MV}, T_{MV}, and AEE_{MV}, the total raw activity counts (CNT_{TOT}), time (T_{TOT}), and AEE (AEE_{TOT}) could be examined. The mean and standard error for each of these variables for one- and ten-minute bouts are shown in Tables 22 and 23. As expected, subjects in the Active group had higher values of CNT_{TOT} and AEE_{TOT} since they engaged in more moderate and vigorous intensity activities. However, the Inactive group had near equal values of T_{TOT} for ten-minute bout durations, indicating that they were engaged in activity for similar durations as the Active group, but at lower intensity levels. Intraclass correlation coefficients were also calculated as explained above for CNT_{TOT}, T_{TOT} and AEE_{TOT} by activity group (Active versus Inactive) to compare with the ICC values for CNT_{MV}, T_{MV} and AEE_{MV}. A summary of the ICC results are shown in Table 24 while the complete ICC Tables are shown in Appendix D.

Table 22. Count, time and activity energy expenditure values (Mean±SE) for all activity intensities (sedentary, light, moderate and vigorous) for Active and Inactive groups from the hip-worn monitor (n = 20 for each group).

	CNT_{TOT} (counts/day)		T_{TOT} (mins/day)		AEE_{TOT} (kcals/day)	
Time Bout (min)	Active	Inactive	Active	Inactive	Active	Inactive
1	301,128 ± 9,561	155,829 ± 3,800	1440.0 ± 0.0	1440.0 ± 0.0	831.4 ± 27.6	522.2 ± 13.5
10	117,943 ± 7,354	22,046 ± 1,934	941.9 ± 8.2	950.2 ±9.1	224.1 ± 13.3	48.8 ± 4.2

CNT_{TOT} = Raw activity monitor counts for all activity intensities. T_{TOT} = Time for all activity intensities. AEE_{TOT} = Activity energy expenditure for all activity intensities.

Table 23. Count, time and activity energy expenditure values (Mean±SE) for all activity intensities (sedentary, light, moderate and vigorous) for Active and Inactive groups from the wrist-worn monitor (n = 20 for each group).

	CNT_{TOT} (counts/day)		T_{TOT} (mins/day)		AEE_{TOT} (kcals/day)	
Time Bout (min)	Active	Inactive	Active	Inactive	Active	Inactive
1	879,632 ± 45,747	592,864 ± 14,501	1440.0 ± 0.0	1440.0 ± 0.0	1499.9 ± 52.7	1151.9 ± 21.6
10	360,614 ± 30,774	166,927 ± 9,483	623.1 ± 8.5	602.77 ± 6.8	517.7 ± 32.1	280.7 ± 12.5

CNT_{TOT} = Raw activity monitor counts for all activity intensities. T_{TOT} = Time for all activity intensities. AEE_{TOT} = Activity energy expenditure for all activity intensities.

Table 24. Number of days for Active and Inactive groups to reach desired ICC of 0.80 for counts, time, and AEE for all intensities (sedentary, light, moderate & vigorous) and moderate to vigorous intensities across all time bouts.

		Days to reach ICC = 0.80			
	Group	Active		Inactive	
Variables	Monitor	Hip	Wrist	Hip	Wrist
Total Activity Variables	CNT_{TOT} (counts/day)	5	17-19	12-44	3-4
	AEE_{TOT} (kcals/day)	2-7	6-13	5-91	4-5
	T_{TOT} (mins/day)	2-6	2-7	2-4	2-4
Moderate to Vigorous Variables	CNT_{MV} (counts/day)	5	15-19	15-42	3-4
	AEE_{MV} (kcals/day)	2-9	7-14	6-70	4-5
	T_{MV} (mins/day)	3-10	4-7	6-102	3-4

CNT_{TOT} = Raw activity monitor counts for all activity intensities. T_{TOT} = Time for all activity intensities. AEE_{TOT} = Activity energy expenditure for all activity intensities. CNT_{MV} = Raw activity monitor counts at or above a moderate intensity activity. T_{MV} = Time at or above a moderate intensity activity. AEE_{MV} = Activity energy expenditure at or above a moderate intensity activity.

Similar ICC results were observed for CNT_{TOT}, T_{TOT} and AEE_{TOT} (total activity variables) as were observed for CNT_{MV}, T_{MV} and AEE_{MV} (moderate to vigorous variables) (Table 24). For example, looking at total activity variables from the wrist-worn monitor, the Inactive group required 2 to 5 monitoring days to reach an ICC of 0.80 while 3 to 5 days were required for moderate to vigorous variables. Intraclass correlation coefficient values were also similarly low (as reflected by a high number of monitoring days) from the wrist-worn monitor among the Active group for both total activity variables and moderate to vigorous variables. For total activity variables, 17 to19 and 6 to 13 monitoring days were required to reach an ICC of 0.80 for CNT_{TOT} and AEE_{TOT}, respectively. Similarly, 15 to 19 and 7 to 14 monitoring days were required for

CNT_{MV} and AEE_{MV} to reach an ICC of 0.80. The time variables (T_{TOT} and T_{MV}) were impacted the most, taking between 2 and 7 days and 3 and 102 days for T_{TOT} and T_{MV}, respectively, to reach an ICC of 0.80 for both activity groups and monitor wearing locations.

CHAPTER FIVE

DISCUSSION

Several studies have been conducted to assess the reliability by which habitual free-living physical activity is measured by accelerometers (Coleman & Epstein, 1998; Gretebeck & Montoye, 1992; Janz, Witt, & Mahoney, 1995; Kochersberger et al., 1996; Matthews et al., 2002; Trueth et al., 2003; Trost et al., 2000). However, all of these studies have used hip-worn accelerometers, while the current study aimed to assess reliability with both hip- and wrist-worn accelerometers. Wrist-worn accelerometers have been used in previous studies, but for various reasons other than assessing reliability, such as improving hip-worn measures (Melanson & Freedson, 1995; Patterson et al., 1993; Swartz et al., 2000). Furthermore, while the Actical® activity monitor has been studied previously in validation studies (Heil, 2006; Pfeiffer et al., 2006; Puyau et al. 2004), no studies have used a wrist-worn Actical® activity monitor to measure habitual free-living physical activity.

Study Design

This was the first study to measure the reliability of habitual free-living physical activity at two monitor wearing locations using three different variables (raw activity counts, time, and activity energy expenditure at or above a moderate intensity: CNT_{MV}, T_{MV} and AEE_{MV}, respectively) across five different time bouts (a minimum of one, three, five, eight and ten consecutive minutes). Furthermore, by analyzing the data across different time bouts, the current study attempted to obtain results more consistent with the guidelines suggested by Pate et al. (1995). These guidelines state that physical activity should be accumulated in eight- to ten-minute bouts to prevent disease and promote health. Thus, by measuring habitual free-living physical activity in bouts $\geq$ 10 mins in duration, the current study attempted to gather data with physiological information consistent with the guidelines set by Pate et al. (1995). In analyzing the data for three different dependent variables (CNT_{MV}, T_{MV} and AEE_{MV}), the current study also aimed to gather a more comprehensive view of habitual free-living physical activity.

The reliability of the hip-worn monitor in the current study (i.e., 2 to 6 days for all three dependent variables to reach an intraclass correlation coefficient—ICC—equal to 0.80) were similar to those reported in previous studies. However, it is important to note that the previously reported hip-worn ICC values were not analyzed by numerous activity bouts of specific time duration as they were in the current study. For example, Matthews et al. (2002) reported 3 to 4 days to reach an ICC of 0.80 while looking at moderate to vigorous movement counts and the total daily time spent above moderate intensity physical activity. However, time was not separated into different bouts, but rather averaged over each monitoring day. With a form of movement counts and metabolic equivalents (METs) as dependent variables, Coleman & Epstein (1998) reported 3 to 4 and 5 to 6 days, respectively, to reach an ICC of 0.80. However, data were averaged over consecutive 10-minute blocks for each monitoring day. Using a slightly different statistical analysis, Gretebeck and Montoye (1992) found 5 to 6 days necessary to reliably measure habitual free-living physical activity (i.e., minimize the intra-individual variance) when AEE and METs were tallied over each full monitoring day. Thus, while the findings of the current study for the hip-worn monitor were similar to those reported in previous studies, they are more consistent with the guidelines suggested by Pate et al. (1995) by analyzing habitual free-living physical activity in similar time bouts.

