Methods of physical activity assessment for older adults

by

Patrick McIntyre

A thesis submitted to the graduate faculty in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Major: Kinesiology (Biological Basis of Physical Activity)

Program of Study Committee:

Warren Franke, Major Professor
Gregory Welk
Lorraine Lanningham-Foster

Iowa State University
Ames, Iowa
2010
# TABLE OF CONTENTS

ABSTRACT ....................................................................................................................................... iv

CHAPTER 1 – INTRODUCTION ........................................................................................................ 1

  Statement of the Problem ........................................................................................................... 3

CHAPTER 2 - REVIEW OF THE LITERATURE ............................................................................... 5

  Doubly Labeled Water ................................................................................................................ 5

  Accelerometers .......................................................................................................................... 6

    Sources of error for an accelerometer ..................................................................................... 7

    ActiGraph, the most popular accelerometer ............................................................................ 9

    ActiGraph in comparison with indirect calorimetry ................................................................. 10

    Pattern recognition monitors ................................................................................................ 11

    Sensewear Pro 3 Armband in comparison with doubly labeled water .................................... 11

    Comparison with indirect calorimetry ..................................................................................... 12

    Further considerations for validity of the Sensewear Pro 3 Armband ................................. 13

  Physical Activity Questionnaires .............................................................................................. 14

    Community Healthy Activities Model Program for Seniors .................................................. 17

    Rapid Assessment of Physical Activity .................................................................................. 20

CHAPTER 3 - METHODS .............................................................................................................. 22

  Subjects ..................................................................................................................................... 22

  Visit 1 ....................................................................................................................................... 22

  Visit 2 ....................................................................................................................................... 22

  Data Processing ....................................................................................................................... 23

CHAPTER 4 - RESULTS ............................................................................................................... 25
CHAPTER 5 - DISCUSSION ................................................................................. 32
Comparison of Accelerometers ........................................................................ 32
Comparison of PAQs with Criterion Measure .................................................... 34
Seven Day Physical Activity Recall .................................................................. 34
YALE Physical Activity Survey ......................................................................... 36
Physical Activity Scale for the Elderly ............................................................... 37
Community Healthy Activities Model Program for Seniors ............................... 37
Rapid Assessment of Physical Activity .............................................................. 38
Limitations ......................................................................................................... 38
Conclusion .......................................................................................................... 39

REFERENCES .................................................................................................... 41

APPENDIX A - Paired Samples t-tests of Significant Relationships .................... 53
APPENDIX B – 7DAY, YPAS and RAPA Pearson Correlations ......................... 54
APPENDIX C – PASE and CHAMPS Pearson Correlations ............................... 55
APPENDIX D – 7DAY, YPAS and RAPA Spearman Correlations ..................... 56
APPENDIX E – PASE and CHAMPS Spearman Correlations ......................... 57
APPENDIX F – ACT Pearson Correlations ........................................................ 58
APPENDIX G – ACT Spearman Correlations ..................................................... 59
ABSTRACT

**Introduction:** The goal of this study was to evaluate the convergent validity of physical activity (PA) assessment methods widely used with older adults with an accelerometer-based pattern recognition monitor, the Sensewear Pro 3 Armband (SP3). The ActiGraph (ACT) accelerometer and the Seven Day Physical Activity Recall (7DAY) physical activity questionnaires (PAQ) are two of the most popular methods of PA assessment; however the understanding of their use with an older adult population is limited. PAQs designed specifically for older adults such as the Community Healthy Activities Model Program for Seniors (CHAMPS), Yale Physical Activity Survey (YPAS), Physical Activity Survey for the Elderly (PASE), and Rapid Assessment of Physical Activity (RAPA) are currently lacking comparison with objective criterion measures. The purpose of the study was to establish validity for PA assessment methods, designed for both the general population and older adults, which are lacking comparison with objective criterion measures in an older adult population.

**Methods:** The participants (n=27; age=74.4 ± 6.5) wore the SP3 and ACT for 7 days of normal activities of daily living and completed the PAQs to recall their activity over the same time frame. ACT physical activity energy expenditure (PAEE) was calculated with the Freedson equation (ACT-F) and Work-Energy-Theorem and Freedson combination (ACT-C). The ACT-F and Matthews cutpoint (ACT-M) were used for estimates of minutes per week of PA. A one way ANOVA was used to find differences between genders. Pearson and Spearman correlations examined significant relationships. Paired samples t-tests and Bland-Altman plots investigated differences between methods.

**Results:** ACT estimates of step count were highly related at 0.96 (p<0.01) with the SP3 although there were differences between methods. The ACT-C showed moderate relationships (r=0.54, p<0.01) with the SP3 in PAEE estimates. A trend of underestimation was present of 78kcal per day. The ACT-M was moderately related
(r=0.64, p<0.01) to the SP3 for minutes of PA. It underestimated 47 minutes per week of PA. No significant differences were found between the ACT-C and ACT-M with the SP3. The 7DAY and YPAS correlated moderately well with the SP3 for PAEE (r=0.69 & 0.85, p<0.01) and for minutes of PA (r=0.68 & 0.84, p<0.01). Spearman rank order was 0.73 (p<0.01), 0.56 (p<0.01) and 0.39 (p<0.05) for the 7DAY, YPAS and PASE with the SP3 for PAEE. Rank order was 0.70 and 0.64 (p<0.01) for the 7DAY and YPAS with the SP3 estimates of PA minutes. Significant differences were not found for 7Day and YPAS with the SP3. Wider limits of agreement existed for the YPAS under Bland-Altman analysis. The CHAMPS showed no significant relationships with the criterion measure. Analysis of the RAPA was not possible due to a small, highly active sample.

**Discussion:** The ACT had reasonable agreement with the SP3 for estimating PAEE and minutes spent in PA. The results support the use of the 7DAY to estimate PAEE in a healthy older adult population. The PAQs designed specifically for older adults such as the YPAS and PASE may only have use for group rankings, while the RAPA may only be useful for classification as active or sedentary. The CHAMPS requires further research with an objective criterion measure before being used for estimates of PA in an older adult population.
CHAPTER 1 – INTRODUCTION

Heart disease is the leading cause of death for adults over 60 years of age in the United States (Loyd-Jones et al., 2008). Physical inactivity is a main risk factor for the development of heart disease (American Heart Association, 2009). Exercising regularly can help raise HDL cholesterol along with maintaining blood glucose levels, blood pressure and weight (American Heart Association, 2009; Starling, 2001). Moderate to vigorous intensity activities such as brisk walking, jogging and swimming can improve heart and lung function while low to moderate intensity activities such as light walking, gardening, yard work and housework can reduce the risk of heart disease as well (La Croix et al., 1996).

A clear, positive relationship exists between physical activity (PA) levels and health outcomes in older adults. Levels of PA are also shown to be a determinant of functional ability, mortality, and quality of life in older adult populations (Shephard, 1993). PA also acts to delay declines in physical and mental health (Christmas et al., 2000). Manini et al. (2009) showed that cumulative energy expenditure (EE) from PA helps maintain mobility function and reduce mobility limitations for older men. Declines in mobility represent a decline in functional health that can often lead to institutionalization (Mor et al., 1994) or death (Hirvenselo et al., 2000). Fewer than 20% of older adults are meeting recommended PA levels (CDC Physical Activity and Health Report, 1996) and only 11% engage in any strength training (CDC, 2004). These unsettling numbers contribute to the rising number of older adults diagnosed with chronic diseases and disabilities (Heckman, 2008). This list of needs is further highlighted by the expectation that 25% of the United States population is expected to be 65 or older by the year 2030 (Starling, 2001).

Accurate subjective and objective methods of estimating PA in older adults with respect to cost, participant burden and ease of administration are needed to further physical activity assessment research (PAAR) of older adults. In order to compare multiple studies to each other, a common measurement outcome such as
EE needs to be derived from all methods used in PAAR. Accurate methods for assessing PA are needed to determine correlates and determinants of behavior. Methods of PA assessment that are quantifiable and sensitive to change are also needed in PAAR to determine if interventions made in older adult populations are effective. Several methods of estimating PA exist; each has its own advantages and disadvantages.

A number of PAAR methods exist. Pedometers are effective in increasing PA, and in turn, decreasing body mass and blood pressure (Bravata et al., 2007). Unfortunately, pedometers provide very little information about the frequency, intensity, duration and types of PA performed. Indirect calorimetry and direct observation are impractical for field research. Heart rate monitoring can be used to estimate EE from PA (Montoye et al., 1996), but is impractical for large-scale interventions (Nieman, 1999; Rowlands et al., 1997). Some physical activity questionnaires (PAQ) have shown encouraging results in previous research with older adults, but each PAQ requires validation. Many of the validation studies for these PAQs use comparison measures of functional tests (Cyarto et al. 2006; Harada et al., 2001), other questionnaires (Topolski et al., 2006) or other methods lacking validity (Stewart et al. 2001). A number of questionnaires have been created solely for the older adult population, but the degree to which they can measure true levels of free living EE in their target population has not yet been clarified. Comparison against a “gold standard” under free living conditions is needed to examine differences in validity, participant burden and ease of administration in order to guide which questionnaires to utilize in future PAAR.

Accelerometers worn on the body have been used in diverse applications such as fall detection (Lindenman 2005 et al.; Kangas et al., 2008) or sleep research (Jean-Louis et al., 2001; Kawada, 2008). However, recent studies have shown that frequency, duration and intensity of PA can be objectively measured by wearing specialized accelerometer-based activity monitors. Accelerometer measuring techniques can provide a high level of accuracy for objectively assessing PA.
(Fairweather, et al., 1999; Ott, et al., Welk, et al., 1999, 2000; Trost, et al., 2000; Nilsson, et al., 2002; Sallis, et al., 2002). Despite widespread use of accelerometers to objectively monitor PA among adults and youth, little attention has been given to their use in older populations (Copeland & Eslinger, 2009). Advancing motion monitor technology allows for long-term collection and simplified uploading of data to computers where detailed analysis of activity patterns can be made (Casaburi, 2007). A limitation of accelerometers is their ability to measure all activities equally well; their ability to measure locomotor movement such as walking, which constitutes most of the observed daily activity of adults, has been documented (Bouten et al., 1994). Some units measure motion in a single axis of movement while other units monitor two or three axes to track bodily movement in multiple dimensions. Measurement of lower intensity movement in three dimensions is more accurate (Midorikawa et al., 2007).

**Statement of the Problem**

The most accurate and precise tools, with respect to cost and participant burden, in the assessment of EE associated with PA in older adults are not yet determined. Several PAQs have been designed for and used with older adults; however validation studies of some methods do not use an objective criterion measure. Widely used methods for the general population, like the ACT and 7DAY, are only assumed to be accurate with older adults as well. Older adults may not have the same PA patterns as the general population due in part to high variability in frequency and duration along with a preference for lower intensity activities. PAQs need to be sensitive to change for a population that performs low levels of PA, typically at light intensities, as well as be accurate in their estimate of EE and time spent in PA. Accelerometers should be unobtrusive and sensitive enough to measure differences between sedentary behavior and sporadic PA. They should also recognize the PA associated with a variety of household and leisure time activities. Comparison with a criterion measure of PA assessment is the first step in understanding the role of currently available methods in accurately estimating PA.
and EE of older adult populations. The PA assessment methods used with older adults need to be compared to an objective criterion measure with older adults before being further utilized in the research field.
CHAPTER 2 - REVIEW OF THE LITERATURE

Doubly Labeled Water

Doubly labeled water (DLW) is currently the gold standard in assessing free-living energy expenditure (EE) (Elia et al., 2000; Starling et al., 1999). DLW is reliable in older adults (Elia et al., 2000) and validity in both lean and obese subjects (Ravussin et al, 1991) which makes it the best choice as a criterion measure for assessment of EE. The DLW method utilizes ingestion of two stable isotopes, $^2$H and $^{18}$O, to track EE by measuring their differences in decline over time.

