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# Validation of Physical Activity Recording by Adolescent Girls

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# VALIDATION OF PHYSICAL ACTIVITY RECORDING

# BY ADOLESCENT GIRLS


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# VALIDATION OF PHYSICAL ACTIVITY RECORDING BY ADOLESCENT GIRLS

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An Abstract of the Thesis Presented
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Physical activity is recorded in bone mineralization studies because physical activity increases bone mass and decreases the risk of osteoporosis. The purpose of this research was to validate a method of physical activity recording used in a longitudinal bone study of adolescent girls. The physical activity recording method was a combination of a diary and an interview-administered recall. The method was validated against an objective measure of physical activity. Twenty-four adolescent girls between the ages of 9.8 and 14.1 wore Stayhealthy RT3 Research Trackers (tri-axial accelerometers) and recorded their activity for 24 hours on a diary form. The activity records were reviewed during telephone interviews the following day. The girls were asked to classify each period of activity into one of three categories: sitting (<1 metabolic equivalent (MET)), low intensity (1-3 METs) and high intensity (>3 METs). Motion detected by the accelerometers was converted to METs and the average recorded METs were determined for each period of reported activity. The means of the recorded METs for the time periods when the subjects reported

sitting, low intensity, and high intensity activities all fell within the pre-determined ranges. When 99% confidence intervals were constructed, the confidence interval for the recorded high intensity METs did not fall within the pre-determined range of >3 METs. It is unclear whether these subjects over-reported their time in high intensity activity or whether the accelerometers under-estimated energy expenditure. On average, adolescent girls were able to accurately classify their activities into one of the three intensity categories. This method of categorizing all daily activities by intensity is useful for comparing overall activity levels at different times of the year and between subjects. It is also potentially useful in documenting results of interventions to increase physical activity for weight control.

## DEDICATION

It is with great pleasure that I dedicate this thesis to my parents, Gerald and Lucille Camesano. It was their unconditional love and support that gave me the determination and desire to complete this project.

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# INTRODUCTION

Accurately recording physical activity in children and adolescents is a task that researchers have been attempting for many years. Gathering information about the types and amount of physical activity that adolescents participate in is important because physical activity is crucial to their future health status as it decreases the risk of disease and premature mortality (1). One of the diseases impacted by physical activity is osteoporosis. Physical activity during adolescence promotes stronger bones and decreases the risk of developing osteoporosis later in life. The higher the peak bone mass (PBM) acquired, the longer it will take for age-related bone loss to decrease bone mass enough to put a person a risk for osteoporosis-related fractures (2).

Before the information about physical activity patterns in relation to bone health can be assessed, an accurate and effective method of documenting and interpreting activity in adolescents needs to be developed. The purpose of this study was to validate a method of measuring physical activity developed at the University of Maine for the Seasonal Bone Study (SBS), a longitudinal bone study of adolescent girls. Currently, no gold standard exists for recording physical activity in adolescents and children (3). Researchers choose methods of physical activity recording based specifically on the needs of their studies. Four methods of self-reporting physical activity that have been used are: interview-administered recall, self-administered recall (including questionnaires), diaries, and proxy reports (4). It is common to enhance data collection by combining two or more of these methods.

A combination of two physical activity recording methods is being used in the SBS. This three-year observational study was designed to track bone development in

girls aged 10-13 years. The subjects record physical activity over four independent days on a diary form. Within 24 hours of keeping the record, the girls report their activity during a telephone interview. This combination of two methods was chosen for several reasons. Since this method does not require recall over several days, recall accuracy is expected to increase with less elapsed time after the activity (4). Also, the use of a diary is intended to serve as a memory cue for the girls to use during their telephone interview. The subjects are expected to account for all waking minutes when they report physical activity. The information from the diary is collected, clarified and classified into one of three categories: sitting, low intensity or high intensity. Physical activity is assessed twice per year in the SBS so comparisons can be made between the types and amounts of physical activity adolescent girls participate in during winter versus summer.

In bone studies, the physical activity reported should be classified by the impact or load on bone. The method chosen for the SBS was to assign all activities into one of three categories: sitting, low intensity or high intensity. The three categories differentiate between the impact on bone during various types of activity. The activities classified as sitting have little or no impact on bone and are generally associated with a lower energy expenditure or metabolic equivalent (MET) of less than one. The activities classified as low intensity are standing activities that have more load on bone than sitting, have a greater energy expenditure and have a MET value between one and three. The activities classified as high intensity are either sitting or standing activities that induce the most strain on bone, have the highest energy expenditure and make the subjects breathe hard or feel tired. High intensity activities have MET values greater than three.