Sources of Variation

Reliability for this study was determined by calculating an intraclass correlation coefficient (ICC) for each of the three dependent variables for each monitoring day (14 total days). It is important to note that ICC values are calculated from the amount of variance of the data, as statistically calculated by an analysis of variance (ANOVA). Thus, to fully understand the data it was essential to determine potential causes of variation.

Perhaps the most commonly examined source of variation in habitual physical activity is the type of day on which activity occurs, i.e., weekdays (Monday through Friday) or weekend days (Saturday and Sunday). Gretebeck & Montoye (1992) and Matthews et al. (2002) both examined the difference in physical activity between weekday and weekend days with contradicting results. Gretebeck & Montoye (1992) found physical activity was less on weekend days, and not as reliable; 2 to 4 monitoring days were required for a reliable measurement (i.e., with less than 5% error) on weekdays versus 3 to 6 monitoring days for all days including weekend days. Matthews et al. (2002) reported opposite findings, where physical activity was less on weekdays by 30 to 45 minutes per day. However, it is difficult to make clear parallel comparisons to the current study because of differences in study populations. Like the current study, Gretebeck & Montoye (1992) had a study population with varying amounts of occupational and recreational physical activity. Unlike the current study, Gretebeck & Montoye (1992) only used male subjects. Furthermore, Matthews et al. (2002) did not describe the physical activity levels of their subjects. For the current study, day type did not have any substantial influence on activity (Tables 13 and 14), although mean values for all three dependent variables and hip-worn monitor wearing time were lower on weekend days.

In addition, when stark differences in activity by day type are reported in the literature, it appears to be more common in child studies, such as those reported by Trost et al. (2000). They reported that in younger children (school grades 1-3) time spent in moderate to vigorous physical activity is significantly greater on weekend days. However, as children age, these values become more similar until time spent in moderate to vigorous physical activity becomes significantly greater on weekdays during adolescence (i.e., school grades 10-12 for boys and 7-12 for girls) (Trost et al., 2000).

Amounts of physical activity varied greatly among the subjects of this study, both occupationally and recreationally. In an attempt to better isolate the sources of variation, subjects were divided post-hoc into Active and Inactive groups, and ICC values for each group were determined as they were for the whole group. The Active group had higher ICC values with the hip-worn monitor, while, conversely, the Inactive group had higher ICC values with the wrist-worn monitor. It is also important to note from Table 17 the unusually low ICC values of the Inactive group's hip-worn monitors, as reflected in the high number of days required to reach an ICC of 0.80 (42, 70, and 102 days for ten-minute bouts for CNT_{MV}, AEE_{MV} and T_{MV}, respectively). These results are indicative of low variability in the Inactive group's hip-worn monitors' values and not necessarily poor reliability. That is, in order for stability reliability to be properly demonstrated, large variability among reported values of between-subject variability is necessary (Portney & Watkins, 2000).

Portney and Watkins (2000) explain that when dependent variable values are homogenous, or when variability is low, the calculated ICC is also low as a result of the way ICC is calculated. In other words, this "false low" in ICC values is a reflection of a limitation of the computational process, and not of actual values. Furthermore, Portney & Watkins (2000) also explain that by examining the significance of the between-subject variance from the ANOVA tables, this computational effect can be checked: If the variance is not significant, the dependent variable values are homogenous, or have low variability. For the Inactive group's hip-worn monitors, the between-subjects F-values for ten-minute bout durations were 2.35, 1.79 and 1.53 for CNT_{MV}, T_{MV} and AEE_{MV}, respectively (α =0.05). The critical F-value was $_{(0.05)}F_{(19,247)} = 1.63$. Thus, while only AEE_{MV} had non-significant variability (an F-value lower than the critical F-value), CNT_{MV} and T_{MV} F-values were still the lowest F-values for any variable, activity group, or monitor wearing location (Other F-values ranged from 4.06 to 22.74).

This low variability was not observed in the wrist-worn monitor data from the Inactive group, as reflected by greater ICC values and thus few monitoring days to reach an ICC = 0.80 (Table 18). For this group and monitor wearing location, this outcome is the opposite of what was hypothesized; that the wrist-worn monitor would be less reliable than the hip-worn monitor because a person's arms can move frequently in activities not directly related to whole-body physical activity. For the Inactive group, however, this additional arm movement appears to have raised the dependent variables' values from very low inactive levels to values approaching that of higher activity, i.e., similar to the hip-worn monitor values from the Active group and for all subjects (Table 19). Thus, while additional arm movement decreased the ICC values of the wrist-worn monitor in the Active group (i.e., more days to reach an ICC = 0.80) it also increased the ICC values of the wrist-worn monitor in the Inactive group (i.e., fewer days to reach an ICC = 0.80).

With the data divided by activity groups, a trend appeared that the T_{MV} ICC values remain largely consistent across each dependent variable and monitor wearing location. This is expected as T_{MV} values are consistently similar compared to CNT_{MV} and AEE_{MV} as a result of the way these variables are calculated. For example, a ten-minute bout of moderate to vigorous activity can have a wide range of CNT_{MV} and AEE_{MV} values; one minute of activity may be just above the moderate intensity cut point, while the next minute may be several times that value and well above the vigorous cut point. Thus, the range and variation of these values can be quite large. However, the T_{MV} from the same ten minutes of activity is simply the sum time that activity was above the threshold, regardless of magnitude. That is, a ten-minute bout yields a T_{MV} of ten minutes.

While there was no difference in activity between weekdays and weekend days for all subjects, it was possible that differences were present within activity groups.

However, looking at the mean and standard error values for each dependent variable by day type across activity groups (Tables 19 and 20), little difference in activity was observed.

The wrist-worn monitors in this study were locked into place and thus remained on each subject for 24 hours a day for all 14 monitoring days. Therefore, there was no potential for variation in the amount of time the wrist monitor was worn. The hip-worn monitors, in contrast, were removable which allowed for varying amounts of wearing time for each day. This potential source of variation was also examined for all groups (i.e., Active, Inactive and All Subjects) (Table 20). Mean wearing times were almost identical for all three groups, with the hip-worn monitor worn approximately one hour less on weekend days than weekdays for all groups. This is consistent with most subjects' notebooks which indicated extra sleep on weekend days.

One potential source of variation that could not be controlled for or measured in the current study was the batch variability of the Actical® test-retest reliability. While Esliger and Tremblay (2006) found the Actical® to have high inter-instrument test-rest ICC values (0.98 to 1.00), they also found a discrepant trend in the variability in count output across testing frequencies that went undetected by the ICC values. It was observed that different batches of Actical® monitors had strikingly different amounts of variation in their reported average counts/min values when tested in a mechanical setup. When Esliger and Tremblay (2006) calculated test-retest reliability with a coefficient of variation (CV) instead of an ICC, they found the Actical® had high intra-instrument reliability (CV = 0.4%) but strikingly lower inter-instrument reliability (CV = 15.5%).

As Esliger and Tremblay (2006) pointed out, this finding calls into question the validity of the Actical® and further research is clearly needed. However, as each subject in the current study wore the same Actical® monitors for all 14 monitoring days, intra-instrument reliability is of greater concern, and the intra-instrument reliability of the Actical® as reported by Esliger and Tremblay (2006) was much higher than the inter-instrument reliability. Regardless, it should be noted that the ICC values reported in the current study could vary due to the potential error in certain batches of Actical® monitors.