Concentration of these hydrogen and oxygen isotopes decline at the same rate due to water turnover in the body, however, oxygen is also lost from carbon dioxide production. Oxygen in respiratory carbon dioxide and body water are the same (Lifson et al., 1955) so the difference found between the two elements in the urine is the same as the amount of expired carbon dioxide. The estimate of expired carbon dioxide is paired with the appropriate respiratory quotient to determine the total amount of oxygen metabolized, thus giving the total energy expenditure (TEE) during the measurement period. DLW only measures TEE so subtracting resting metabolic rate (RMR) and the thermic effect of feeding are required to determine EE due to physical activity (PA). The RMR is estimated by resting measurements taken by indirect calorimetry. The thermic effect of feeding in the elderly has been estimated at 10% of TEE (Poehlman et al., 1991). Overall, this specific process is highly accurate in comparison to near continuous indirect calorimetry with a low coefficient of variation (Schoeller & Hnilicka, 1996).

The next strength of DLW is that it allows a participant to be assessed in a free-living environment. Participants are able to engage in all land and water based activities, household chores, self care and miscellaneous leisure time activities with no loss in EE measurement. Additionally, EE from small or non-volitional movements are recorded which may not be captured by accelerometry and physical activity questionnaires (PAQ). These movements are thought to account for 100-800 kcal per day (Ravussin et al, 1986). For example, TEE as measured by DLW was
compared with PA recall and pedometers (Levine et al., 1999) to examine these differences. The incongruence between the three was partially attributed to the movement that occurs without planning or remembrance known as non-exercise activity thermogenesis (Levine, 2008). While pedometers and PA recalls show moderate ability to estimate EE (Welk, 2002), the ability of DLW to record all EE accounts for it being a highly valid method of estimating TEE in humans.

The DLW method gives an accurate measurement of EE; however, it gives few details about the manner of EE. Variables such as frequency, intensity, and duration are not present in the data and may be important to the researcher. DLW is an expensive method of EE assessment due to the cost of the isotopes along with the equipment and time needed to process it. The high cost and participant burden can be prohibitive, so DLW is often reserved for studies with large budgets and small sample sizes.

Accelerometers

Accelerometers are small, noninvasive units attached to the body that measure changes in velocity over time in a single plane of motion and store the information internally for later retrieval and processing. A greater change in velocity indicates greater movement of the part of the body associated with the unit’s attachment site. This movement is defined as PA and information gathered from the accelerometer can be used to estimate EE associated with the PA. Current accelerometers rely on a piezoelectric sensor that measures movement and converts it to an electrical signal. “Piezoelectric” refers to the ability of a material to generate an electric charge in response to an applied mechanical stress. Mechanical stress creates electrical voltage by a mass exerting force on the piezoelectric material. The piezoelectric sensor in the accelerometers is comprised of a ceramic piece with an attached brass weight that bends during movement which generates an electric charge proportional to the force exerted. Acceleration is determined using the known mass of the brass and the measurement of the recorded force as determined by the electrical charge.
The electric signals are then input into a microprocessor for storage and future computer download. These signals are filtered to include only values in the normal range of human movement. High pass filters (HPF) and low pass filters (LPF) are utilized for this action. A HPF will eliminate low frequency signals such as normal g-force. A LPF removes higher frequencies that could be due to electrical interferences or other disturbances (Welk, 2002). If these units measure acceleration and deceleration, mounting them to the body where these occur in a pattern during movement would be used to estimate movement of the entire body and thus EE. Despite differences in acceleration at the waist, upper leg, lower leg and foot, head and trunk, lower arm and hand, and upper arm, each location is highly accurate in predicting EE (Bouten et al, 1997). This may leave the design of accelerometer placement to be decided by unobtrusiveness and comfort.

Accelerations are summed over time (e.g. epochs) into units referred to as counts. Typical epochs are one minute, resulting in 1440 lines of counts per day. Software is available to help analyze data and in most cases, it is possible to examine the raw data of 1440 measures of counts per day. The application of accelerometer specific algorithms to the counts results in an estimate of EE. This estimate of EE comes from a prediction equation associated with the individual monitor. These prediction equations are regression equations unique to each monitor and can vary depending on the types of activities performed. Some prefer to analyze the data as counts. Appropriate conversion equations may not exist for older adults (Leenders et al., 2000) and the conversion process may add errors that do not exist in raw data (Crouter et al., 2006a). Minute by minute recording of data over several days offers the ability to evaluate specific time points over the measurement period. A researcher would be able to study EE from certain days or trends at a certain time point over a number of days.

**Sources of error for an accelerometer**

Due to their nature of placement, accelerometers are at risk for accidental contact or insecure attachment. This could result in movement of the unit
independent of the body thus adding error. Measuring movement of the body is an ability of the accelerometer, however the inability to account for increased EE associated with movement against an increased resistance may increase error. An example of this could be walking up a hill or steps, lifting or pushing an item, or carrying a load. Despite an increased physical effort, if acceleration patterns remain constant, a change in EE is not recorded by the accelerometer. Additionally, with accelerometers measuring the acceleration of a segment of the body, it is possible for a unit to fail to detect an activity all together. A waist or arm unit would be unlikely to measure cycling while a lower body unit would not capture the entirety of activities requiring throwing. Accelerometers determine movement along a specified axis and thus do not record movement taking place along other axes. Some units address this by making use of two or three accelerometers in order to obtain movement from multiple planes. During secure attachment to the body, it is critical that the placement of the accelerometry unit is in accordance with the plane of movement to be measured.

Assessment of multiple bodily segments could gather more information on overall movement and its contribution to EE, but the improvement would not be enough to justify the additional cost and participant burden (Bouten 1997, SP3rtz 2000). Additionally, as accelerometers rely on electrical properties, they are not suitable for use in or around water and should be removed in those situations. Removal will cause the accelerometer not to record data during that time although EE may occur. It may be useful to have participants keep a journal describing the times they removed the monitor. The removal of a monitor at times other than those specified is deemed noncompliance and determined by examining movement counts. Welk et al. (2001) studied data in thirty minute blocks and determined a series of four consecutive blocks with zero counts signified removal of the unit. Most accelerometers are sensitive enough that even during periods of rest some counts would be recorded. Failure to wear the monitor as directed could result in spurious data.
**ActiGraph, the most popular accelerometer**

The ActiGraph (Fort Walton Beach, FL) is a small uni-axial accelerometer the same size as a pedometer and is worn on the waistband or belt. The newest model, GT1M, can hold up to a year’s worth of minute by minute data and will retain all collected information even with complete power loss of the rechargeable battery (Manufacturer website, www.ActiGraph.com). The ActiGraph (ACT) is the most widely used activity motion monitor in PA research (Welk, 2004; Plasqui & Westerterp, 2007). The ACT is the only commercially available uniaxial accelerometer to correlate significantly with a true criterion measure such as DLW in estimates of TEE with children and adults (Plasqui & Westerterp, 2007), but there is not yet sufficient evidence of the same ability to estimate EE in older adults. This limits the understanding of their utility in assessing PA in an older adult population and algorithms for this specific subset of the population are not yet defined. While the ACT has been used to assess activity patterns of older adults (Hagströmer et al., 2007; Davis & Fox, 2007; Copeland & Esliger, 2009), at this time there is very limited information regarding the validity of the ACT in that population. The GT1M model appears to be a more consistent measurement tool than previous ACTs, yet may have a decreased sensitivity in differentiating light intensity activity from sedentary behavior (Rothney et al., 2008). These issues demand comparison against a criterion measure in an older adult population.

Previous PAAR has utilized the Intelligent Device for Energy Expenditure and Physical Activity (IDEEA). It uses a complex series of sensors placed at five points along the body to determine postures and motions of the body. It is shown to demonstrate accurate detection of most movement patterns and provide highly accurate estimates of EE (Zhang et al., 2003; Zhang et al., 2004). While impractical for measuring free living conditions, it can be useful as a validation measure. Compared to the IDEEA, Welk et al. (2007) found the ACT to be an excellent marker ($r^2 = 0.94$) for estimating minutes per day of PA among 30 college aged participants when using the ACT count cutpoint proposed by Mathews (2005).
**ActiGraph in comparison with indirect calorimetry**

The ACT has been validated against indirect calorimetry (IC) in several studies. Due to the nature of IC, a majority of the studies were conducted in a lab setting including participants performing activities like treadmill walking and running (Mathews, 2005). King et al. (2004) found the ACT to be an excellent predictor of EE at walking and jogging speeds but only used subjects with a VO2 max above 50ml/kg/min. During a two hour bout of moderate to vigorous activity in 20 adults (19-56 years of age), the ACT was measured against IC and found to overestimate EE by 2.5% (Berntsen et al., 2008). Similar results were found by Crouter et al. (2006a) when assessing 48 men and women (age=35±11.3 years) doing multiple routines of sedentary behavior, light and moderate housework, and light and moderate PA. Of the regression equations applied to the ACT counts, the closest to the IC estimates of EE ($R^2 = 0.82$) were the Freedson equation (Freedson et al., 1998). Others have found it to overestimate the EE of walking (Welk et al., 2000) and underestimate all other activities (Crouter et al., 2006b). This emphasizes that a single regression equation is probably not ideal for estimating EE across a wide range of PA intensities.

Crouter et al. (2000b) explored the idea of using multiple regression equations with data from this previous study. The ACT regression equations typically were most accurate at the modalities they were derived from and lost accuracy during different activities. This made it difficult for a single regression equation to estimate EE accurately across a wide range of PA intensities. Identifying the coefficient of variation during activity could determine if an activity was a rhythmic locomotor activity such as walking and jogging or an activity more sporadic in nature such as golf or household work. The application of establishing a coefficient of variation threshold to apply one equation for some activities and a different equation for others intensities provided for a significant improvement in EE estimates over any previously available single regression equation. This advanced method may help address some of the shortcomings inherit with assessing PA with accelerometers.
Pattern recognition monitors

The Sensewear Pro 3 Armband (SP3) is an accelerometer based, pattern recognition monitor worn on the upper arm. A pattern recognition monitor utilizes one or more sensors to estimate positions and movements of the entire body for a more accurate estimate of EE. Typical accelerometers merely sum counts associated with a single site on the body and use them to estimate EE. The most recent SP3 model, the WMS, has a tri-axial accelerometer along with sensors to measure skin temperature, galvanic skin response, and heat flux associated with near body temperature. Information from the 4 sensors is used to estimate TEE, EE from PA, frequency, duration and intensity of PA and step count (Manufacturer website, www.Sensewear.com). These parameters along with demographic data (age, gender, weight, height, right or left handed, smoker or non-smoker) are input to the software program provided by the manufacturer. This software program uses a proprietary, non-linear algorithm to estimate EE from the multitude of variables. The SP3 is held in place by an elastic strap on the back of the upper right arm and designed to fit comfortably under clothing.

Sensewear Pro 3 Armband in comparison with doubly labeled water

St-Onge et al. (2007) used DLW and the SP3 to compare EE of 45 subjects over a ten day period. The subjects were men and women with an age range of 20 – 78 and a BMI range of 18 to 34. The SP3 underestimated 117kcal per day (2375±366 vs. 2492±366, p≤0.01) for TEE and 218kcal per day (857±326 vs. 639±248, p≤0.01) for PAEE. Individual TEE comparisons between DLW and the SP3 were close, as only 19% of the variance was due to differences between methods. While there were differences between methods, enough agreement existed that made the authors state the armband may be useful to estimate daily EE. Recently Johannsen et al. (2010) compared the 14 day TEE and PAEE of a group of 30 adults ages 24-60 with DLW and two different SP3s in free living conditions. The dual-axial Sensewear Pro 3 Armband (SP3) underestimated TEE by only 4% (-112kcal per day) while the most recent SP3, the tri-axial Mini, underestimated by
<1% (22kcal per day). Although only an approximate 8% absolute error rate exists for both monitors in estimating TEE, this error rate increased to 26% for the SP3 and 28% for the Mini in estimating PAEE. This is due to a trend of underestimating PAEE (SP3 = -123kcal per day, p≤0.02; Mini = -119kcal per day, p≤0.03) that could possibly contribute to the observed underestimation of TEE. While EE associated with PA was underestimated to a degree, SP3 estimates of TEE are shown to be accurate in adults.