Once a method of recording physical activity has been established, the validity and reliability should be evaluated in a group of children similar to the target population (5). Validation studies involve testing a method of physical activity recording against an objective measure of physical activity. Tri-axial accelerometers were chosen as the objective measure of physical activity in this validation study. Adolescent girls kept records of their daily activities for one day, classified each activity as sitting, low intensity or high intensity, and wore accelerometers to record METs during the 24 hour period. The METs recorded by the accelerometers were compared to the subjects' reported physical activity. This information was used to determine how well adolescent girls classify activities into one of the three predetermined categories.

## LITERATURE REVIEW

### Physical Activity and Bone Mineral Density in Adolescence

Physical activity is defined as any bodily movement that leads to energy expenditure greater than resting energy expenditure (6). Adequate physical activity has been linked to a decreased risk of many diseases including osteoporosis (1). Osteoporosis is a skeletal disease characterized by low bone mass, increased bone fragility and increased fracture risk that occurs with aging (2,7). Prevention of osteoporosis in females involves maximizing the bone mass acquired during youth, maintaining bone mass during young adulthood, and slowing bone loss after menopause. Maximizing bone mass during adolescence is key to preventing osteoporosis later in life. The greater peak bone mass (PBM) acquired during adolescence, the longer it will take for age-related bone loss to decrease bone mass enough to put someone at risk for developing osteoporosis and the associated fractures (2).

Physical activity can increase total bone mineral density (BMD) by accelerating the rate of bone acquisition during adolescence. An accelerated rate of bone acquisition during adolescence leads to a higher PBM because bone modeling is accelerated. PBM is the highest level of bone mass achieved through normal skeletal growth (2,8,9). Up to 50% of total bone mass is acquired during puberty in girls and 90% of PBM is accumulated by age 18 (10).

The period of puberty is also defined as adolescence. Adolescence begins at about the same time as puberty and continues until growth and maturation are complete (11). Because of the variability between males and females, and within each gender, the

Handbook of Pediatric Nutrition defines adolescence as the time period between 11 and 18 years (11).

Throughout life, bone tissue is constantly changing through the processes of bone growth, bone remodeling and bone modeling. At any given time, one process may dominate or all three may occur simultaneously (12). During the first process, bone growth, the entire skeleton is enlarged. This process takes place during the growing years, is controlled by genetics, and occurs independently of other changes in the shape of bones that may be resulting in response to skeletal loading (12).

The next process, bone remodeling, involves the constant resorption and formation of bone by two types of cells, osteoclasts and osteoblasts. During resorption, bone is dissolved by osteoclasts. Osteoclasts dissolve bone to form small cavities on the surfaces and insides of bone. These cavities are later filled in with new bone by osteoblasts in a process referred to as bone formation (13). When the two processes of resorption and formation occur at equal rates, bone mass is maintained at a stable level. Bone mass is maintained at a stable rate after adolescence when PBM has been reached (13).

During the third process, bone modeling, BMD increases. During bone modeling, the shape and internal architecture of bones are improved. Through bone modeling, bone mass is added at the bone sites where external loading is increased. One example of this is during weight-bearing exercise. Weight-bearing exercise is defined as any exercise where the muscles are pulled against bone in the presence of gravity (13). During weight-bearing exercise, the feet and legs bear the weight of the body. Examples of these types of exercises are running, jumping, jogging and stair climbing. Weight-bearing

exercise has a positive effect on BMD because the pull of the muscles on bone and body weight generate compression forces on bone that stimulate osteoblast activity. When osteoblast activity increases and osteoclast activity remains constant, BMD increases and bone modeling occurs.

The process of applying strain to bones from various forces such as muscle contractions or external loads is referred to as induced mechanical strain. The magnitude of the strain applied determines the effect on the skeleton (12-15). The induced mechanical strain during weight bearing exercise causes minute changes in the surface curvature of bones. The changes that occur are slight bending and curving of the bones. When one area of bone becomes compressed because of the bending or curving, interstitial fluid moves from compressed areas to non-compressed areas of bones. The movement of interstitial fluid stimulates cellular and tissue reactions that initiate bone modeling in an attempt of the skeleton to withstand the new load being applied (12,16). If the load applied is great enough, bone formation will occur at a faster rate than bone resorption and bone mass will increase. All of these internal changes to bone are directly related to the external forces and are in accordance with Wolff's Law (17). Wolff's Law states "every change in the form and function of a bone or of their function alone is followed by certain definitive changes in their internal architecture, and equally definite secondary alteration in their external conformation, in accordance with mathematical laws" (17).