Summary

Overall, the degree to which the Actical® activity monitor assessed the reliability of habitual free-living physical activity depended largely on both monitor wearing location and the activity level of the subject. As expected, the wrist-worn monitor had lower ICC values than the hip-worn monitor for all subjects and the Active group. While not statistically significant, the greater number of monitoring days to reach a desired ICC with the wrist-worn monitor has clear practical importance for clinicians, investigators, and of course the subjects themselves. While activity monitoring is fairly non-invasive, it is in the interest of all parties to gather enough information to make sound conclusions in as few monitoring days as possible.

Of more interest, however, was the finding that the wrist-worn monitor measured habitual free-living physical activity with greater reliability than the hip-worn monitor for subjects in the Inactive group. This is of particular importance since those who are habitually non-active and fall below the guidelines set by Pate et al. (1995) are exactly those who can benefit most from activity monitoring. However, it should be noted that high ICC values are not necessarily indicative of high validity. While observed wrist-worn monitor values from the Inactive group were similar, it is unclear as to how well they were reflective of subjects' actual activity behaviors. Regardless, future research should focus on the use of wrist-worn activity monitors with inactive populations.

CHAPTER SIX

CONCLUSIONS

The findings of this study indicate that the reliability measures (Intraclass correlation coefficients) of a wrist-worn Actical® accelerometer during habitual free-living physical activity were generally, but not significantly, lower than a hip-worn Actical®. Stability reliability was determined by calculating intraclass correlation coefficients (ICC) for three dependent variables (raw activity monitor counts CNT_{MV}, time T_{MV}, and activity energy expenditure AEE_{MV} at or above a moderate intensity activity) across 14 consecutive monitoring days and five time bouts (minimum bouts of one, three, five, eight and ten consecutive minutes). When subjects were divided post-hoc by activity level (Active or Inactive), ICC values for the hip- and wrist-worn monitors changed drastically. The Active group had much higher ICC values for the hip-worn monitor while the Inactive group had much higher ICC values for the wrist-worn monitor. Furthermore, as time bouts increased from one to ten minutes, ICC values decreased for both the hip- and wrist-worn monitors.

These findings have several practical implications. First, clinicians and investigators interested in using a wrist-worn Actical® should identify which dependent variable is of greatest interest as ICC values between dependent variables differed substantially. Time (T_{MV}) had the highest ICC values for the wrist-worn monitor (3 to 5 days to reach an ICC = 0.80) followed by AEE_{MV} (5 to 8 days) and CNT_{MV} (10 to 12 days), respectively. Future investigators can also benefit from knowing *a priori* the general activity level of their study population of interest and plan their monitoring wearing locations and monitoring periods accordingly. However, since current research is often focused on inactive populations, the findings of the current study indicate that a wrist-worn Actical® will reach a desired ICC value in fewer monitoring days than a hip-worn monitor in inactive populations. Further research is recommended with a wrist-worn Actical® and exclusively inactive populations.

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APPENDICES

APPENDIX A

SUBJECT CONSENT FORM

SUBJECT CONSENT FOR PARTICIPATION IN HUMAN RESEARCH
MONTANA STATE UNIVERSITY—BOZEMAN

PROJECT TITLE: Reliably measuring habitual free-living physical activity with the Actical® activity monitor.

FUNDING: Product and participant support was provided by the Mini Mitter Co. (Bend, OR).

PROJECT DIRECTOR: Michael Webster
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Hoseaus Complex. Montana State University
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PURPOSE: The U.S. Surgeon General currently recommends that all adults accumulate at least 30 minutes a day of moderate intensity physical activity most days of the week to decrease their health risk profile for chronic diseases related to physical inactivity. Accelerometers are common devices used by clinicians and researchers to measure and record an individual's physical activity. Specifically, these devices provide detailed minute-to-minute information about frequency, intensity, and duration of bodily movements throughout the day. Accelerometers are most commonly worn on the hip, yet when worn at this location they do a poor job of reliably measuring physical activity that involves large amounts of upper body activity (e.g. yard work, housework, tennis, golf, etc.) The Mini Mitter Company's (Bend, OR) Actical accelerometry-based activity monitor is capable of measuring acceleration in more than one plane, or omnidirectional, making it more appropriate for detecting acceleration at the wrist. The Actical activity monitor has been validated in a lab-based setting for predicting energy expenditure when worn on the wrist, but it has not yet been tested in field-based research of free-living activity. The purpose of this study is to determine the number of days necessary to reliably measure habitual free-living activity in adults with a wrist-worn Actical activity monitor. To accomplish this goal, data from a wrist-worn Actical activity monitor will be compared to a hip-worn Actical activity monitor. Thus, each participant will be required to wear two Actical activity monitors, one at the wrist and one at the hip, for 14 consecutive days while continuing their daily free-living activities. In addition, some participants will also be asked to wear a pedometer (to count daily steps) during the same time period as an additional measure of physical activity.

All volunteers must be between 18 and 55 years of age and pass the health screening as described below.

> **Health Screening Prior to Testing:** Prior to any testing each study volunteer is required to read and sign a Subject Consent Form. In addition, medical clearance will be obtained using the ***Physical Activity Readiness Questionnaire (PAR-Q)*** and/or clearance from your physician (the PAR-Q is attached to the end of this

document). Answering *"Yes"* to any question on the PAR-Q *may* automatically disqualify you from participating in this study without further clearance from your physician. Factors that will exclude you from participating as a subject in this study include all known contraindications to participating in submaximal exercise activities. Some examples include:

✓ Preexisting musculoskeletal/joint injury or disorder (for example, severe arthritis) that limits your ability to walk normally.
✓ You have been diagnosed with cardiovascular or pulmonary disease.
✓ You are recovering from recent surgery.
✓ You have a metabolic disorder, such as diabetes.
✓ You are currently sick or recovering from a cold or flu.
✓ You have a history of reoccurring and/or untreated low-back pain.

All testing and screening procedures are in accordance with those outlined for testing "Low Risk" adults by the American College of Sports Medicine[1]. Please talk with the Project Director, Michael Webster, about any pre-existing health conditions that may limit your participation in this project *BEFORE* testing.

STUDY PROCEDURES: Each subject is asked to participate in three lab visits and 14 days of monitoring as described below:

☐ **Lab Visits.**
Participation in this study requires three visits to the Movement Science/Human Performance Lab in Romney Building at Montana State University. The duration of the first visit will be approximately one hour. The second and third visits will be approximately 15 minutes each.

After arriving at the lab for the first visit, you will first fill out some paperwork (the Informed Consent Document, PAR-Q) and then have demographic variables measured and recorded such as age, body weight and body height. You will then be given two Actical® activity monitors to be worn on the wrist and the hip. The Actical monitor worn on the wrist will be secured with a plastic band and locked into place. Once locked, the wrist band can only be removed by cutting the plastic. The Actical monitor worn on the hip will be worn on the front waist line at belt level. This monitor is to be worn during all waking hours (a minimum of 12 consecutive hours), and removed only for showering, swimming, or sleeping. A notebook will also be provided to you to record the times the hip-worn monitor is taken off and put on, including times you go to bed and times you awake.

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[1]American College of Sports Medicine (2006). *ACSM's Guidelines for Exercise Testing and Prescription* (7th edition). Lea & Fibiger; Philedelphia, PA.

Some participants will also be given a pedometer to wear in addition to the hip-worn monitor. This pedometer is to put on and taken off at the same times as the Actical hip-monitor (all waking hours), and taken off only for the same reasons (sleeping, showering, or swimming). You will need to record in the notebook the times the pedometer is taken off and put on, as well as the total number of steps taken each day. The pedometer and security strap ($20 value) will be yours to keep at the end of the study.

Before the end of the first visit, a time for the second visit will be established within one week of the date of the first visit. Furthermore, you will be contacted by the investigator by phone and e-mail the day after the first visit to again remind you to wear the hip-worn Actical monitor.