Comparison with indirect calorimetry

Currently, the only published study (Cole et al., 2004) involving the SP3 and a cohort of older adults (age=62±8.1 years) was a group of cardiac rehabilitation patients. They performed arm ergometry, treadmill walking, recumbent stepping and rowing ergometry while simultaneously being monitored by IC and a SP3. The correlations between IC and the SP3 had a moderately high range between 0.78 and 0.90. This suggests the armband’s accuracy could be dependent on the exercise modality. Similarly, Jakicic et al. (2004) had forty adult subjects (age=23.2±3.8 years) perform incremental walking, cycling, stepping and arm ergometry exercises while wearing a SP3 and having EE measured by IC. It was determined that the application of an exercise specific algorithm was needed for data processing. Otherwise the armband significantly underestimated PA EE. The newly developed algorithm presented no significant differences in EE estimates between the two methods. Berntsen et al. (2008) used IC, a SP3 and an ACT to measure TEE of 14 men and 6 women (19-56 years of age) performing 120 minutes of various modes of moderate to vigorous PA. The correlation between IC and the SP3 was 0.73, due to underestimation (-43kcal per day). The ACT EE estimates as compared with IC showed a lower 0.55 correlation (-50kcal per day), however, that is still moderate agreement between methods. King et al. (2004) measured TEE of 11 subjects walking or running at 2, 3, 4, 5, 6, 7 and 8mph with IC and several activity monitors, two of which were the ACT and SP3. The SP3 was found to be the single or second most accurate EE estimate over all speeds. Correlations with IC
ranged between 0.75 and 0.85 across all except the slowest speed, which still showed a 0.65 relationship. The ACT, using the Freedson equation, was the first or second best of the group (0.64-0.73) when compared to IC at the three slowest speeds. Dwyer et al. (2009) had 17 subjects with cystic fibrosis (age=26±6 years) and 17 control subjects (age=29±7 years) perform moderate intensity treadmill walking (4.7±0.9km per/hour or 6.1±0.7km/hour for cystic fibrosis and control subjects respectively) at a 0% incline for 10 minutes along with an additional 10 minutes at a 5% incline for the cystic fibrosis group and a 10% incline for the control group. EE was simultaneously measured by IC and the SP3. No differences in EE estimates of the SP3 were found between groups at flat or incline walking, but the SP3 significantly underestimated EE during 10% incline walking. Similar results were previously found by Fruin et al. (2001) who studied EE during treadmill walking of 20 young adults (age=25±3 years) with 10 being male and the other 10 female. Simultaneous measurement of EE by IC and SP3 was performed. At a 5% incline and 4mph the SP3 underestimated EE and reported nearly the same EE values as the same speed at a flat incline. These show that walking solely at an incline can hinder the accuracy of EE estimates with the SP3.

**Further considerations for validity of the Sensewear Pro 3 Armband**

While initial results are promising, a trend of underestimating EE of walking at higher intensities is seen in healthy adults, cardiac rehabilitation patients and those with cystic fibrosis. The accuracy of estimating PAEE with motion monitors decreases as intensity increases (Calabro et al., 2007), however older adults are shown to spend more time in lower intensity activity than moderate or high intensity activity (Westerterp & Meijer, 2001). Additionally, despite using heat related sensors to estimate EE, no significant differences have been found during bouts of low and moderate intensity walking while wearing short or long sleeved shirts covering the monitor (Davis et al., 2007).

Welk et al. (2007) used the IDEEA and SP3 to simultaneously measure TEE of 30 college aged participants for a day. While the TEE correlation of the IDEEA
and SP3 was high at 0.71, using the algorithm from the recently updated software (version 3.9 vs. 4.1) provided an even closer relationship of 0.82. These updates help improve accuracy of PA assessment. Version 6.1 was recently used with the SP3 to yield very similar results to TEE determined by DLW (Johannsen et al., 2010). Due to its validity in estimating EE and detailed output, the SP3 has been previously used as a criterion measure to validate other self report PA recalls (Calabro et al., 2009) and remains a reasonable choice for determining validity of other PAAR measurement tools.

**Physical Activity Questionnaires**

A physical activity questionnaire (PAQ) is a self report method of estimating PA and EE. They are written tests either administered by an interviewer or self-administered. PAQs can be designed to examine an array of time periods or populations and should not influence PA habits. PAQs are not an objective measurement of EE such as pedometers, direct observation, heart rate monitors, accelerometers or doubly labeled water. However their low cost and ease of use make them useful for research. Whether a PAQ is self-administered or performed by interview, it ultimately relies on a participant’s accurate recall of their PA. Self-administered tests may be more popular in studies with larger populations where it is not practical to use interviewers. Interviewer administered PAQs have the benefit of the interviewer aiding the memory recall process, ensuring comprehension of the test, and thereby collecting more accurate data.

Information about the frequency, intensity, duration and types of activity performed are gathered with a PAQ. Using the data obtained from a PAQ, estimates of EE due to PA can be made. This is typically accomplished by associating an activity with a recognized intensity level (Ainsworth et al., 1993) and multiplying by the duration spent in the corresponding activity. Activities are then summed for estimates of MET hours, EE, or time spent in PA. A disadvantage with this approach is that it represents the average energy cost of an activity and may not accurately
represent the actual energy cost for a specific person. In some tests, proprietary scores are the only outcome given.

The factors influencing error in PAQs can be summarized into two categories, systemic variation and random variation. Systemic variation is comprised of reporting bias, seasonal variation, and day of the week effect (Welk, 2002). Reporting bias describes a participant under or over-reporting their PA levels. While most questionnaires try to cover a broad spectrum of activities, it is possible that some activities may not be reported or even forgotten. Taylor et al. (1984) demonstrated that higher intensity activities are generally remembered with acceptable accuracy while 40% of lower to moderate intensity activities over the same time period were not reported by adult males. Obese subjects often over-report PA by nearly 50% (Lichtman et al., 1992). This may partially be explained by observations showing overweight people perceive exercise to be relatively harder and possibly over-report exercise intensity in comparison with their normal weight counterparts (Ekkakakis et al., 2006). Another study found obese subjects underestimating their activity levels in comparison with the normal weight subjects (Klesges et al., 1990). Higher levels of adiposity may present challenges to validity in PAQs.

Another important aspect of reporting bias is the memory processes associated with activity recall. Matthews (Welk, 2002) suggests, “If physical activity events are never stored in memory, there is no chance that a specific episode of activity can be recalled with any accuracy.” Baranowski (1994) developed a cognitive model of encoding and retrieving information. He proposed that in response to PA, the sensory register can focus attention on certain pieces of information in the midst of many stimuli. The information that receives attention is then comprehended by the short term (or working) memory. Within the short term memory, the information is evaluated by the experience monitor before potentially being transferred to long term memory for encoding. The information encoded into long term memory can be divided by its significance. Events of PA that do not stand
out may not be encoded individually but be encoded into blocks of memory called contextual information (Sudman et al., 1996). This suggests that an act of PA has to pass both the sensory register and short term memory and then be properly encoded into long term memory in order to be recalled. Declines in encoding ability are seen with increasing age (Friedman et al., 2007; Zacks et al., 1994; Salthouse, 1990) as are problems recalling encoded information (Conor et al. 2001; Hashtroudi et al., 1989). Conor et al. (2001) stated, “The first, and most reliable, principle is that memory tasks requiring a high degree of effort, such as free recall and working memory activities, will exhibit the largest changes with aging.” This could partially explain the common failure to report PA of low to moderate intensities (Washburn et al., 1990, Taylor et al., 1984) and suggest an increase in failure to report with older adult populations.

Self reported activity levels can also vary depending on the season a given assessment period takes place in. Matthews (2001) found lower activity levels during the winter than any other season in Massachusetts residents. Dannenberg et al. (1989) found a significant decline in EE between the summer and the winter of adults living in Maryland. Levin et al. (1999) reported highest activity levels of adults in Minnesota between April and September, with the lowest activity levels between October and March. A day of the week effect has also been seen where activity levels are commonly lowest on weekends (Levin et al., 1999, Matthews et al., 2001). Validity research, such as the proposed study, may not need to take this into consideration provided that different methods account for the same time periods.

There are many different PAQs available for several different populations and reliability and validity of PAQs will vary between questionnaires and populations. PAQs specifically for the older adult population have been created since age neutral questionnaires have been shown to underestimate PA in older individuals (Washburn et al., 1990). The PAQs to be used in the proposed study, the Community Healthy Activities Model Program for Seniors and Rapid Assessment of Physical Activity, will be discussed under individual headings.
Community Healthy Activities Model Program for Seniors

The Community Healthy Activities Model Program for Seniors (CHAMPS) is a 41 item PAQ designed for older adults. It assesses usual weekly PA of the past four weeks and provides outcome measures (Stewart et al., 2001a). The final question of the CHAMPS questionnaire allows a respondent to enter a specific type of PA not listed with the intent that information from the Compendium of Physical Activities (Ainsworth et al., 1993) can be used to assign a MET value. Otherwise the MET value of the most similar activity is to be used. The two primary outcome measures calculated by the CHAMPS are total minutes of PA during a typical week and the EE per week from PA as determined by the associated MET value of each activity. In order to do so, four key areas are addressed: assessing appropriate types and amounts of PA, facilitating accurate recall and reporting, minimizing socially desirable responding and enhancing sensitivity to change. Assessing appropriate types and amounts of PA is done by focusing on activities older adults are more likely to engage in and reporting total time per week instead of an average bout of activity. To facilitate accurate recall and reporting of activities specific activities are listed on the left side of each question. Only having questions related to PA might cause a rise in socially desirable responding. To minimize this, a variety of questions are including social activities, volunteering and hobbies that would not necessarily impact PA estimates. By targeting lower intensity activities more specifically, sensitivity to change should be further enhanced. To increase the scope of PA research, a Spanish version of the CHAMPS questionnaire has recently been deemed valid for use (Rosario et al., 2008). The CHAMPS has been shown to be sensitive to change after 6 month (Stewart et al., 1997) and 12 month (Stewart et al., 2001b) intervention programs.

Resnick et al. (2008) had data of 718 older adults from three different studies who were assessed by the CHAMPS, Yale Physical Activity Survey (YPAS) and Vitality and Mental Health subscales from the 36-item Short-Form Health Survey (SF-36). The YPAS (DiPietro et al., 1993) is another PAQ specifically for older adults
and the SF-36 (Ware et al., 1996; Ware & Sherbourne, 1992) assesses 8 health concepts: limitations in physical and social activities or role because of physical or emotional problems, bodily pain, general mental health, vitality, and general health perceptions throughout the previous week. Both PAQs were used to determine their ability to measure mental health and vitality. Both were more likely to determine perceived vitality better than mental health and EE as measured by CHAMPS was 86% associated with perceived vitality while the YPAS was 58%. The YPAS consistently measured more minutes of PA than the CHAMPS, however an objective criterion measure was not available.