According to Wolff's Law (17), if the load applied to bone is too low to increase osteoblast activity and osteoclast activity remains constant, a net decrease in BMD will be observed (18). An example of an activity that does not induce adequate strain on

bones to maintain or increase BMD is prolonged bed rest. When a person is lying down for an extended period of time, two factors affect bone remodeling. The first factor that plays a role is the decrease in muscle activity. During bed rest, the muscles are not being pulled against bone; therefore, osteoblast activity is not increased. The second factor that affects bone remodeling is the inadequate skeletal loading. During bed rest, the bones are not bearing the weight of the body which leads to a decrease in the forces or strain applied to the bones. As a result, osteoblast activity decreases while osteoclast activity remains constant. If a person were to remain on prolonged bed rest, they would experience a net decrease in BMD (18). Although the results of bone loss from prolonged bed rest are far greater than from a few hours of inactivity or sitting per day, a decrease in BMD is also seen with inactivity (18). In a meta-analysis of several studies, it has been noted that physically active people have a 30% greater BMD than inactive people (18).

Different types of physical activity affect bones differently. In a meta-analysis of many studies, Branca (18) discussed various physical activities and their effect on BMD. Those who participate in cycling and swimming have lower BMD than those who participate in walking or weight training. Swimming is a non-weight-bearing activity that loads the skeleton primarily through muscle contraction. During swimming, the body's weight is supported by water and not by the skeleton. Therefore during swimming, no additional loads besides muscle contractions are present because the skeleton is not bearing the weight of the body in the presence of gravitational forces (19). The effects on BMD during cycling are similar. When a person bicycles, their weight is supported by the bike and not by their skeleton.

The American College of Sports Medicine notes this lack of benefit to bones in their recommendations on exercise for osteoporosis prevention (16). They recommend weight-bearing exercise for osteoporosis prevention and state that non-weight-bearing exercise such as swimming and cycling does not induce adequate strain on bones to initiate bone modeling and increase BMD (16).

In a study conducted by Grimston et al. (20), the effects of swimming and impact loading activities (either running, gymnastics, tumbling or dance) on BMD were compared. In the study, 17 children (eight males and nine females) competing regularly in an impact loading sport were matched for race, gender, puberty and weight with a competitive swimmer. When these two groups were compared, it was found that the children participating in swimming had lower BMD at the femoral neck than those participating in impact loading sports. It was concluded that the forces generated by muscle contractions during swimming may not be sufficient to exceed the minimum strain level needed to initiate bone modeling and increase BMD in the swimmers (20).

In a study by Heinonen et al. (15), it was determined that the BMD of the cyclists was no different than the BMD of the sedentary subjects participating in the study (15). Those findings indicate that the load applied to bone during cycling through muscle contractions may not be great enough to initiate bone modeling and increase BMD.

In two longitudinal studies, the effects of physical activity on BMD were observed (19,21). In the University of Saskatchewan Bone Mineral Accrual Study (21), the nutrition, behavior and activity patterns of girls and boys ages 8-14 were observed for six years in order to observe changes during adolescence. Physical activity was assessed three times per year during the first three years and twice per year during the last three

years. Physical activity was measured using a Physical Activity Questionnaire (PAC-Q). This PAC-Q had nine items designed to assess physical activity throughout the school year. For this study, physical activity was defined as; "sports, games, gym, dance, or other activities that make you breathe harder, make your legs feel tired, and make you sweat" (21). Each item listed was scored using a five-point scale where a score of five indicates the highest level of activity. Total physical activity was summed for each individual based on the score given to each of the nine items. At the end of the six years, the researchers separated the subjects into quartiles based on their total reported physical activity. When children in the highest and lowest quartiles of activity were compared, significant differences were seen in the bone mineral densities at the lumbar spine. When the data was corrected for stage of puberty, an 18% higher bone mineral content (BMC) was observed at the lumbar spine and femoral neck of those in the highest quartile compared with those in the lowest quartile one year after peak bone mass was achieved (21). These results suggested that the differences observed were not a result of hormonal differences between the subjects and were related to an increase in the strain on bones induced by physical activity.