The second visit will be used to determine any problems you've faced with the monitoring and attempt to solve those problems.

The third visit will take place two weeks after the first visit. During this visit the investigator will collect the two Actical monitors and the notebook. This time will also be used to discuss any problems you may have faced during the monitoring.

☐ **Free-Living Monitoring Days.**

After the first visit, you will be asked to wear both Actical monitors for 14 consecutive days. During this time you are to carry out your daily free-living activities, occupations and recreational, as usual. The investigator is not interested in the amount of your physical activity, but rather how well the Actical monitors record your activity behavior. Thus, you should continue with your daily activities as if you were not wearing any monitors.

POTENTIAL RISKS: There are no known risks associated with participation in this study.

BENEFITS: Participants that complete the 14 monitoring days will receive $50. Should circumstances arise that lead you to choose to withdrawal from the study, and if at least seven monitoring days have been completed, you will receive $15. Should you choose to withdraw prior to seven completed monitoring days you will receive no compensation. In addition, participants wearing the pedometer during the 14 days of monitoring will get to keep the pedometer and security strap (worth $20). Lastly, participants may also request a summary of the study findings by contacting the Project Director, Michael Webster, by phone (406-994-2181) or E-mail (mwebster@montana.edu).

CONFIDENTIALITY: The data and personal information obtained from this project will be regarded as privileged and confidential. They will not be released except upon your written request. Your right to privacy will be maintained in any ensuing analysis and/or presentation of the data by using coded identifications of each person's data.

FREEDOM OF CONSENT: You may withdraw consent for participation in writing, by telephone, or in person without prejudice or loss of benefits (as described above). Please contact the Project Director, Michael Webster, by phone (406-994-2181) or E-mail (mwebster@montana.edu) to discontinue participation. *Participation in this project is completely voluntary*.

In the UNLIKELY event that your participation in this project results in physical injury to you, the Project Director will advise and assist the participant in receiving medical treatment. Montana State University cannot be held responsible for injury, accidents, or expenses that may occur as a result of your participation in this project. In addition, Montana State University cannot be held responsible for injury, accidents, or expenses that may occur as a result of traveling to and from your appointments at the Movement Science / Human Performance Lab. *Further information regarding medical treatment may be obtained by calling the Project Director, Michael Webster, at 406-994-2181.* You are encouraged to express any questions, doubts or concerns regarding this project. The Project Director will attempt to answer all questions to the best of his ability prior to any testing. The Project Director fully intends to conduct the study with your best interest, safety and comfort in mind. *Additional questions about the rights of human subjects can be answered by the Chairman of the Human Subjects Committee, Mark Quinn, at 406-994-5721.*

PROJECT TITLE: *Reliably Measuring Habitual Free-Living Physical Activity with the Actical® Activity Monitor.*

STATEMENT OF AUTHORIZATION

I, *the participant*, have read the Informed Consent Document and understand the discomforts, inconvenience, risks, and benefits of this project. I, ____ *(print your name)*, agree to participate in the project described in the preceding pages. I understand that I may later refuse to participate, and that I may withdraw from the study at any time. I have received a copy of this consent form for my own records.

Signed:______________________________ **Age** _______ **Date**__________
Subject's Signature

Witness: ______________________ ______________________ Date _____
Print Name *Sign Name*

APPENDIX B

ACTIVITY QUESTIONNAIRE

PROJECT TITLE: *Reliably Measuring Habitual Free-Living Physical Activity with the Actical® Activity Monitor*

PROJECT DIRECTOR: Michael Webster, Master of Science Candidate, Exercise Physiology
Dept. of Health and Human Development, Movement Science Laboratory
Montana State University, Bozeman, MT 59717-3540
Phone: (406) 994-2181; E-mail: mwebster@montana.edu

Thank you for your interest in this study! Please take a moment to fill out the following questionnaire.

This questionnaire is designed for the Project Director to better classify your physical activity habits and ultimately analyze the data. However, because the Actical® Activity Monitor measures some physical activities better than others, frequent participation in some activities may disqualify you from participating in this study.

If you have any questions, please contact the Project Director, Michael Webster.

PERSONAL/CONTACT INFORMATION

Name:____ Age:__________

Department:________________________ Telephone:____________________

E-mail:__________________________ Sex: Male □ Female □

OCCUPATIONAL ACTIVITIES

Does your job require you to be active or on your feet for more than three hours a day?
NO □ YES □

Does your job require you to be seated at a workstation, or otherwise be sedentary for the majority of your day (i.e., are you physically active for *less* than a cumulative time of three hours each day)?
NO □ YES □

Does your job require the removal of jewelry, such as a watch or bracelet?
NO □ YES □

RECREATIONAL ACTIVITIES

Please indicate if you regularly participate in any of the following activities. For each activity answered **YES**, please indicate how many times per week you participate in that activity.

	NO	**YES**	**Times Per Week**
1. Swimming	□	□	____________________
2. Bicycling (Road or Mountain)	□	□	____________________
3. Roller skating, Rollerblading, or Roller skiing	□	□	____________________
4. Weight Lifting	□	□	____________________
5. Rock Climbing	□	□	____________________
6. Kayaking	□	□	____________________
7. Stationary Machines (Elliptical, Rowing, or Bicycle)	□	□	____________________
8. Walking	□	□	____________________
9. Running (Including Treadmill Running)	□	□	____________________
10. Hiking	□	□	____________________
11. Racquetball, Tennis, or Squash	□	□	____________________
12. Yard Work	□	□	____________________
13. Other ______________________________	□	□	____________________

APPENDIX C

PAR-Q: PHYSICAL ACTIVITY READINESS QUESTIONNAIRE

PAR-Q: PHYSICAL ACTIVITY READINESS QUESTIONNAIRE

PAR-Q is designed to help you help yourself. Many health benefits are associated with regular exercise and completion of a PAR-Q is a sensible first step to take if you are planning to increase the amount of physical activity in your life. For most people, physical activity should not pose any problem or hazard. PAR-Q has been designed to identify the small number of adults for whom physical activity might be inappropriate or those who should have medical advice concerning the type of activity most suitable for them.

Common sense is your best guide in answering these few questions. Please read the following questions carefully and check the ***YES*** or ***NO*** opposite the question if it applies to you.

YES	***NO***	
☐	☐	**1.** Has your doctor ever said you have heart trouble?
☐	☐	**2.** Do you ever have pains in your heart or chest?
☐	☐	**3.** Do you ever feel faint or have spells of severe dizziness?
☐	☐	**4.** Has a doctor ever said your blood pressure was too high?
☐	☐	**5.** Has a doctor ever said your blood cholesterol was too high?
☐	☐	**6.** Have you ever been diagnosed with diabetes mellitus?
☐	☐	**7.** Has your doctor ever told you that you have a bone or joint problem such as arthritis that has been aggravated by exercise, or might be made worse with exercise?
☐	☐	**8.** Is there a good physical reason not mentioned here why you should not follow an activity program even if you wanted to?
☐	☐	**9.** Are you over the age of 65 or NOT accustomed to vigorous exercise?
☐	☐	**10.** Are you a habitual cigarette or cigar smoker? If *"Yes"*, how many years? __________ If *"No"* AND you have recently quit smoking, how long ago did you quit?__________ (give answer in months or years)
☐	☐	**11.** Is there any other physical ailment not mentioned above that could be considered a health risk if you were to participate in the testing described by the Informed Consent Document? If "***Yes"***, please describe below...

*If you answered "**YES**" to one or more questions...*

If you have not recently done so, consult with your personal physician by telephone or in person before increasing your physical activity, taking a fitness test, or participating in the present research study. Tell the physician what questions you answered *"YES"* on PAR-Q or show a copy of this form. Be certain to talk with the principal investigator before preceding further with your involvement in this study.

*If you answered **"NO"** to all questions...*

You have reasonable assurance that your participation in the present study will not put you at higher risk for injury for illness.