Moore et al. (2008) had a sample of 54 independent-living, older adults (age=66.9±9.8 years) complete the CHAMPS, YPAS, Modified Baecke (Baecke et al., 1982) and Physical Activity Scale for the Elderly (PASE) (Washburn et al., 1993) PAQs along with the CS-PFP10 (Cress et al., 2005). The four PAQs for older adults were compared against the CS-PFP10. The CS-PFP10 is a ten item physical test to measure functional ability related to activities of daily living. It also provides a 100 point score reflective of overall functional fitness level. The CHAMPS showed a higher relationship than the YPAS, Modified Baecke, or PASE (0.50 vs. 0.40, 0.17, 0.45) for estimating weekly PAEE when compared to the CS-PFP10. It was not indicated in detail how the PAQs were related to the 100 point scale.

Harada et al. (2001) studied a sample of 87 older adults (age=75±6 years) in the Los Angeles area by administering the PASE, YPAS and CHAMPS along with completing the SF-36, 6-minute walk and Short Physical Performance Battery (Guralnik et al., 2004) which measures lower body functioning by strength, balance and walking tests. Additionally, a Mini-Logger activity monitor (Mini-Mitter Company, Sunriver, OR) was worn for 7 days. To test for reliability, the CHAMPS questionnaire was mailed out 2 weeks after the second visit. Reliability of the CHAMPS for EE from all measure of PA showed a relationship of 0.62 (Pearson & intraclass) with moderate intensity PA recall reliability of 0.76 (Pearson & intraclass). Pearson correlation coefficients of the CHAMPS PAEE per week with the motion monitor and
functional tests all showed significant (P<0.01), but low to moderate relationships. The important comparisons from the Mini-Logger worn at the waist, Short Physical Performance Battery, 6 minute walk test and measure of physical function from the SF-36 were all moderately correlated at 0.42, 0.46, 0.46 and 0.39. This shows the CHAMPS to be a good indicator of functional health and compares well to an objective method of estimating EE.

Cyarto et al. (2006) administered the CHAMPS to 167 independent-living older adults (79.1±6.3 years of age). They compared the results to functional ability tests (Chair stand, step test, 8ft up & go, and tandem balance) and the SF-12 Health Survey (Wares, 1998) which measures physical and mental health. The categorization of participants into groups based on their level of activity was used for comparison. Additionally, 1 week test-retest reliability of the CHAMPS was determined by a subsample of that group (n= 43). MET hours per week (MET value of activity x total time spent in that activity) of all activities was the greatest predictor of performance in functional tests. The chair stand, step test, 8ft up and go, and tandem balance significantly (P≤0.01) correlated with total MET hours with correlations of 0.21, 0.28, 0.28 and 0.29. Total MET hours also significantly (P≤0.01) correlated with the physical health portion of the SF-12 at 0.24, but not the mental health section. Reliability measurement of hours of PA, frequency of PA and MET hours per week showed intraclass correlations of 0.76, 0.79 and 0.75 for all activities. The relationships were the highest for moderate intensity activities (0.85, 0.81 and 0.880 while lower for light intensity (0.67, 0.65 & 0.66) and lowest for vigorous intensity (0.34, 0.45 and 0.44). This is similar to results seen by Harada et al. (2001). The data suggest that the CHAMPS is valid for measurement of functional ability and physical health and has acceptable test re-test reliability. It was also noted that approximately 25% of participants required assistance to complete the CHAMPS questionnaire which agrees somewhat with Resnick et al. (2008) having uncompleted responses from 10% of a sample group that did not have an interviewer present. While these results mostly indicate the CHAMPS questionnaire is a positive predictor of functional ability, that is not what it was intended to
measure. The primary outcomes are total PA per week and the EE associated with that PA, however there has not yet been enough validation with an objective method of estimating EE.

**Rapid Assessment of Physical Activity**

The Rapid Assessment of Physical Activity (RAPA) is a 9 item PAQ created at the University of Washington for use in an adult population at least 50 years old. It was developed after extensive review of previously available questionnaires that were thought to be too long or not sensitive to change (Topolski et al., 2006). The RAPA contains instructions showing pictures and verbal examples of various modes of light, moderate and vigorous activity. This allows respondents to visualize differences in intensities. The RAPA is also available in Spanish and Vietnamese. The University of Washington also created a telephone version of the RAPA known as the Telephone Assessment of Physical Activity or TAPA (Mayer et al., 2007). The RAPA asks seven yes or no questions quantifying the frequency and duration of the indicated intensities of PA over a typical week. A score of six or seven indicates a person regularly meeting or exceeding PA guidelines. Two additional questions ask if the participate engages in resistance training or flexibility exercises at least once a week.

Topolski et al. (2006) studied a group of 115 older adults (age=73.3±9.6) that were administered the RAPA, Behavioral Risk Factor Surveillance System (BRFSS) PA questions, Patient-centered Assessment and Counseling for Exercise (PACE) and the CHAMPS. The PACE and BRFSS are larger surveys used to address many aspects of health behavior and only the PA related questions were used. The CHAMPS was used as the criterion measure for comparison. In estimating TEE of all activities and TEE of moderate PA, the RAPA outperformed the others with Spearman Correlation Coefficients of 0.48 and 0.54 ($p<0.001$). This rank order relationship may partially be due to the similarity of methods. The RAPA can differentiate between older adults meeting and not meeting PA guidelines and has been used in multiple clinical and community-based interventions. However it still
lacks any testing of agreement with objective methods of assessing EE (Meriwether et al., 2007). This is the only study to date regarding validity of the RAPA and does not use an objective criterion method of assessing EE to comparison.
CHAPTER 3 - METHODS

Subjects

27 adults of at least 60 years of age were recruited for this study. Subjects were required to demonstrate the mental capacity required to give consent and participate (Folstein et al., 1975). Those with implanted electromagnetic devices were excluded from the study.

Visit 1

Once the participant signed and dated the consent form they begin the study. Only members of the research team had access to the data and identification numbers. The participant had their height measured to the nearest 0.1 cm and their weight measured to the nearest 0.1 kg. The Sensewear Pro 3 Armband (SP3) was attached by an elastic strap to their right upper arm. The ActiGraph (ACT) was clipped on to the belt or waistband on the right side of the body along the anterior axillary line on the waist. Data from attachment at anterior, mid, and posterior axillary lines have been shown to be significantly different from each other with the ACT (Jones et al, 1999), so great care was taken in the precision of the attachments over a study. Participants were taught proper wear and positioning of the activity monitors. The participants were asked to wear both monitors for seven consecutive days, removing them only for bathing and swimming.

Visit 2

The participant returned seven days later. Upon arrival, the Act and SP3 Armband were removed for downloading of data. The participant was asked to complete the Seven Day Physical Activity Recall Questionnaire (Sallis et al., 1985), YALE Physical Activity Survey (DiPietro et al., 1993), Physical Activity Scale for the Elderly (Washburn et al., 1993), Rapid Assessment of Physical Activity (RAPA) (Topolski et al., 2006) and Community Health Activities Model Program for Seniors (CHAMPS) (Stewart et al, 2001). Order of administration was randomized between
the participants. Once the participant completed these instruments they were thanked and allowed to leave. SP3 reports of physical activity (PA) levels and energy expenditure (EE) over the monitoring period were provided for each participant. For completing the visits, participants chose a $25 gift card to a local retailer or a free semester in the Iowa State University Exercise Clinic.

**Data Processing**

The recorded data from the ACT and SP3 were downloaded to a computer. Once downloaded, activity monitor specific software allowed for compilation of data into a seven day period. Appropriate equations were determined and applied for estimates of time in PA and physical activity energy expenditure (PAEE). The SP3 used proprietary algorithms (Software version 6.0) determined from the movement patterns along with height, weight, age, gender and other factors to estimate total EE and PAEE. The ACT counts were applied to multiple equations and cutpoints to determine PAEE and minutes of PA. The Freedson equation (ACT-F) and Freedson/Work-Energy-Theorem combination equation (ACT-C) were used to estimate PAEE. The ACT-F and Matthews cutpoint (ACT-M) were used to estimate minutes of PA. Any monitor found to be missing eleven or more total hours of data was not included in the analysis.

The methods used to assess PA varied in their outcome variables. To facilitate a thorough investigation of the utility of each method, multiple variables had to be considered when comparing the methods. Variables from the criterion measure (i.e., SP3 activity monitor) included TEE, PAEE, minutes of PA and step count. When possible, PA (defined as activity at 3.0 METS or higher) was gleaned from the ACT and PAQs. A direct comparison was able to be made between the SP3 and the ACT, 7DAY, CHAMPS and YPAS due to the ability to calculate EE associated with PA. The YPAS and PASE do not take bodyweight into account so SP3 estimates could be corrected for bodyweight in order to make a proper comparison when necessary. The RAPA is primarily used to determine if a person is considered physically active or not. A comparison of active vs. non-active was attempted. Due to
a highly active population and lack of underactive participants, comparisons were not able to be made between active and non-active participants.

The questionnaires were scored, and in combination with weight, height and age, a score, estimate of EE or minutes of PA were made. The estimated EE of the ACT and PAQs were reported as PAEE in kcal per day. Estimates of kcal per day were examined for significant differences at the 0.05 level with Pearson correlation coefficients. Rank order was established using Spearman's rank correlation coefficient. RAPA classification as active or non-active was compared to SP3 estimates of time spent in PA exceeding 3.0 METS. Current ACSM and AHA guidelines (American College of Sports Medicine, 2009) suggest at least 150 minutes per week of moderate activity to be considered physically active. A one-way ANOVA was used to find differences between genders. Paired samples t-tests were used to determine differences between methods showing high correlations. Additionally, methods without significant differences to the SP3 were investigated through the use of Bland-Altman analysis (Altman & Bland, 1983). Individual comparisons can be made between the SP3 and the alternative methods to establish limits of agreement and determine the level of confidence each would have as a proxy of the SP3.
CHAPTER 4 - RESULTS

A total of 27 subjects completed all aspects of data collection. Table 1 describes the characteristics of the observed population. The men were taller and heavier than the women (P<0.01) although BMI did not differ.

Table 1 - Sample Characteristics (means ± SD)

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Age (yr)</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
<th>BMI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>19</td>
<td>73.9 ± 6.4</td>
<td>161.2 ± 4.6</td>
<td>67.7 ± 9.9</td>
<td>26.1 ± 3.9</td>
</tr>
<tr>
<td>Male</td>
<td>8</td>
<td>75.5 ± 7.2</td>
<td>177.8 ± 10.0*</td>
<td>84.6 ± 18.4*</td>
<td>26.6 ± 4.3</td>
</tr>
<tr>
<td>All</td>
<td>27</td>
<td>74.4 ± 6.5</td>
<td>166.1 ± 10.1</td>
<td>72.7 ± 14.9</td>
<td>26.3 ± 3.9</td>
</tr>
</tbody>
</table>

*P<0.01 Males vs. Females

Tables 2 and 3 provide descriptive statistics for estimates of PAEE, step count and minutes of PA. Gender differences were also seen for physical activity energy expenditure (PAEE) and minutes of PA with the SP3 (P≤0.01) and minutes of PA with Matthews cutpoint (ACT-M) (P<0.05). Neither the Freedson equation (ACT-F) nor combination (ACT-C) equation showed significant differences between genders.