Slemenda et al. (19) observed similar results in another longitudinal study. This study was conducted using 59 pairs of monozygotic twins between the ages of 5.3 and 14 years. All subjects had bone mineral mass measurements taken. The subjects also completed an activity questionnaire designed for the National Children and Youth Fitness Study. This questionnaire provided a list of activities that are popular among children in this age group. The subjects were asked to check off activities that they participate in on a weekly basis and indicate how much time they normally spend doing each activity per

week. Subjects also completed questions about their physical education classes and the intensity of the activities done in those classes. High intensity activities were classified as those that "make you breathe hard". They also answered open-ended questions about other activities they participated in frequently. In addition to this questionnaire, the subjects' mothers also completed a shorter questionnaire that was used for comparison (19). The mothers' questionnaire asked about the total time spent in vigorous activities, the level of their child's activity versus other children, the amount of time their child watched television, and a few open-ended questions about activities frequently done by their child. Statistical analyses were carried out to conclude that those children participating in more physical activity had higher BMD in the radius and all three hip sites when compared to the less active children (19). From this data, Slemenda et al. (19) estimated that more active children enter adulthood with 5-10% greater bone mass than non-active children depending on the skeletal site measured (19).

In addition to longitudinal studies, experimental studies also show positive correlations between BMD and physical activity. Fuchs et al. (22) recruited ninety-nine children (56 boys and 43 girls) and randomized them into two treatment groups, a jumping group and a control group. Both groups met three times per week for 20 minutes in addition to their regularly scheduled physical education classes. They met for a total of 73 exercise sessions during seven months. Those in the jumping group performed a series of jumps from 61 cm high boxes. The number of jumps performed increased as the study progressed until it reached 100 jumps per day during the final 58 sessions. The control group also met on the same days as the jumping group and their exercise program consisted of non-impact stretching exercises. They completed a series

of six to eight upper body exercises and spent an equivalent amount of time with their instructors as those in the jumping group (22). The results of the exercise program were monitored with bone mass measurements. Bone mineral content (BMC), bone area (BA) and BMD of the left proximal femoral neck and lumbar spine were measured by dual-energy x-ray absorptiometry at baseline and after seven months. At baseline, there was no significant difference between BMC or BMD at the femoral neck or lumbar spine between the two groups. After seven months, those in the jumping group had significantly greater increases in BMC and BA at the femoral neck along with greater increases in the BMC and BMD of the lumbar spine. Since increased bone mass at the femoral neck and lumbar spine are inversely related to future spine and hip fractures, it is believed that higher PBM at those sites may reduce the risk of osteoporosis-related fractures later in life (22). A follow-up of these research participants will be necessary to determine if these increases in bone mineral density in the hip and spine in the intervention group will still be apparent during adulthood.

Although some of the physical activity research available in children and adolescents is controversial, one fact seems clear, exercise during growth positively influences bone mass (23). Those adolescents and children participating in more physical activity have higher bone mineral densities than those with low levels of reported physical activity, and those children and adolescents participating in weight-bearing exercises have higher BMD than those participating in non-weight-bearing exercises (18,19,21,22).

**Methods of Recording Physical Activity in Adolescents**

Interview-administered recalls, self-administered recalls (including questionnaires), diaries and proxy reports are the four most commonly used methods when recording physical activity in children and adolescents (4). No single method has been established as a gold standard because of the great variability and heterogeneity of the activities of children and adolescents (3).

Adolescents and children typically vary their routines from day-to-day and participate in a wide-range of activities (3). Because of the great variety of activities they participate in, some of the physical activity recording methods with standard lists of activities may not be appropriate for that population. If a questionnaire is used to assess physical activity, some irregular, play activities that the subjects participate in may be excluded leading to an inaccurate estimation of the impact of physical activity on BMD.

The second challenge that exists when recording physical activity in children and adolescents is the heterogeneous nature of their activities, which may lead to children and adolescents not using the same terminology to describe an activity as adults use. An example is swimming. While for adults, continuous lap swimming is usually classified as having no beneficial effect on BMD; but swimming may include other activities when children self-report physical activity. Swimming, as reported by children and adolescents, may be more heterogeneous. Children and adolescents may be running around at the pool or beach, jumping in and out of the water, and playing water sports. Those activities, especially running and jumping, induce strain on bones and will have beneficial effects on BMD. Therefore, when children or adolescents report swimming on

activity records, researchers should ask open-ended questions to clarify what was involved with participating in that activity.