NOTE: Postpone exercise testing if you suffer from minor illness such as a common cold or flu!

Your signature below indicates that you have filled out the preceding PAR-Q form to the best of your knowledge.

Signed:____________________________________Date____________
Subject's Signature

Signed:____________________________________Date____________
Project Technician

APPENDIX D

ICC TABLES AND 95% CONFIDENCE INTERVALS

FOR ACTIVE & INACTIVE GROUPS

Intraclass correlation coefficients (ICC) with 95% confidence intervals (CI) for hip-worn raw counts per minute at or above a moderate intensity (CNT_{MV}) from the Active group. Boxed ICC values indicate desired reliability of ≥ 0.80 (n = 20).

Time Bout (min)		Day 1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	ICC	0.45	0.62	0.71	0.77	0.81	0.83	0.85	0.87	0.88	0.89	0.90	0.91	0.92	0.92
	Upper 95% CI	0.75	0.84	0.88	0.90	0.92	0.93	0.94	0.95	0.95	0.96	0.96	0.96	0.97	0.97
	Lower 95% CI	0.02	0.25	0.40	0.49	0.57	0.62	0.66	0.69	0.72	0.74	0.76	0.78	0.80	0.81
10	ICC	0.46	0.63	0.72	0.77	0.81	0.84	0.86	0.87	0.88	0.89	0.90	0.91	0.92	0.92
	Upper 95% CI	0.75	0.84	0.88	0.91	0.92	0.93	0.94	0.95	0.95	0.96	0.96	0.97	0.97	0.97
	Lower 95% CI	0.02	0.26	0.41	0.50	0.57	0.63	0.67	0.70	0.73	0.75	0.77	0.79	0.80	0.71

Intraclass correlation coefficients (ICC) with 95% confidence intervals (CI) for hip-worn raw counts per minute at or above a moderate intensity (CNT_{MV}) from the Inactive group. Boxed ICC values indicate desired reliability of ≥ 0.80 (n = 20).

Time Bout (min)		Day 1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	ICC	0.22	0.35	0.45	0.52	0.58	0.62	0.66	0.69	0.71	0.73	0.75	0.77	0.78	0.79
	Upper 95% CI	0.60	0.69	0.75	0.78	0.81	0.84	0.85	0.87	0.88	0.89	0.90	0.90	0.91	0.92
	Lower 95% CI	-0.25	-0.11	0.01	0.11	0.18	0.25	0.30	0.35	0.39	0.43	0.46	0.49	0.52	0.54
10	ICC	0.09	0.16	0.22	0.28	0.32	0.37	0.40	0.43	0.46	0.49	0.51	0.54	0.56	0.57
	Upper 95% CI	0.51	0.56	0.61	0.64	0.67	0.70	0.72	0.74	0.75	0.77	0.78	0.79	0.80	0.81
	Lower 95% CI	-0.37	-0.30	-0.24	-0.19	-0.14	-0.09	-0.05	-0.01	0.03	0.06	0.09	0.12	0.15	0.18

Intraclass correlation coefficients (ICC) with 95% confidence intervals (CI) for wrist-worn raw counts per minute at or above a moderate intensity (CNT_{MV}) from the Active group. Boxed ICC values indicate desired reliability of ≥ 0.80 (n = 20).

		Day													
Time Bout (min)		1	2	3	4	5	6	7	8	9	10	11	12	13	14
	ICC	0.22	0.35	0.45	0.52	0.58	0.62	0.66	0.69	0.71	0.73	0.75	0.77	0.78	0.79
1	Upper 95% CI	0.60	0.69	0.75	0.78	0.81	0.84	0.85	0.87	0.88	0.89	0.90	0.90	0.91	0.92
	Lower 95% CI	-0.25	-0.11	0.01	0.11	0.18	0.25	0.30	0.35	0.39	0.43	0.46	0.49	0.52	0.54
	ICC	0.18	0.31	0.40	0.47	0.52	0.57	0.61	0.64	0.66	0.69	0.71	0.73	0.74	0.75
10	Upper 95% CI	0.58	0.66	0.72	0.75	0.78	0.81	0.83	0.84	0.86	0.87	0.88	0.88	0.89	0.90
	Lower 95% CI	-0.29	-0.16	-0.05	0.03	0.11	0.17	0.22	0.27	0.31	0.35	0.39	0.42	0.44	0.47

Intraclass correlation coefficients (ICC) with 95% confidence intervals (CI) for wrist-worn raw counts per minute at or above a moderate intensity (CNT_{MV}) from the Inactive group. Boxed ICC values indicate desired reliability of ≥ 0.80 (n = 20).

		Day													
Time Bout (min)		1	2	3	4	5	6	7	8	9	10	11	12	13	14
	ICC	0.61	0.76	0.82	0.86	0.89	0.90	0.92	0.93	0.93	0.94	0.94	0.95	0.95	0.96
1	Upper 95% CI	0.83	0.90	0.93	0.94	0.95	0.96	0.97	0.97	0.97	0.98	0.98	0.98	0.98	0.98
	Lower 95% CI	0.23	0.47	0.60	0.68	0.73	0.77	0.80	0.82	0.84	0.85	0.86	0.87	0.88	0.89
	ICC	0.55	0.71	0.78	0.83	0.86	0.88	0.89	0.91	0.92	0.92	0.93	0.94	0.94	0.94
10	Upper 95% CI	0.80	0.88	0.91	0.93	0.94	0.95	0.96	0.96	0.97	0.97	0.97	0.97	0.98	0.98
	Lower 95% CI	0.14	0.38	0.52	0.61	0.67	0.71	0.75	0.77	0.80	0.81	0.83	0.84	0.85	0.86

Intraclass correlation coefficients (ICC) with 95% confidence intervals (CI) for hip-worn time at or above a moderate intensity (T_{MV}) from the Active group. Boxed ICC values indicate desired reliability of ≥ 0.80 (n = 20).

Time Bout (min)		Day 1	2	3	4	5	6	7	8	9	10	11	12	13	14
	ICC	0.61	0.76	0.83	0.86	0.89	0.91	0.92	0.93	0.93	0.94	0.95	0.95	0.95	0.96
1	Upper 95% CI	0.83	0.90	0.93	0.95	0.96	0.96	0.97	0.97	0.97	0.98	0.98	0.98	0.98	0.98
	Lower 95% CI	0.24	0.48	0.61	0.68	0.74	0.77	0.80	0.82	0.84	0.85	0.87	0.88	0.89	0.89
	ICC	0.30	0.46	0.56	0.63	0.68	0.72	0.75	0.77	0.79	0.81	0.82	0.83	0.85	0.86
10	Upper 95% CI	0.65	0.75	0.80	0.84	0.86	0.88	0.89	0.91	0.91	0.92	0.93	0.93	0.94	0.94
	Lower 95% CI	-0.17	0.02	0.15	0.26	0.34	0.40	0.46	0.50	0.54	0.57	0.60	0.62	0.64	0.66

Table 10. Intraclass correlation coefficients (ICC) with 95% confidence intervals (CI) for hip-worn time at or above a moderate intensity (T_{MV}) from the Inactive group. Boxed ICC values indicate desired reliability of ≥ 0.80 (n = 20).