Table 2 - ACT EE and Step Count Characteristics (means ± SD)

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>SP3 PAEE (kcal/day)</th>
<th>ACT-F PAEE (kcal/day)</th>
<th>ACT-C PAEE (kcal/day)</th>
<th>SP3 Steps</th>
<th>ACT Steps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>19</td>
<td>228 ± 196</td>
<td>62 ± 68</td>
<td>254 ± 108</td>
<td>6816 ± 2228</td>
<td>5546 ± 2033</td>
</tr>
<tr>
<td>Male</td>
<td>8</td>
<td>622 ± 481**</td>
<td>134 ± 155</td>
<td>351 ± 168</td>
<td>7955 ± 4101</td>
<td>6787 ± 5506</td>
</tr>
<tr>
<td>All</td>
<td>27</td>
<td>365 ± 367</td>
<td>87 ± 108</td>
<td>288 ± 137</td>
<td>7212 ± 2970</td>
<td>5978 ± 3555</td>
</tr>
</tbody>
</table>

**P<0.01 Males vs. Females

Table 3 – ACT Minutes Per Week Characteristics (means ± SD)

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>SP3 PA (min/week)</th>
<th>ACT-F PA (min/week)</th>
<th>ACT-M PA (min/week)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>19</td>
<td>350 ± 271</td>
<td>92 ± 92</td>
<td>446 ± 219</td>
</tr>
<tr>
<td>Male</td>
<td>8</td>
<td>867 ± 734</td>
<td>172 ± 276</td>
<td>553 ± 378</td>
</tr>
<tr>
<td>All</td>
<td>27</td>
<td>530 ± 530</td>
<td>120 ± 177</td>
<td>483 ± 280*</td>
</tr>
</tbody>
</table>

*P<0.05 Males vs. Females
Step counts were strongly correlated between the ACT and the SP3 (Table 4). ACT-F estimates of PAEE were not significantly correlated (r=0.37, P=0.85) although rank order, or Spearman, correlations (Table 5) showed a significant relationship between estimates of PAEE (r=0.59, P<0.01). The ACT-C produced a moderate PAEE relationship for both Pearson correlation (r=0.54, P<0.01) and rank order (r=0.59, P<0.01). ACT-F showed a moderate correlation (r=0.45, P<0.05) and a moderate Spearman relationship (r=0.51, P<0.05) for minutes of PA. The ACT-M produced a moderately high correlation (r=0.64, P<0.01) and a moderate Spearman relationship (r=0.52, P<0.01) for minutes of PA.

Table 4 - ACT Pearson Correlation Coefficients

<table>
<thead>
<tr>
<th></th>
<th>ACT-F PAEE (kcal/day)</th>
<th>ACT-C PAEE (kcal/day)</th>
<th>ACT-F PA (min/week)</th>
<th>ACT-M PA (min/week)</th>
<th>ACT Daily Steps</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP3 PAEE (kcal/day)</td>
<td>.37</td>
<td>.54**</td>
<td>.37</td>
<td>.61**</td>
<td>.45*</td>
</tr>
<tr>
<td>SP3 PA (min/week)</td>
<td>.40</td>
<td>.54**</td>
<td>.45*</td>
<td>.64**</td>
<td>.52*</td>
</tr>
<tr>
<td>SP3 Daily Steps</td>
<td>.83**</td>
<td>.87**</td>
<td>.88**</td>
<td>.92**</td>
<td>.96**</td>
</tr>
</tbody>
</table>

**P<0.01, *P<0.05

Table 5 - ACT Spearman Correlation Coefficients

<table>
<thead>
<tr>
<th></th>
<th>ACT-F PAEE (kcal/day)</th>
<th>ACT-C PAEE (kcal/day)</th>
<th>ACT-F PA (min/week)</th>
<th>ACT-M PAEE (min/week)</th>
<th>ACT Daily Steps</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP3 PAEE (kcal/day)</td>
<td>.59*</td>
<td>.59*</td>
<td>.47*</td>
<td>.51</td>
<td>.50</td>
</tr>
<tr>
<td>SP3 PA (min/week)</td>
<td>.55**</td>
<td>.53**</td>
<td>.51*</td>
<td>.52*</td>
<td>.58**</td>
</tr>
<tr>
<td>SP3 Daily Steps</td>
<td>.64**</td>
<td>.81**</td>
<td>.69**</td>
<td>.81**</td>
<td>.92**</td>
</tr>
</tbody>
</table>

**P<0.01, *P<0.05

Estimates of PA by questionnaire based methods are shown in tables 6 and 7. None of the questionnaires showed significant gender differences in their estimates as the SP3 did.
Table 6 - PAQ EE and Score Characteristics (means ± SD)

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>SP3 PAEE (kcal/day)</th>
<th>7DAY PAEE (kcal/day)</th>
<th>YPAS PAEE (kcal/day)</th>
<th>CHAMPS (score)</th>
<th>PASE (score)</th>
<th>RAPA (score)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>19</td>
<td>242 ± 185</td>
<td>260 ± 379</td>
<td>361 ± 225</td>
<td>42 ± 23</td>
<td>111 ± 50</td>
<td>5.8 ± 1.1</td>
</tr>
<tr>
<td>Male</td>
<td>8</td>
<td>648 ± 464**</td>
<td>483 ± 376</td>
<td>673 ± 646</td>
<td>32 ± 24</td>
<td>101 ± 51</td>
<td>6.1 ± 0.8</td>
</tr>
<tr>
<td>All</td>
<td>27</td>
<td>362 ± 342</td>
<td>326 ± 385</td>
<td>453 ± 411</td>
<td>39 ± 23</td>
<td>108 ± 50</td>
<td>5.9 ± 1.0</td>
</tr>
</tbody>
</table>

**P<0.01 Males vs. Females

Table 7 - PAQ Minutes Per Week Characteristics (means ± SD)

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>SP3 PA (min/week)</th>
<th>7DAY PA (min/week)</th>
<th>YPAS PA (min/week)</th>
<th>CHAMPS PA (min/week)</th>
<th>PASE (min/week)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>19</td>
<td>380 ± 262</td>
<td>375 ± 487</td>
<td>513 ± 312</td>
<td>637 ± 323</td>
<td>446 ± 459</td>
</tr>
<tr>
<td>Male</td>
<td>8</td>
<td>898 ± 712**</td>
<td>617 ± 522</td>
<td>936 ± 818</td>
<td>473 ± 318</td>
<td>387 ± 349</td>
</tr>
<tr>
<td>All</td>
<td>27</td>
<td>533 ± 492</td>
<td>447 ± 500</td>
<td>638 ± 535</td>
<td>588 ± 324</td>
<td>429 ± 424</td>
</tr>
</tbody>
</table>

**P<0.01 Males vs. Females

Table 8 represents either the estimated PAEE or the score derived from the physical activity questionnaires (PAQs). Of the PAQs, only the 7DAY and YPAS demonstrated significant relationships (r>.69 and r>.85, P<.01) with the criterion measure for PAEE (Table 8) and minutes of PA (r>.68 and r>.84, P<.01). This association changes when the rank order of these different methods are assessed (Table 9). The 7DAY exhibits a similar relationship for PAEE (r>.73, P<.01) while the YPAS is considerably lower (r>.56, P<.01). Similar results occur for rank order relationships of the 7DAY and YPAS for minutes of PA (r>.70 and r>.64, P<.01). The PASE score showed a moderate relationship for rank order (r<.39, P<.05). No other meaningful relationships are present.
Table 8 - PAQ Pearson Correlation Coefficients

<table>
<thead>
<tr>
<th></th>
<th>SP3 PAEE (kcal/day)</th>
<th>SP3 PAEE (kcal/kg/day)</th>
<th>SP3 TEE (kcal/day)</th>
<th>SP3 PA (min/week)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7DAY PAEE (kcal/day)</td>
<td>.69**</td>
<td>.64**</td>
<td>.58**</td>
<td>.65**</td>
</tr>
<tr>
<td>7DAY PA (min/week)</td>
<td>.70**</td>
<td>.67**</td>
<td>.52**</td>
<td>.68**</td>
</tr>
<tr>
<td>YPAS PAEE (kcal/day)</td>
<td>.85**</td>
<td>.83**</td>
<td>.58**</td>
<td>.83**</td>
</tr>
<tr>
<td>YPAS PA (min/week)</td>
<td>.88**</td>
<td>.84**</td>
<td>.61**</td>
<td>.84**</td>
</tr>
<tr>
<td>CHAMPS PAEE (kcal/day)</td>
<td>-.17</td>
<td>-.20</td>
<td>.03</td>
<td>-.32</td>
</tr>
<tr>
<td>CHAMPS PA (min/week)</td>
<td>-.44*</td>
<td>-.43*</td>
<td>-.27</td>
<td>-.44*</td>
</tr>
<tr>
<td>PASE Score</td>
<td>.12</td>
<td>.15</td>
<td>-.06</td>
<td>.14</td>
</tr>
<tr>
<td>PASE PA (min/week)</td>
<td>-.07</td>
<td>-.02</td>
<td>-.19</td>
<td>-.02</td>
</tr>
</tbody>
</table>

**P<0.01, *P<0.05

Table 9 - PAQ Spearman Correlation Coefficients

<table>
<thead>
<tr>
<th></th>
<th>SP3 PAEE (kcal/day)</th>
<th>SP3 PAEE (kcal/kg/day)</th>
<th>SP3 TEE (kcal/day)</th>
<th>SP3 PA (min/week)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7DAY PAEE (kcal/day)</td>
<td>.73**</td>
<td>.70**</td>
<td>.56**</td>
<td>.68**</td>
</tr>
<tr>
<td>7DAY PA (min/week)</td>
<td>.70**</td>
<td>.72**</td>
<td>.40*</td>
<td>.70**</td>
</tr>
<tr>
<td>YPAS PAEE (kcal/day)</td>
<td>.56**</td>
<td>.58**</td>
<td>.36</td>
<td>.56**</td>
</tr>
<tr>
<td>YPAS PA (min/week)</td>
<td>.64**</td>
<td>.65**</td>
<td>.36</td>
<td>.64*</td>
</tr>
<tr>
<td>CHAMPS PAEE (kcal/day)</td>
<td>-.27</td>
<td>-.33</td>
<td>.12</td>
<td>-.24</td>
</tr>
<tr>
<td>CHAMPS PA (min/week)</td>
<td>-.38</td>
<td>-.31</td>
<td>-.31</td>
<td>-.31</td>
</tr>
<tr>
<td>PASE Score</td>
<td>.34</td>
<td>.39*</td>
<td>.01</td>
<td>.36</td>
</tr>
<tr>
<td>PASE PA (min/week)</td>
<td>.11</td>
<td>.14</td>
<td>-.21</td>
<td>.15</td>
</tr>
</tbody>
</table>

**P<0.01, *P<0.05

Paired sample t-tests examined all significant relationships to find differences with the criterion measure (Appendix F). The ACT underreported step count by 1234 steps per day and was found to be significantly different from the SP3. The ACT-C estimate of PAEE and ACT-M estimate of minutes of PA were not different from the criterion measure. The 7DAY estimates of PAEE and minutes of PA were not different from the SP3 estimates. The YPAS estimate of minutes of PA was not significantly different from the criterion measure while the PAEE estimate was.

Bland-Altman plots allow for a more direct comparison of the methods not different from the SP3. ACT-C estimates of daily PAEE are lower by 78kcal (Figure 3). The 7DAY PAQ underreports by 36kcal per day (Figure 4) and 87 minutes per week (Figure 4). The YPAS overreported time in PA by 105 minutes per week.
While statistically different, a plot was included for the YPAS estimates of PAEE (Figure 6). It overestimated by 92kcal per day.

Figure 1 – ACT-C and SP3 PAEE Differences

Figure 2 – ACT-M and SP3 Minutes of PA Differences
Figure 3 – 7DAY and SP3 PAEE Differences

Figure 4 – 7DAY and SP3 minutes of PA Differences
Figure 5 – YPAS and SP3 Minutes of PA Differences

Figure 6 – YPAS and SP3 PAEE Differences
CHAPTER 5 - DISCUSSION

A goal of this study was to examine convergent validity of various methods of estimating physical activity (PA) levels of older adults. A variety of widely used instruments were compared to an objective criterion measure, the Sensewear Pro 3 Armband (SP3). Two monitors were worn for the same seven days and then PAQs were administered at the end of the monitoring period. Comparisons between estimates should be considered consistent for the period of observation.

Comparison of Accelerometers

It has been reported that 6,000 to 8500 steps per day is normal for healthy older adults (Tudor-Locke et al., 2008). The SP3 estimates of 7212 steps per day fall into the midpoint of this range while the ACT estimate of 5978 steps per day fall just below it. The step count relationship appeared to be quite high at $r=0.96$ (P<0.01), however significant differences did exist between methods (P<0.01). It should be noted that the SP3 has not been established as a criterion measure for step count.