When choosing a method of physical activity recording, both the great variety of activities that children and adolescents participate in and the heterogeneous nature of their activities need to be considered to ensure accuracy in data collection.

Questionnaires

Questionnaires are a method of physical activity recording commonly used in research studies. Questionnaires provide general information about physical activity patterns and about specific activities. They can be composed of multiple-choice or open-ended questions depending on the type of information desired by the researchers. Since children and adolescents participate in a great variety of activities each week, questionnaires are most helpful when they are used to collect data over several days.

In a longitudinal study by Slemenda et al. (19), 118 subjects between the ages of 5.3 and 14 years were asked both open-ended and multiple-choice questions. Problems arose with the open-ended questions because the responses given to those questions were proven to be unreliable. It was determined that the younger children reported time estimates that were unrealistic. As a result, the responses that were deemed unrealistic were not included in the data analysis thus resulting in limited and incomplete information from many subjects. With the tool that was used, it was difficult to determine if subjects had participated in activities that were not listed on the questionnaire since many of the open-ended responses were not used in the data analysis. Because of the great variety of activities that children and adolescents enjoy,

questionnaires that do not allow for open-ended responses will not include all possible activities. As a result, incomplete data may be collected.

Although the questionnaire used by Slemenda et al. (19) provided some incomplete information about those activities not mentioned specifically, it did answer the major questions about physical activity patterns and served its purpose in this study. From the data gathered, researchers were able to draw some conclusions about physical activity levels and compare those to the BMD measurements (19).

Proxy Reports

Proxy reports are a second option available to researchers when assessing physical activity. Usually, parents or teachers make proxy reports for research participants who are too young to report activity on their own. Proxy reports can be used alone or in addition to the participant's report of their own physical activity (5).

Studies conducted on the use of proxy reports have shown significant correlations between teachers' and parents' reports of children's activity. The reports received from the teachers were more strongly correlated with objective measures of physical activity than the reports received from the parents (5).

Diaries

Diaries are another common physical activity recording method available to researchers. These devices involve subjects recording activity throughout the day on a diary form. Diaries have been used in several studies of physical activity and researchers have identified benefits and problems associated with their use (5).

A problem associated with the use of diaries is the burden they create for the subjects and the researchers (5). The subjects need to write in the diary many times

throughout the day, which can become quite time consuming. The researchers have to review and code all of the activity information recorded. Diaries may not be practical for use in large studies.

Sallis (7) acknowledged some benefits of using diaries to assess physical activity. The first benefit of using diaries is that they have the strongest validity data of any method of physical activity recording tested. Diaries also can benefit the subjects. If an interview of subjects is conducted after they keep their diaries, the diaries can serve as a memory cue to help them recall portions of the day. Memory cues are commonly used in research studies to help improve recall accuracy.

Recalls

Recalls are the fourth method of physical activity recording available for researchers. During interview-administered recalls, the subjects report their activity to researchers and are asked a specific set of questions about their reports.

Several variations of an interview-administered recall were used and validated by Sallis et al. (24). One example is the Seven-day Physical Activity Recall (PAR). Using this method, all subjects were interviewed for approximately 10-15 minutes and asked to recall activities from the past seven days. The interview process was made easier with the use of memory cues. In order to assist the subjects, the interviewers broke the days up into morning, afternoon and evening segments and they also provided a list of several activities ranging in intensity to help the subjects classify the intensity of their activities. After the data was analyzed, they determined that the reliability of each response increased as the time between the day of activity and the interview decreased. Thus,

recall accuracy was highest when activities were reported no more than a few days later (24).

Overall, Sallis et al. (24) determined that: recall information would be optimal if the subjects report their activity the following day, several 24-hour recalls would provide the most reliable information, and that children ages 10-16 years could provide reasonably reliable and valid reports of their daily activities (24). In this study, each subject completed four single-day food and activity diaries twice per year. Within 24 hours of completing each single-day record, they were interviewed over the phone. The use of diaries as memory cues and scheduling the phone interviews within 24 hours was expected to help increase recall accuracy (24).

Evidence supporting the ability of children and adolescents to report physical activity can also be found in the research on dietary recalls. In one study conducted by Greger and Entyre (25), 12.5-14.5 years olds were capable of recalling their dietary intake after 24 hours when they were not warned previously that a diet recall was going to be completed. Their reports were within two-thirds to four-thirds of what they actually consumed (25).