Time Bout (min)		Day 1	2	3	4	5	6	7	8	9	10	11	12	13	14
	ICC	0.40	0.57	0.66	0.73	0.77	0.80	0.82	0.84	0.86	0.87	0.88	0.89	0.90	0.90
1	Upper 95% CI	0.72	0.81	0.86	0.88	0.90	0.92	0.93	0.94	0.94	0.95	0.95	0.96	0.96	0.96
	Lower 95% CI	-0.05	0.17	0.32	0.42	0.49	0.55	0.60	0.63	0.67	0.69	0.71	0.73	0.75	0.77
	ICC	0.04	0.07	0.10	0.13	0.16	0.19	0.21	0.24	0.26	0.28	0.30	0.32	0.34	0.35
10	Upper 95% CI	0.47	0.50	0.52	0.54	0.56	0.58	0.60	0.62	0.63	0.64	0.66	0.67	0.68	0.69
	Lower 95% CI	-0.41	-0.38	-0.35	-0.33	-0.30	-0.28	-0.25	-0.23	-0.21	-0.19	-0.17	-0.15	-0.13	-0.11

Intraclass correlation coefficients (ICC) with 95% confidence intervals (CI) for wrist-worn time at or above a moderate intensity (T_{MV}) from the Active group. Boxed ICC values indicate desired reliability of ≥ 0.80 (n = 20).

Time Bout (min)		Day 1	2	3	4	5	6	7	8	9	10	11	12	13	14
	ICC	0.51	0.68	0.76	**0.81**	0.84	0.86	0.88	0.89	0.90	0.91	0.92	0.93	0.93	0.94
1	Upper 95% CI	0.78	0.86	0.90	0.92	0.94	0.94	0.95	0.96	0.96	0.97	0.97	0.97	0.97	0.98
	Lower 95% CI	0.09	0.33	0.47	0.57	0.63	0.68	0.72	0.75	0.77	0.79	0.81	0.825	0.83	0.84
	ICC	0.39	0.56	0.66	0.72	0.76	0.79	**0.82**	0.84	0.85	0.86	0.88	0.88	0.89	0.90
10	Upper 95% CI	0.71	0.80	0.85	0.88	0.90	0.92	0.93	0.93	0.94	0.95	0.95	0.95	0.96	0.96
	Lower 95% CI	-0.06	0.16	0.30	0.41	0.48	0.54	0.59	0.63	0.66	0.68	0.71	0.73	0.74	0.76

Intraclass correlation coefficients (ICC) with 95% confidence intervals (CI) for wrist-worn time at or above a moderate intensity (T_{MV}) from the Inactive group. Boxed ICC values indicate desired reliability of ≥ 0.80 (n = 20).

Time Bout (min)		Day 1	2	3	4	5	6	7	8	9	10	11	12	13	14
	ICC	0.59	0.74	**0.81**	0.85	0.88	0.90	0.91	0.92	0.93	0.93	0.94	0.94	0.95	0.95
1	Upper 95% CI	0.82	0.89	0.92	0.94	0.95	0.96	0.96	0.97	0.97	0.97	0.98	0.98	0.98	0.98
	Lower 95% CI	0.20	0.44	0.57	0.66	0.71	0.75	0.78	0.80	0.82	0.84	0.85	0.86	0.87	0.88
	ICC	0.52	0.69	0.77	**0.81**	0.85	0.87	0.88	0.90	0.91	0.92	0.92	0.93	0.93	0.94
10	Upper 95% CI	0.78	0.87	0.90	0.92	0.94	0.95	0.95	0.96	0.96	0.97	0.97	0.97	0.97	0.98
	Lower 95% CI	0.10	0.35	0.49	0.58	0.64	0.69	0.73	0.76	0.78	0.80	0.81	0.83	0.84	0.85

Intraclass correlation coefficients (ICC) with 95% confidence intervals (CI) for hip-worn activity energy expenditure at or above a moderate intensity (AEE_{MV}) from the Active group. Boxed ICC values indicate desired reliability of ≥ 0.80 (n = 20).

Time Bout (min)		Day 1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	ICC	0.68	0.81	0.86	0.90	0.91	0.93	0.94	0.94	0.95	0.96	0.96	0.96	0.97	0.97
	Upper 95% CI	0.86	0.92	0.95	0.96	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.99	0.99	0.99
	Lower 95% CI	0.34	0.57	0.68	0.75	0.79	0.82	0.85	0.86	0.88	0.89	0.90	0.91	0.91	0.92
10	ICC	0.32	0.49	0.59	0.65	0.70	0.74	0.77	0.79	0.81	0.83	0.84	0.85	0.86	0.87
	Upper 95% CI	0.67	0.77	0.82	0.85	0.87	0.89	0.90	0.91	0.92	0.93	0.94	0.94	0.94	0.95
	Lower 95% CI	-0.14	0.06	0.20	0.30	0.38	0.44	0.49	0.54	0.57	0.60	0.63	0.65	0.68	0.69

Intraclass correlation coefficients (ICC) with 95% confidence intervals (CI) for hip-worn activity energy expenditure at or above a moderate intensity (AEE_{MV}) from the Inactive group. Boxed ICC values indicate desired reliability of ≥ 0.80 (n = 20).

Time Bout (min)		Day 1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	ICC	0.40	0.57	0.67	0.73	0.77	0.80	0.83	0.84	0.86	0.87	0.88	0.89	0.90	0.90
	Upper 95% CI	0.72	0.81	0.86	0.89	0.91	0.92	0.93	0.94	0.94	0.95	0.95	0.96	0.96	0.96
	Lower 95% CI	-0.05	0.18	0.32	0.42	0.50	0.56	0.60	0.64	0.67	0.70	0.72	0.74	0.76	0.77
10	ICC	0.05	0.10	0.15	0.19	0.22	0.26	0.29	0.32	0.34	0.37	0.39	0.41	0.43	0.45
	Upper 95% CI	0.42	0.52	0.55	0.58	0.61	0.63	0.65	0.67	0.68	0.70	0.71	0.72	0.73	0.74
	Lower 95% CI	-0.40	-0.36	-0.32	-0.28	-0.24	-0.21	-0.18	-0.15	-0.12	-0.09	-0.07	-0.04	-0.02	0.01

Intraclass correlation coefficients (ICC) with 95% confidence intervals (CI) for wrist-worn activity energy expenditure at or above a moderate intensity (AEE_{MV}) from the Active group. Boxed ICC values indicate desired reliability of ≥ 0.80 (n = 20).

Time Bout (min)		Day 1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	ICC	0.36	0.53	0.63	0.69	0.74	0.77	**0.80**	0.82	0.83	0.85	0.86	0.87	0.88	0.89
	Upper 95% CI	0.69	0.79	0.84	0.87	0.89	0.91	0.92	0.93	0.93	0.94	0.94	0.95	0.95	0.96
	Lower 95% CI	-0.10	0.11	0.26	0.36	0.44	0.50	0.55	0.59	0.62	0.65	0.68	0.70	0.72	0.73
10	ICC	0.23	0.37	0.47	0.54	0.60	0.64	0.68	0.70	0.73	0.75	0.77	0.78	0.79	**0.80**
	Upper 95% CI	0.61	0.70	0.76	0.80	0.82	0.84	0.86	0.87	0.89	0.90	0.90	0.91	0.92	0.92
	Lower 95% CI	-0.24	-0.08	0.04	0.13	0.21	0.28	0.33	0.38	0.42	0.46	0.49	0.52	0.54	0.57

Intraclass correlation coefficients (ICC) with 95% confidence intervals (CI) for wrist-worn activity energy expenditure at or above a moderate intensity (AEE_{MV}) from the Inctive group. Boxed ICC values indicate desired reliability of ≥ 0.80 (n = 20).

Time Bout (min)		Day 1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	ICC	0.55	0.71	0.79	**0.83**	0.86	0.88	0.90	0.91	0.92	0.93	0.93	0.94	0.94	0.95
	Upper 95% CI	0.80	0.88	0.91	0.93	0.94	0.95	0.96	0.96	0.97	0.97	0.97	0.98	0.98	0.98
	Lower 95% CI	0.15	0.39	0.53	0.62	0.68	0.72	0.75	0.78	0.80	0.82	0.83	0.84	0.86	0.86
10	ICC	0.48	0.64	0.73	0.78	**0.82**	0.84	0.86	0.88	0.89	0.90	0.91	0.92	0.92	0.93
	Upper 95% CI	0.76	0.85	0.89	0.91	0.93	0.94	0.95	0.95	0.96	0.96	0.96	0.97	0.97	0.97
	Lower 95% CI	0.04	0.28	0.43	0.52	0.59	0.64	0.68	0.71	0.74	0.76	0.78	0.80	0.81	0.82

APPENDIX E

ICC TABLES AND 95% CONFIDENCE INTERVALS FOR DEPENDENT VARIABLES FROM ALL INTENSITY ACTIVITIES

Intraclass correlation coefficients (ICC) with 95% confidence intervals (CI) for hip-worn raw counts per minute for all intensities (CNT_{TOT}) from the Active group. Boxed ICC values indicate desired reliability of ≥ 0.80 (n = 20).