The estimates of PAEE and minutes of PA from the two monitors were also highly variable. The ACT experienced similar bodily movement patterns as the SP3, yet the derived data are different. ACT counts associated with activity patterns are generally interpreted by use of a regression equation; however results depend on which equation is used. Equations derived from lifestyle patterns typically over-report EE, while locomotor based equations under-report when used in non-locomotor activities (Strath et al., 2003; Schmidt et al., 2003; Welk et al., 2007). The locomotor based ACT-F required 1952 counts per minute to be considered PA. This equation is considered to be moderately accurate for estimating EE of locomotor activities (Crouter, 2006a), however free living activity likely includes a combination of lifestyle and locomotor type activities. This presents a challenge in translating ACT counts to EE. This may explain why the ACT-F grossly underestimated PAEE by 278kcal per day. The underestimation trend is similar to that of Crouter et al. (2006a).
The ACT-C approach provides an alternative way to process the data. It uses the Freedson equation for time above 1952 counts per minute and the Work-Energy-Theorem (Utilizing the physics equivalent of energy) for time below. This approach yielded stronger relationships ($r=0.54, P<0.01$) with the SP3 than the commonly used ACT-F. The ACT trend of underestimation was the least with the ACT-C (78kcal per day) and the Bland-Altman plot appeared to have a moderate limit of agreement. Matthews (2005) suggested the Freedson equation cutoff of 1952 may be too high for the general population and a lower cutpoint of 760 counts per minute should be used to increase sensitivity to moderate PA. The ACT-M also showed a moderate relationship ($r=0.65, P<0.01$) and was the only method tested to recognize the same gender differences ($P<0.05$) that the SP3 detected ($P<0.01$). The much lower cutpoint appeared to detect non-locomotor PA overlooked by the standard ACT-F equation. The lower cutoff captured higher amounts of moderate PA, thus raising the estimates of minutes of PA. The ACT-M underestimated much less (47 minutes per week) than the ACT-F (410 minutes per week) and not found to be different from the SP3.

Of the three equations, the ACT-M may be the best choice of the three as it had the highest Pearson and Spearman correlations, along with detecting the same gender differences, as the criterion measure. Positive results with the Matthews cutpoint have also been found by Welk et al. (2007) and Rothney et al. (2008). If lowering the PA cutpoint to 760 counts per minute helped decrease underestimation of the ACT, the possibility of an even lower cutpoint for older adults should be investigated. The lower step count and PA estimates may suggest a low sensitivity of the ACT in older adults. Combining this higher sensitivity with an equation specific to older adults may provide better estimates as well.

Additionally, it may not be appropriate for a single, linear regression equation to estimate all activities (Crouter et al., 2006b). The SP3 is a pattern recognition monitor and applies a specific equation to each movement pattern. This could be one of the largest reasons why it has shown such high validity (St. Onge et al., 2007;
Johannsen et al., 2009) and is appropriate as a criterion measure. Crouter et al. (2006b; 2010) explored the utility of a two-regression model for the ACT to more accurately estimate EE by using multiple equations along with an inactivity threshold. An appropriate equation is used for locomotor based activities while another equation is used for lifestyle activities. Additionally, the shorter epochs identify transitional minutes of PA not captured by 60 second epochs. The data in this study were not recorded in the 10 second epoch format necessary for such analysis. This approach may yield more accurate results. It may be particularly important for older adults who primarily walk for PA.

**Comparison of PAQs with Criterion Measure**

**Seven Day Physical Activity Recall**

The 7DAY appeared to provide the most accurate estimates of PAEE. It was one of the only methods to show relatively high correlations for both Pearson (r=0.69, P<0.01) and Spearman (r=0.73, P<0.01) comparisons. It should be noted that scores were achieved using a modified scoring method, in that only activities over 3.0 METS were tabulated to provide for direct comparison of PAEE. This included time spent in categories known as moderate, vigorous, very vigorous and strength. Time spent in sleep, light activity and flexibility were not included. While flexibility activities are important and recommended for older adults (Nelson et al., 2007), they are not currently considered to be moderate PA (Ainsworth et al., 1993). Unfortunately, this modified approach would not be appropriate for estimating TEE. A different modified scoring approach for the 7DAY has shown higher accuracy when comparing TEE to an accelerometer-based device (Welk et al.; 2001). Our modified scoring method for this study takes slightly less time due to less categories requiring calculation, which should ease administrator burden.

The correlations found were higher than those of recent comparisons of the 7DAY (r=0.51-0.53) with accelerometer based methods for EE (Welk et al, 2001); however this was with adults 38-57 years of age comparing TEE estimates instead
of PAEE estimates. Previous concerns over the ability of the 7DAY to assess moderate intensity PA accurately has been previously noted by Matthews and Freedson (1995) and Taylor et al. (1984). Given that 98% of the PA recorded by the SP3 was 3.0-6.0 METS, the moderately high significant correlations seen here should alleviate some of those concerns. This is supported by comparison of moderate PA with doubly labeled water (DLW) TEE (r=0.52, P<0.05) by Bonnefoy et al. (2001).

The results indicated that 7DAY estimates of EE (36 kcal per day) and minutes of PA (87 minutes per week) were not significantly different to those of the SP3. The SP3 records minute by minute data allowing several short bouts of PA to be recorded. The 7DAY only counts PA lasting at least ten minutes. Additionally, due to memory recall, other short bouts of PA may not be remembered for recall. This could lead to the minor difference seen between methods. Conversely, research has shown previous versions of the SP3 to underestimate compared to a 24 hour PA recall with adults (Calabro et al., 2009). The 7DAY has also been found to underestimate time in PA in adults (Matthews and Freedson, 1995). Our results did not agree with those findings.

The 7DAY was not designed specifically for use with older adults; however, it did show the best results. This is evidenced by high correlations, the lowest levels of under-estimation, no significant differences with the criterion measure and relatively narrow limits of agreement with Bland-Altman analysis. The 7DAY is a direct method of determining PA patterns and appears to require the most interviewer skill of the interview based questionnaires. The time and skill required for proper interviewing may prevent the 7DAY from being an ideal method for use with very large sample sizes. On the other hand, a self administered version has been developed (Dishman & Steinhardt., 1998) and shown to have good correspondence with the interview version for estimating EE (r=0.83, P<0.01).
YALE Physical Activity Survey

The YPAS is one of the few PAQs to have been compared with DLW. Bonnefoy et al. (2001) compared TEE from DLW to the YPAS summary index and EE estimates without finding any significant relationships. Starling et al. (1999) found the YPAS to be well correlated with DLW as neither estimates of PAEE were significantly (P<0.05) different from DLW in men or women. Starling also stated that the YPAS was developed for use as a ranking tool rather than to determine absolute PA levels. PA above 3.0 METS (Ainsworth et al., 1993) can be separated for estimating PAEE as EE is the intended outcome for the YPAS. In the present study, Pearson correlations with the SP3 was moderately high at r=0.85 (P<0.01). On the other hand, our rank order was a lower (r=0.56, P<0.01) relationship. Harada et al. (2001) found a similar moderate relationship (r=0.61, P<0.01) with a waist worn activity monitor. We found the YPAS to be the only tool to overestimate PAEE (92kcal per day and 105 minutes per week). Large over-estimations, mixed paired samples t-test results, and wide limits of agreement from Bland-Altman analysis hinder the utility of the YPAS; however the rank order showed good results.

The YPAS interview process is scripted to minimize interviewer error and also includes prompting cards for the participant. A self administered version may be possible in the future due to the design of the YPAS interview process. There should not be a large difference between an interviewer being told exactly what to say to the participant and record versus having the participant read the instruction and record their own answers. Most validity studies finding positive results have used functional health measures (DiPietro et al., 1993; Young et al., 2001) or energy balance (Kruskall et al., 2004) as criterion measures. While currently in use as a research device, the YPAS lacks extensive comparison with objective criterion measures and has demonstrated mixed results.
**Physical Activity Scale for the Elderly**

The PASE yields different outcomes than the other measures so comparisons are more difficult. Contrary to the other PAQs, separating general activity into moderate and higher PA was not possible with the PASE questions. For example, the third question asks if the participant engaged in any of several activities described as “light sport or recreational.” These activities varied between moderate and sedentary intensities (Ainsworth et al., 1993), yet the same weight is given to all activities in that category when scoring. Similar occurrences in intensity variability are found in other questions. The estimates of activity duration and intensities are tabulated to create a score; however, a score format only allows for group rankings.

In the present study, the only significant results found between the PASE and the SP3 were a Spearman rho of 0.40 (P<0.05) for PAEE. This rank order is similar (r=0.43-0.64, P<0.01) to that of previous findings with other activity monitors (Dinger MK et al., 2004; Washburn et al., 1999). The PASE score was not significantly related to DLW for Pearson or Spearman correlations (Bonnefoy, 2001), but others found it to be moderately correlate (r=0.58, P<0.01) to DLW (Schuit et al., 1997). Our results were not similar to others that found significant relationships (r=0.49, P<0.05; r=0.52, P<0.01) between the PASE and an activity monitor (Washburn & Ficker, 1999; Harada et al., 2001). The discrepancy of results across studies in combination does not give a clear indicator of the utility of the PASE in estimating PA. The PASE may have use for assessing group responses when a non-interviewer based PAQ is needed, however it may not be a good choice for estimating absolute levels of PA.

**Community Healthy Activities Model Program for Seniors**

The CHAMPS score is essentially a total estimate of MET hours per week. This information can be used to estimate EE and time spent in PA. Further discrimination was made among the CHAMPS questions to eliminate light activities and only include activities above 3.0 METS (Ainsworth et al., 1993). In doing so, a
MET hour estimate was made, combined with body weight, and then used to estimate PAEE. The CHAMPS outcomes had no positive significant relationships found with the SP3 criterion measure.

Previously the CHAMPS was shown to underestimate activity levels in comparison to the YPAS with a sample of 718 (Resnick et al., 2008). However, our CHAMPS estimates of PAEE were much higher than that of the YPAS. Harada et al. (2001) found a moderate relationship ($r=0.48$, $P<0.01$) in older adults wearing an accelerometer at the waist. Our findings show much weaker results. This further suggests the CHAMPS is not valid as an accurate method for estimating PA. This may partially be due to a small sample size, although no comparisons were close to approaching positive significance.

**Rapid Assessment of Physical Activity**

Comparisons of the RAPA to the criterion are not possible with the data set. The activity levels of RAPA are relatively broad such that participants can be categorized as either active or non-active in accordance with 2008 PA guidelines (Department of Health and Human Services, 2008). Additionally, most of the participants in the present study were highly active with 23 of the 27 meeting PA guidelines according to SP3 data. Nevertheless, the RAPA appears to be best suited for quickly identifying active and sedentary individuals. The RAPA was designed to be a quick and easy tool to assess levels of PA in older adults (Topolski et al., 2006).

**Limitations**

Our findings agreed with previous researchers that assistance was often required by multiple participants when completing self administered questionnaires (Cyarto, 2006; Resnick, 2008). It is unclear if the assistance altered any participant data and therefore the results to any degree. Because of the limited sample size and lack of diversity in PA habits, it is possible that these findings would not represent the general older adult population. All data were collected during the fall in Iowa and
the week of SP3 monitoring may not be truly representative of the participants' usual activity patterns. In general, the PAQs relied on memory recall as opposed to the activity monitors. The 7DAY is a recall over the previous week while the others are usual activity habits, typically over the last month. All participants were retired, community dwelling older adults and these findings may not transfer to older adults still employed or under supervised care. Alternative methods of scoring were used to represent PAEE. Typically the 7DAY, YPAS and CHAMPS would include EE estimates including activities below 3.0 METS or be reported as TEE. It was our goal not to take any liberties with the questionnaires; however it was important to examine their utility of estimating moderate and higher PA. The PAQs were not misused; activity below 3.0 METS was not included whenever possible.

Conclusion

In answering the initial question of which methods are most appropriate in assessing PA of older adults, the ACT, 7DAY and YPAS are the only ones to be considered. Great care must be taken when deciding which of the many ACT equations to use for data analysis. While a single equation system may not be the most accurate method for estimating EE, the ACT-C proved to be the best of the ones compared to the SP3. The ACT-M was the best indicator of minutes of PA. Regarding the PAQs, both showed encouraging results; however, the data should be interpreted with caution. The YPAS was slightly better in Pearson comparisons with the SP3, however significant differences were present for PAEE estimates and not minutes of PA. The 7DAY was much better in a rank order comparison and not found to have significant differences with the SP3 for estimates of PAEE or minutes of PA. From examining the Bland-Altman plots, it is clear the 7DAY has a relatively narrow limit of agreement. The YPAS possesses wider limits of agreement and higher error in estimates. Our data suggest that the 7DAY, while not specifically designed for use with older adults, is a better choice for PA assessment research than any of the current PAQs specifically designed for older adults that were tested. This does not agree with previous research (Washburn et al., 1990) suggesting that
age-neutral questionnaires underestimate PA too much to be used with older adults. Moreover, only interviewer administered questionnaires were acceptable. This suggests that the use of an interviewer provides more accurate results as opposed to the design of the questions.

Many factors must be considered when choosing a PA measurement device. The widely used ACT provided moderately accurate estimates of PAEE; however, strict compliance is necessary to achieve proper results. Research of an older adult specific equation or a cutpoint lower than that suggested by Matthews (2005) may be the next step in more accurately assessing PA in this growing subset of the population. Simple classification of active or sedentary may be done with the RAPA. Group rankings may be done with the 7DAY, YPAS or PASE. The PASE is the only one of these that is currently self-administered and did not work well in the present study. The 7DAY is the only PAQ tested to be used when PAEE is the desired outcome. PAEE should be the desired outcome whenever possible as it is the only modifiable aspect of TEE.
REFERENCES


Rosario MG, Vázquez JM, Cruz WI, Ortiz A. (2008) Internal consistency of the CHAMPS physical activity questionnaire for Spanish speaking older adults *Puerto Rican Health Science Journal*, 27(3)224-8

Rothney MP, Schaefer EV, Neumann MM, Choi L, Chen KY. (2008a) Validity of physical activity intensity predictions by ActiGraph, Actical and RT3 accelerometers. *Obesity*, 16(8)1946-52


Washburn RA, Jette AM, Janney CA (1990) Using age-neutral physical activity questionnaires in research with the elderly. Journal of Aging and Health, 2(3)341-356


**APPENDIX A - Paired Samples t-tests of Significant Relationships**

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP3 Daily Steps - ACT Daily Steps</td>
<td>1234.22</td>
<td>1124.44</td>
<td>5.26</td>
<td>22.00</td>
<td>.00</td>
</tr>
<tr>
<td>SP3 PAEE (kcal/day) - ACT-C PAEE (kcal/day)</td>
<td>77.71</td>
<td>314.63</td>
<td>1.18</td>
<td>22.00</td>
<td>.25</td>
</tr>
<tr>
<td>SP3 PA (min/week) - ACT-M PA (min/week)</td>
<td>46.52</td>
<td>411.20</td>
<td>.54</td>
<td>22.00</td>
<td>.59</td>
</tr>
<tr>
<td>SP3 PA (min/week) - ACT-F PA (min/week)</td>
<td>410.35</td>
<td>478.41</td>
<td>4.11</td>
<td>22.00</td>
<td>.00</td>
</tr>
<tr>
<td>SP3 PAEE (kcal/day) - 7Day PAEE (kcal/day)</td>
<td>35.93</td>
<td>289.12</td>
<td>.65</td>
<td>26.00</td>
<td>.52</td>
</tr>
<tr>
<td>SP3 PAEE (kcal/day) - YPAS PAEE (kcal/day)</td>
<td>-91.50</td>
<td>214.58</td>
<td>-2.22</td>
<td>26.00</td>
<td>.04</td>
</tr>
<tr>
<td>SP3 PA (min/week) - 7DAY PA (min/week)</td>
<td>86.67</td>
<td>397.32</td>
<td>1.13</td>
<td>26.00</td>
<td>.27</td>
</tr>
<tr>
<td>SP3 PA (min/week) - YPAS PA (min/week)</td>
<td>-105.00</td>
<td>290.31</td>
<td>-1.88</td>
<td>26.00</td>
<td>.07</td>
</tr>
</tbody>
</table>
### APPENDIX B – 7DAY, YPAS and RAPA Pearson Correlations

<table>
<thead>
<tr>
<th>Gender</th>
<th>Age</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
<th>BMI</th>
<th>7DAY PAEE (kcal/day)</th>
<th>7DAY PA (min/week)</th>
<th>YPAS PAEE (kcal/day)</th>
<th>YPAS PA (min/week)</th>
<th>RAPA Aerobic Score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>0.00</td>
<td>0.04</td>
<td>0.08</td>
<td>0.10</td>
<td>0.14</td>
<td>0.18</td>
<td>0.22</td>
<td>0.23</td>
<td>0.23</td>
<td>0.25</td>
</tr>
<tr>
<td>0.10</td>
<td>0.14</td>
<td>0.22</td>
<td>0.27</td>
<td>0.29</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>0.14</td>
<td>0.18</td>
<td>0.22</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>0.18</td>
<td>0.22</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>0.22</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
</tr>
</tbody>
</table>

**Correlation Coefficients:**

- **Gender:** 1.00
- **Age:** 0.11
- **Height (cm):** 0.77 (**), 0.73 ('), 0.67 (**), 0.65 (')
- **Weight (kg):** 0.53 (**), 0.55 (**), 0.54 ('), 0.51 (')
- **BMI:** 0.06 (')
- **SP3 PAEE (kcal/day):** 0.55 (**), 0.55 ('), 0.31 ('), 0.09 (')
- **SP3 PAEE (kcal/kg/day):** 0.48 (*), 0.23 ('), 0.06 ('), 0.25 (')
- **SP3 PA (min/week):** 0.49 (**), 0.31 ('), 0.24 ('), 0.21 (')
- **SP3 TEE (kcal/day):** 0.79 (**), 0.17 ('), 0.73 (**), 0.69 (**), 0.30 ('), 0.70 (')
- **7DAY PAEE (kcal/day):** 0.27 ('), 0.06 ('), 0.15 ('), 0.18 ('), 0.18 ('), 0.69 (')
- **7DAY PA (min/week):** 0.23 ('), 0.01 ('), 0.08 ('), 0.10 ('), 0.10 ('), 0.70 (')
- **YPAS PAEE (kcal/day):** 0.35 ('), 0.06 ('), 0.14 ('), 0.14 ('), 0.14 ('), 0.85 (')
- **YPAS PA (min/week):** 0.37 ('), 0.12 ('), 0.18 ('), 0.07 ('), 0.04 ('), 0.88 (')
- **RAPA Aerobic Score:** 0.15 ('), 0.06 ('), 0.03 ('), 0.06 ('), 0.06 ('), 0.10 ('), 0.10 ('), 0.10 ('), 0.02 ('), 0.20 ('), 0.20 ('), 0.04 ('), 0.09 ('), 1.00 (')

**Notes:**
- **p<0.01,** **p<0.05**

---

**Legend:**
- **7DAY:** 7-day recall
- **YPAS:** Youth Physical Activity Scale
- **RAPA:** Rating of Aerobic Performance
- **PAEE:** Physical Activity Energy Expenditure
- **PA:** Physical Activity
## APPENDIX C – PASE and CHAMPS Pearson Correlations