Time Bout (min)		Day 1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	ICC	0.45	0.62	0.71	0.77	0.81	0.83	0.85	0.87	0.88	0.89	0.90	0.91	0.92	0.92
	Upper 95% CI	0.75	0.84	0.88	0.90	0.92	0.93	0.94	0.95	0.95	0.96	0.96	0.96	0.97	0.97
	Lower 95% CI	0.02	0.25	0.40	0.49	0.57	0.62	0.66	0.69	0.72	0.74	0.76	0.78	0.80	0.81
10	ICC	0.46	0.63	0.72	0.77	0.81	0.84	0.86	0.87	0.88	0.89	0.90	0.91	0.92	0.92
	Upper 95% CI	0.75	0.84	0.88	0.91	0.92	0.93	0.94	0.95	0.95	0.96	0.96	0.97	0.97	0.97
	Lower 95% CI	0.02	0.26	0.41	0.50	0.57	0.63	0.67	0.70	0.73	0.75	0.77	0.79	0.80	0.81

Intraclass correlation coefficients (ICC) with 95% confidence intervals (CI) for hip-worn raw counts per minute for all intensities (CNT_{TOT}) from the Inactive group. Boxed ICC values indicate desired reliability of ≥ 0.80 (n = 20).

Time Bout (min)		Day 1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	ICC	0.25	0.40	0.50	0.57	0.63	0.67	0.70	0.73	0.75	0.77	0.79	0.80	0.81	0.83
	Upper 95% CI	0.63	0.72	0.77	0.81	0.84	0.86	0.87	0.89	0.90	0.91	0.91	0.92	0.92	0.93
	Lower 95% CI	-0.21	-0.05	0.08	0.18	0.23	0.32	0.38	0.42	0.46	0.50	0.53	0.56	0.58	0.60
10	ICC	0.08	0.16	0.22	0.27	0.32	0.36	0.39	0.42	0.45	0.48	0.50	0.53	0.55	0.56
	Upper 95% CI	0.51	0.56	0.60	0.64	0.67	0.69	0.71	0.73	0.75	0.76	0.77	0.79	0.80	0.81
	Lower 95% CI	-0.37	-0.31	-0.25	-0.20	-0.15	-0.10	-0.06	-0.02	0.01	0.05	0.08	0.11	0.14	0.16

Intraclass correlation coefficients (ICC) with 95% confidence intervals (CI) for wrist-worn raw counts per minute for all intensities (CNT_{TOT}) from the Active group. Boxed ICC values indicate desired reliability of ≥ 0.80 (n = 20).

		Day													
Time Bout (min)		1	2	3	4	5	6	7	8	9	10	11	12	13	14
	ICC	0.20	0.33	0.43	0.50	0.55	0.60	0.64	0.67	0.69	0.71	0.73	0.75	0.76	0.78
1	Upper 95% CI	0.59	0.68	0.73	0.77	0.80	0.82	0.84	0.86	0.87	0.88	0.89	0.90	0.90	0.91
	Lower 95% CI	-0.27	-0.13	-0.02	0.07	0.15	0.21	0.27	0.32	0.36	0.40	0.43	0.46	0.49	0.51
	ICC	0.18	0.30	0.40	0.47	0.52	0.57	0.60	0.64	0.66	0.69	0.71	0.72	0.74	0.75
10	Upper 95% CI	0.58	0.66	0.71	0.75	0.78	0.81	0.83	0.84	0.86	0.87	0.88	0.88	0.89	0.90
	Lower 95% CI	-0.29	-0.16	-0.06	0.03	0.10	0.17	0.22	0.27	0.31	0.35	0.38	0.41	0.44	0.47

Intraclass correlation coefficients (ICC) with 95% confidence intervals (CI) for wrist-worn raw counts per minute for all intensities (CNT_{TOT}) from the Inactive group. Boxed ICC values indicate desired reliability of ≥ 0.80 (n = 20).

		Day													
Time Bout (min)		1	2	3	4	5	6	7	8	9	10	11	12	13	14
	ICC	0.61	0.76	0.83	0.86	0.89	0.91	0.92	0.93	0.93	0.94	0.95	0.95	0.95	0.96
1	Upper 95% CI	0.83	0.90	0.93	0.95	0.96	0.96	0.97	0.97	0.97	0.98	0.98	0.98	0.98	0.98
	Lower 95% CI	0.24	0.48	0.61	0.68	0.74	0.77	0.80	0.82	0.84	0.85	0.87	0.88	0.89	0.89
	ICC	0.56	0.72	0.79	0.84	0.87	0.89	0.90	0.91	0.92	0.92	0.93	0.94	0.94	0.95
10	Upper 95% CI	0.81	0.88	0.92	0.93	0.95	0.95	0.96	0.97	0.97	0.97	0.97	0.98	0.98	0.98
	Lower 95% CI	0.16	0.41	0.54	0.63	0.69	0.73	0.76	0.79	0.81	0.82	0.84	0.85	0.86	0.87

Intraclass correlation coefficients (ICC) with 95% confidence intervals (CI) for hip-worn time for all intensities (T_{TOT}) from the Active group. Boxed ICC values indicate desired reliability of ≥ 0.80 (n = 20).

Time Bout (min)		Day 1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	ICC	0.70	0.83	0.88	0.90	0.92	0.93	0.94	0.95	0.96	0.96	0.96	0.97	0.97	0.97
	Upper 95% CI	0.87	0.93	0.95	0.96	0.97	0.97	0.98	0.98	0.98	0.98	0.99	0.99	0.99	0.99
	Lower 95% CI	0.38	0.60	0.71	0.77	0.81	0.84	0.85	0.86	0.88	0.89	0.90	0.91	0.92	0.93
10	ICC	0.43	0.61	0.70	0.75	0.79	0.82	0.84	0.86	0.87	0.89	0.89	0.90	0.91	0.92
	Upper 95% CI	0.74	0.83	0.87	0.90	0.92	0.93	0.94	0.94	0.95	0.95	0.96	0.96	0.96	0.97
	Lower 95% CI	-0.01	0.22	0.37	0.47	0.54	0.60	0.64	0.68	0.70	0.73	0.75	0.77	0.78	0.79

Intraclass correlation coefficients (ICC) with 95% confidence intervals (CI) for hip-worn time for all intensities (T_{TOT}) from the Inactive group. Boxed ICC values indicate desired reliability of ≥ 0.80 (n = 20).

Time Bout (min)		Day 1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	ICC	0.70	0.83	0.88	0.90	0.92	0.93	0.94	0.95	0.96	0.96	0.96	0.97	0.97	0.97
	Upper 95% CI	0.87	0.93	0.95	0.96	0.97	0.97	0.98	0.98	0.98	0.98	0.99	0.99	0.99	0.99
	Lower 95% CI	0.38	0.60	0.71	0.77	0.81	0.84	0.86	0.88	0.89	0.90	0.91	0.92	0.92	0.93
10	ICC	0.54	0.71	0.78	0.83	0.86	0.88	0.89	0.91	0.92	0.92	0.93	0.93	0.94	0.94
	Upper 95% CI	0.80	0.88	0.91	0.93	0.94	0.95	0.96	0.96	0.97	0.97	0.97	0.97	0.98	0.98
	Lower 95% CI	0.14	0.38	0.52	0.61	0.67	0.71	0.75	0.77	0.79	0.81	0.83	0.87	0.85	0.86

Intraclass correlation coefficients (ICC) with 95% confidence intervals (CI) for wrist-worn time for all intensities (T_{TOT}) from the Active group. Boxed ICC values indicate desired reliability of ≥ 0.80 (n = 20).