<table>
<thead>
<tr>
<th></th>
<th>Gender</th>
<th>Age</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
<th>BMI</th>
<th>SP3 PAEE (kcal/day)</th>
<th>SP3 PAEE (kcal/kg/day)</th>
<th>SP3 PA (min/week)</th>
<th>SP3 TEE (kcal/day)</th>
<th>PASE Score</th>
<th>PASE PA (min/week)</th>
<th>CHAMPS Score</th>
<th>CHAMPS PAEE (kcal/day)</th>
<th>CHAMPS PA (min/week)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>.00</td>
<td>.11</td>
<td>.77</td>
<td>.53</td>
<td>.77</td>
<td>.49</td>
<td>.55</td>
<td>.06</td>
<td>.48</td>
<td>.55</td>
<td>.09</td>
<td>.04</td>
<td>.06</td>
<td>.28</td>
</tr>
<tr>
<td>Age</td>
<td>.11</td>
<td>.00</td>
<td>.53</td>
<td>.77</td>
<td>.53</td>
<td>.49</td>
<td>.55</td>
<td>.06</td>
<td>.48</td>
<td>.55</td>
<td>.09</td>
<td>.04</td>
<td>.06</td>
<td>.28</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>.11</td>
<td>.11</td>
<td>.00</td>
<td>.00</td>
<td>.00</td>
<td>.49</td>
<td>.55</td>
<td>.06</td>
<td>.48</td>
<td>.55</td>
<td>.09</td>
<td>.04</td>
<td>.06</td>
<td>.28</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>.11</td>
<td>.11</td>
<td>.53</td>
<td>.77</td>
<td>.53</td>
<td>.49</td>
<td>.55</td>
<td>.06</td>
<td>.48</td>
<td>.55</td>
<td>.09</td>
<td>.04</td>
<td>.06</td>
<td>.28</td>
</tr>
<tr>
<td>BMI</td>
<td>.11</td>
<td>.11</td>
<td>.53</td>
<td>.77</td>
<td>.53</td>
<td>.49</td>
<td>.55</td>
<td>.06</td>
<td>.48</td>
<td>.55</td>
<td>.09</td>
<td>.04</td>
<td>.06</td>
<td>.28</td>
</tr>
<tr>
<td>SP3 PAEE (kcal/kg/day)</td>
<td>.11</td>
<td>.11</td>
<td>.53</td>
<td>.77</td>
<td>.53</td>
<td>.49</td>
<td>.55</td>
<td>.06</td>
<td>.48</td>
<td>.55</td>
<td>.09</td>
<td>.04</td>
<td>.06</td>
<td>.28</td>
</tr>
<tr>
<td>SP3 PA (min/week)</td>
<td>.11</td>
<td>.11</td>
<td>.53</td>
<td>.77</td>
<td>.53</td>
<td>.49</td>
<td>.55</td>
<td>.06</td>
<td>.48</td>
<td>.55</td>
<td>.09</td>
<td>.04</td>
<td>.06</td>
<td>.28</td>
</tr>
<tr>
<td>SP3 TEE (kcal/day)</td>
<td>.11</td>
<td>.11</td>
<td>.53</td>
<td>.77</td>
<td>.53</td>
<td>.49</td>
<td>.55</td>
<td>.06</td>
<td>.48</td>
<td>.55</td>
<td>.09</td>
<td>.04</td>
<td>.06</td>
<td>.28</td>
</tr>
<tr>
<td>PASE Score</td>
<td>.11</td>
<td>.11</td>
<td>.53</td>
<td>.77</td>
<td>.53</td>
<td>.49</td>
<td>.55</td>
<td>.06</td>
<td>.48</td>
<td>.55</td>
<td>.09</td>
<td>.04</td>
<td>.06</td>
<td>.28</td>
</tr>
<tr>
<td>PASE PA (min/week)</td>
<td>.11</td>
<td>.11</td>
<td>.53</td>
<td>.77</td>
<td>.53</td>
<td>.49</td>
<td>.55</td>
<td>.06</td>
<td>.48</td>
<td>.55</td>
<td>.09</td>
<td>.04</td>
<td>.06</td>
<td>.28</td>
</tr>
<tr>
<td>CHAMPS Score</td>
<td>.11</td>
<td>.11</td>
<td>.53</td>
<td>.77</td>
<td>.53</td>
<td>.49</td>
<td>.55</td>
<td>.06</td>
<td>.48</td>
<td>.55</td>
<td>.09</td>
<td>.04</td>
<td>.06</td>
<td>.28</td>
</tr>
<tr>
<td>CHAMPS PAEE (kcal/kg/day)</td>
<td>.11</td>
<td>.11</td>
<td>.53</td>
<td>.77</td>
<td>.53</td>
<td>.49</td>
<td>.55</td>
<td>.06</td>
<td>.48</td>
<td>.55</td>
<td>.09</td>
<td>.04</td>
<td>.06</td>
<td>.28</td>
</tr>
<tr>
<td>CHAMPS PA (min/week)</td>
<td>.11</td>
<td>.11</td>
<td>.53</td>
<td>.77</td>
<td>.53</td>
<td>.49</td>
<td>.55</td>
<td>.06</td>
<td>.48</td>
<td>.55</td>
<td>.09</td>
<td>.04</td>
<td>.06</td>
<td>.28</td>
</tr>
<tr>
<td>Gender</td>
<td>Age</td>
<td>Height (cm)</td>
<td>Weight (kg)</td>
<td>BMI</td>
<td>7DAY PAEE (kcal/day)</td>
<td>YPAS PAEE (kcal/day)</td>
<td>RAPA Aerobic Score</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------</td>
<td>-----</td>
<td>------------</td>
<td>------------</td>
<td>-----</td>
<td>---------------------</td>
<td>---------------------</td>
<td>------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>.32</td>
<td>.41</td>
<td>.41</td>
<td>.06</td>
<td>.16</td>
<td>.16</td>
<td>.16</td>
<td>.32</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-.38</td>
<td>.34</td>
<td>.34</td>
<td>.07</td>
<td>.16</td>
<td>.16</td>
<td>.16</td>
<td>.38</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-.09</td>
<td>.28</td>
<td>.28</td>
<td>.16</td>
<td>.16</td>
<td>.16</td>
<td>.16</td>
<td>-.09</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-.13</td>
<td>.34</td>
<td>.34</td>
<td>.11</td>
<td>.11</td>
<td>.11</td>
<td>.11</td>
<td>-.13</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-.15</td>
<td>.10</td>
<td>.10</td>
<td>.03</td>
<td>.03</td>
<td>.03</td>
<td>.03</td>
<td>-.15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-.10</td>
<td>.16</td>
<td>.16</td>
<td>.11</td>
<td>.11</td>
<td>.11</td>
<td>.11</td>
<td>-.10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-.13</td>
<td>.28</td>
<td>.28</td>
<td>.16</td>
<td>.16</td>
<td>.16</td>
<td>.16</td>
<td>-.28</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-.15</td>
<td>.29</td>
<td>.29</td>
<td>.11</td>
<td>.11</td>
<td>.11</td>
<td>.11</td>
<td>-.15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-.38</td>
<td>.30</td>
<td>.30</td>
<td>.16</td>
<td>.16</td>
<td>.16</td>
<td>.16</td>
<td>-.38</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-.36</td>
<td>.31</td>
<td>.31</td>
<td>.16</td>
<td>.16</td>
<td>.16</td>
<td>.16</td>
<td>-.36</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-.10</td>
<td>.01</td>
<td>.01</td>
<td>.16</td>
<td>.16</td>
<td>.16</td>
<td>.16</td>
<td>-.31</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-.13</td>
<td>.13</td>
<td>.13</td>
<td>.16</td>
<td>.16</td>
<td>.16</td>
<td>.16</td>
<td>-.13</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-.13</td>
<td>.36</td>
<td>.36</td>
<td>.16</td>
<td>.16</td>
<td>.16</td>
<td>.16</td>
<td>-.13</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-.64</td>
<td>.36</td>
<td>.36</td>
<td>.16</td>
<td>.16</td>
<td>.16</td>
<td>.16</td>
<td>-.13</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-.56</td>
<td>.01</td>
<td>.01</td>
<td>.16</td>
<td>.16</td>
<td>.16</td>
<td>.16</td>
<td>-.64</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>.09</td>
<td>.36</td>
<td>.36</td>
<td>.16</td>
<td>.16</td>
<td>.16</td>
<td>.16</td>
<td>.36</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-.40</td>
<td>.70</td>
<td>.70</td>
<td>.70</td>
<td>.70</td>
<td>.70</td>
<td>.70</td>
<td>.09</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-.56</td>
<td>.70</td>
<td>.70</td>
<td>.70</td>
<td>.70</td>
<td>.70</td>
<td>.70</td>
<td>.40</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>.97</td>
<td>.97</td>
<td>.97</td>
<td>.97</td>
<td>.97</td>
<td>.97</td>
<td>.97</td>
<td>.56</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>.38</td>
<td>.97</td>
<td>.97</td>
<td>.97</td>
<td>.97</td>
<td>.97</td>
<td>.97</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>.25</td>
<td>.97</td>
<td>.97</td>
<td>.97</td>
<td>.97</td>
<td>.97</td>
<td>.97</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>.33</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**P<0.01, *P<0.05**
<table>
<thead>
<tr>
<th>Gender</th>
<th>Age</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
<th>BMI</th>
<th>SP3 TEE (kcal/day)</th>
<th>SP3 PAEE (kcal/day)</th>
<th>SP3 PAEE (kcal/kg/day)</th>
<th>SP3 PA (min/week)</th>
<th>CHAMPS Score</th>
<th>CHAMPS PAEE (kcal/day)</th>
<th>CHAMPS PA (min/week)</th>
<th>PASE Score</th>
<th>PASE PA (min/week)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.00</td>
<td>1.00</td>
<td>0.66</td>
<td>4.7</td>
<td></td>
<td></td>
<td>0.02</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.00</td>
<td>1.00</td>
<td>0.86</td>
<td>2.7</td>
<td></td>
<td></td>
<td>0.02</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.00</td>
<td>1.00</td>
<td>0.00</td>
<td>0.00</td>
<td></td>
<td></td>
<td>0.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.00</td>
<td>1.00</td>
<td>0.00</td>
<td>0.00</td>
<td></td>
<td></td>
<td>0.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.00</td>
<td>1.00</td>
<td>0.00</td>
<td>0.00</td>
<td></td>
<td></td>
<td>0.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.00</td>
<td>1.00</td>
<td>0.00</td>
<td>0.00</td>
<td></td>
<td></td>
<td>0.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.00</td>
<td>1.00</td>
<td>0.00</td>
<td>0.00</td>
<td></td>
<td></td>
<td>0.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.00</td>
<td>1.00</td>
<td>0.00</td>
<td>0.00</td>
<td></td>
<td></td>
<td>0.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.00</td>
<td>1.00</td>
<td>0.00</td>
<td>0.00</td>
<td></td>
<td></td>
<td>0.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**P<0.01, *P<0.05**
## APPENDIX F – ACT Pearson Correlations

<table>
<thead>
<tr>
<th>Gender</th>
<th>Age</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
<th>BMI</th>
<th>ACT Daily Steps</th>
<th>ACT-PAEE (kcal/day)</th>
<th>ACT-PA (min/week)</th>
<th>SP3 Daily Steps</th>
<th>SP3 PAEE (kcal/day)</th>
<th>SP3 PA (min/week)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>1.00</td>
<td>0.00</td>
<td>0.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>1.00</td>
<td>0.00</td>
<td>0.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note:** *P<0.01, *P<0.05
### APPENDIX G – ACT Spearman Correlations

<table>
<thead>
<tr>
<th></th>
<th>Gender</th>
<th>Age</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
<th>BMI</th>
<th>SP3 PA</th>
<th>SP3 PAEE (kcal/day)</th>
<th>SP3 Daily Steps</th>
<th>ACT Daily Steps</th>
<th>ACT-&lt;F PAEE (kcal/day)</th>
<th>ACT-&lt;C PAEE (kcal/day)</th>
<th>ACT-&lt;M PAEE (kcal/day)</th>
<th>ACT-&lt;F PA (min/week)</th>
<th>ACT-&lt;C PA (min/week)</th>
<th>ACT-&lt;M PA (min/week)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>1.00</td>
<td>.10</td>
<td>.16</td>
<td>.93</td>
<td>.63</td>
<td>.00</td>
<td>1.00</td>
<td>.17</td>
<td>1.00</td>
<td>.08</td>
<td>.22</td>
<td>.00</td>
<td>.00</td>
<td>.00</td>
<td>.00</td>
</tr>
<tr>
<td>Age</td>
<td>.10</td>
<td>1.00</td>
<td>.83</td>
<td>.16</td>
<td>.46</td>
<td>.00</td>
<td>1.00</td>
<td>.10</td>
<td>1.00</td>
<td>.08</td>
<td>.22</td>
<td>.00</td>
<td>.00</td>
<td>.00</td>
<td>.00</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>.10</td>
<td>.16</td>
<td>.83</td>
<td>.00</td>
<td>.00</td>
<td>1.00</td>
<td>1.00</td>
<td>.10</td>
<td>1.00</td>
<td>.08</td>
<td>.22</td>
<td>.00</td>
<td>.00</td>
<td>.00</td>
<td>.00</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>.10</td>
<td>.16</td>
<td>.83</td>
<td>.00</td>
<td>.00</td>
<td>1.00</td>
<td>1.00</td>
<td>.10</td>
<td>1.00</td>
<td>.08</td>
<td>.22</td>
<td>.00</td>
<td>.00</td>
<td>.00</td>
<td>.00</td>
</tr>
<tr>
<td>BMI</td>
<td>.10</td>
<td>.16</td>
<td>.83</td>
<td>.00</td>
<td>.00</td>
<td>1.00</td>
<td>1.00</td>
<td>.10</td>
<td>1.00</td>
<td>.08</td>
<td>.22</td>
<td>.00</td>
<td>.00</td>
<td>.00</td>
<td>.00</td>
</tr>
<tr>
<td>SP3 PA</td>
<td>.10</td>
<td>.16</td>
<td>.83</td>
<td>.00</td>
<td>.00</td>
<td>1.00</td>
<td>1.00</td>
<td>.10</td>
<td>1.00</td>
<td>.08</td>
<td>.22</td>
<td>.00</td>
<td>.00</td>
<td>.00</td>
<td>.00</td>
</tr>
<tr>
<td>SP3 PAEE (kcal/day)</td>
<td>.10</td>
<td>.16</td>
<td>.83</td>
<td>.00</td>
<td>.00</td>
<td>1.00</td>
<td>1.00</td>
<td>.10</td>
<td>1.00</td>
<td>.08</td>
<td>.22</td>
<td>.00</td>
<td>.00</td>
<td>.00</td>
<td>.00</td>
</tr>
<tr>
<td>SP3 Daily Steps</td>
<td>.10</td>
<td>.16</td>
<td>.83</td>
<td>.00</td>
<td>.00</td>
<td>1.00</td>
<td>1.00</td>
<td>.10</td>
<td>1.00</td>
<td>.08</td>
<td>.22</td>
<td>.00</td>
<td>.00</td>
<td>.00</td>
<td>.00</td>
</tr>
<tr>
<td>ACT Daily Steps</td>
<td>.10</td>
<td>.16</td>
<td>.83</td>
<td>.00</td>
<td>.00</td>
<td>1.00</td>
<td>1.00</td>
<td>.10</td>
<td>1.00</td>
<td>.08</td>
<td>.22</td>
<td>.00</td>
<td>.00</td>
<td>.00</td>
<td>.00</td>
</tr>
</tbody>
</table>

*P<0.01, *P<0.05