Time Bout (min)		Day 1	2	3	4	5	6	7	8	9	10	11	12	13	14
	ICC	0.70	0.83	0.88	0.90	0.92	0.93	0.94	0.95	0.96	0.96	0.96	0.97	0.97	0.97
1	Upper 95% CI	0.87	0.93	0.95	0.96	0.97	0.97	0.98	0.98	0.98	0.98	0.99	0.99	0.99	0.99
	Lower 95% CI	0.38	0.60	0.71	0.77	0.81	0.84	0.86	0.88	0.89	0.90	0.91	0.92	0.92	0.93
	ICC	0.36	0.53	0.63	0.69	0.74	0.77	0.80	0.82	0.83	0.85	0.86	0.87	0.88	0.89
10	Upper 95% CI	0.69	0.79	0.84	0.87	0.89	0.90	0.92	0.93	0.93	0.94	0.94	0.95	0.95	0.96
	Lower 95% CI	-0.10	0.11	0.26	0.36	0.44	0.50	0.55	0.59	0.62	0.65	0.67	0.70	0.72	0.73

Intraclass correlation coefficients (ICC) with 95% confidence intervals (CI) for wrist-worn time for all intensities (T_{TOT}) from the Inactive group. Boxed ICC values indicate desired reliability of ≥ 0.80 (n = 20).

Time Bout (min)		Day 1	2	3	4	5	6	7	8	9	10	11	12	13	14
	ICC	0.70	0.83	0.88	0.90	0.92	0.93	0.94	0.95	0.96	0.96	0.96	0.97	0.97	0.97
1	Upper 95% CI	0.87	0.93	0.95	0.96	0.97	0.97	0.98	0.98	0.98	0.99	0.99	0.99	0.99	0.99
	Lower 95% CI	0.38	0.60	0.71	0.77	0.81	0.84	0.86	0.88	0.89	0.90	0.91	0.92	0.92	0.93
	ICC	0.54	0.70	0.78	0.82	0.85	0.88	0.89	0.90	0.91	0.92	0.93	0.93	0.94	0.94
10	Upper 95% CI	0.79	0.87	0.91	0.93	0.94	0.95	0.96	0.96	0.97	0.97	0.97	0.97	0.98	0.98
	Lower 95% CI	0.13	0.38	0.51	0.60	0.66	0.71	0.74	0.77	0.79	0.81	0.82	0.84	0.85	0.86

Intraclass correlation coefficients (ICC) with 95% confidence intervals (CI) for hip-worn activity energy expenditure for all intensities (AEE_{TOT}) from the Active group. Boxed ICC values indicate desired reliability of ≥ 0.80 (n = 20).

Time Bout (min)		Day 1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	ICC	0.76	0.86	0.90	0.93	0.94	0.95	0.96	0.96	0.97	0.97	0.97	0.97	0.98	0.98
	Upper 95% CI	0.90	0.94	0.96	0.97	0.98	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99
	Lower 95% CI	0.47	0.68	0.77	0.82	0.85	0.87	0.89	0.90	0.91	0.92	0.93	0.93	0.94	0.94
10	ICC	0.38	0.55	0.65	0.71	0.76	0.79	0.81	0.83	0.85	0.86	0.87	0.88	0.89	0.90
	Upper 95% CI	0.71	0.80	0.85	0.88	0.90	0.91	0.92	0.93	0.94	0.94	0.95	0.95	0.96	0.96
	Lower 95% CI	-0.07	0.155	0.29	0.40	0.47	0.53	0.58	0.62	0.65	0.68	0.70	0.72	0.74	0.75

Intraclass correlation coefficients (ICC) with 95% confidence intervals (CI) for hip-worn activity energy expenditure for all intensities (AEE_{TOT}) from the Inactive group. Boxed ICC values indicate desired reliability of ≥ 0.80 (n = 20).

Time Bout (min)		Day 1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	ICC	0.46	0.63	0.72	0.77	0.81	0.83	0.85	0.87	0.88	0.89	0.90	0.91	0.92	0.92
	Upper 95% CI	0.75	0.84	0.88	0.91	0.92	0.93	0.94	0.95	0.95	0.96	0.96	0.96	0.97	0.97
	Lower 95% CI	0.02	0.26	0.40	0.50	0.57	0.62	0.66	0.70	0.72	0.75	0.77	0.78	0.80	0.81
10	ICC	0.04	0.08	0.12	0.15	0.18	0.21	0.24	0.26	0.29	0.31	0.33	0.35	0.37	0.38
	Upper 95% CI	0.48	0.51	0.53	0.56	0.58	0.60	0.62	0.63	0.65	0.66	0.67	0.69	0.70	0.71
	Lower 95% CI	-0.41	-0.37	-0.34	-0.31	-0.28	-0.26	-0.23	-0.20	-0.18	-0.16	-0.13	-0.11	-0.09	-0.07

Intraclass correlation coefficients (ICC) with 95% confidence intervals (CI) for wrist-worn activity energy expenditure for all intensities (AEE_{TOT}) from the Active group. Boxed ICC values indicate desired reliability of ≥ 0.80 (n = 20).

Time Bout (min)		Day 1	2	3	4	5	6	7	8	9	10	11	12	13	14
	ICC	0.40	0.57	0.67	0.73	0.77	0.80	0.82	0.84	0.86	0.87	0.88	0.89	0.90	0.90
1	Upper 95% CI	0.72	0.81	0.86	0.89	0.90	0.92	0.93	0.94	0.94	0.95	0.95	0.96	0.96	0.96
	Lower 95% CI	-0.05	0.17	0.32	0.42	0.50	0.55	0.60	0.64	0.67	0.70	0.72	0.74	0.75	0.77
	ICC	0.24	0.39	0.49	0.56	0.61	0.65	0.69	0.72	0.74	0.76	0.78	0.79	0.80	0.81
10	Upper 95% CI	0.62	0.71	0.76	0.80	0.83	0.85	0.87	0.88	0.89	0.90	0.91	0.91	0.92	0.92
	Lower 95% CI	-0.23	-0.07	0.06	0.15	0.23	0.30	0.35	0.40	0.44	0.48	0.51	0.54	0.56	0.58

Intraclass correlation coefficients (ICC) with 95% confidence intervals (CI) for wrist-worn activity energy expenditure for all intensities (AEE_{TOT}) from the Inactive group. Boxed ICC values indicate desired reliability of ≥ 0.80 (n = 20).Table 10. Inactive wrist (AEE)

Time Bout (min)		Day 1	2	3	4	5	6	7	8	9	10	11	12	13	14
	ICC	0.54	0.70	0.78	0.82	0.85	0.88	0.89	0.90	0.91	0.92	0.93	0.93	0.94	0.94
1	Upper 95% CI	0.79	0.87	0.91	0.93	0.94	0.95	0.96	0.96	0.97	0.97	0.97	0.97	0.98	0.98
	Lower 95% CI	0.13	0.37	0.51	0.60	0.66	0.71	0.74	0.77	0.79	0.81	0.82	0.84	0.85	0.86
	ICC	0.47	0.64	0.73	0.78	0.82	0.84	0.86	0.88	0.89	0.90	0.91	0.91	0.92	0.93
10	Upper 95% CI	0.76	0.84	0.89	0.91	0.93	0.94	0.95	0.95	0.96	0.96	0.96	0.97	0.97	0.97
	Lower 95% CI	0.04	0.28	0.42	0.52	0.59	0.64	0.68	0.71	0.74	0.76	0.78	0.79	0.81	0.82