**Classification of Physical Activity in Adolescents**

Before analyzing the physical activity reported by children and adolescents, it is important to determine how the activity will be classified. In order for physical activity to have a beneficial effect on BMD, the load applied to bone must be great enough to stimulate osteoblast activity and increase bone modeling. When a person participates in additional weight bearing exercise, greater than their usual activity, osteoblast activity is

initiated and BMD increases (20). Reported activities need to be categorized according to their potential impact on bone.

In a longitudinal study conducted by Slemenda et al. (21), the effects of total physical activity and weight-bearing physical activity were determined. In this study, a group of 118 children between the ages of 5.3 and 14 years completed activity questionnaires. The associations between total hours spent in specific activities and BMD were determined along with associations between total physical activity and BMD. BMD measurements were taken in the radius, spine and hip. For this study, a list of common activities and sports were given to the subjects. It was found that those activities typically categorized as weight bearing, such as high intensity sports or weight-lifting, had greater correlations with increased BMD than those typically classified as non-weight bearing such as swimming and cycling. The results indicated a skeletal benefit when overall physical activity was increased in children and adolescents. However, the researchers were unable to conclude that specific activities had greater associations with BMD than other activities. The inability to draw those types of conclusions may be due to the possibility that children may estimate the time spent in specific activities inaccurately and may report some activities more accurately than others (19). The results of the study by Slemenda et al. (19) demonstrate the difficulty in trying to quantify specific physical activities by their impact on bone mass, especially when the subject group studied is children or adolescents.

A second option available for classifying physical activity in research studies is by metabolic equivalents (METs). A higher MET value assigned to an activity implies a greater energy expenditure, greater intensity and greater work by muscles required to

complete that activity. The Compendium of Physical Activity compiled by Ainsworth et al. (26) was developed in response to the need for a standardized system for coding physical activity in the field. This list includes a variety of activities and the typical METs associated with them (26) (Appendix A).

In a fifteen-year longitudinal study by Kemper et al. (27), physical activity was classified by both METs and the strain induced on bone. Physical activity was measured a total of six times using an interview-administered recall in the form of a questionnaire. Kemper et al. (27) calculated METs per week for each subject using the amount of time spent in an activity and the reported intensity. The amount of time spent in an activity had to be greater than five minutes to be included in the analysis. METs per week were calculated for activities with a minimum MET value of four. To assess the impact of each activity on bones, a literature search was performed and the ground reaction forces of each activity were determined. BMD was measured in the lumbar region, the femoral neck (hip) and the distal radius (wrist). At the conclusion of the study, they found a correlation between both METs and BMD and the strain applied to bone and BMD. Since a correlation was found between METs and BMD at the lumbar spine and hip, classifying activities by the energy expended or METs may be an acceptable way to estimate the impact on bone. In most cases, when greater energy expenditure or METs is required to complete an activity, it is indicative of greater strain applied to bone which would increase bone modeling thus leading to an increase in BMD.

One drawback of classifying activities by METs or energy expenditure as an index of impact on bone is seen when swimming or cycling activity is reported by subjects. In those cases, the skeleton is not bearing the weight of the body; therefore,

adequate strain is not being induced on bones to increase bone modeling and BMD. In those cases, caution needs to be taken to ensure that those activities are accurately categorized by their impact on bone.

Because of both the heterogeneous nature of children and adolescent's activities and the great variety of activities that they participate in, it would not be practical to review each activity over the phone with the subjects to determine the impact of specific activities on bone. As a result, researchers have chosen to determine correlations between total physical activity and BMD and to classify physical activity by intensity or METs.

**Objective Measures of Physical Activity**

When children and adolescents report physical activity, their reports are compared to objective measures of physical activity to validate those reports. For the past decade, the doubly labeled water (DLW) method of assessing physical activity has been viewed as the gold standard for measuring energy expenditure and validating physical activity reports. Because of the increased cost associated with using this method, other instruments are also used in validation studies (28). Heart rate monitors, pedometers and accelerometers are all accepted means of assessing physical activity in validation studies.

Doubly labeled water

The DLW method of measuring physical activity is a form of indirect calorimetry (30). Subjects receive an oral dose of $^{2}H_2{}^{18}O$ and their elimination rates are observed. The $^{2}H$ is eliminated as water and the $^{18}O$ is eliminated in water and $CO_2$. The differences in elimination are tracked in a respiratory chamber (29). The rate of $CO_2$ elimination is

used to measure energy expenditure. The DLW method is a very accurate method for validating physical activity reports.

Although this method has been referred to as a gold standard, many disadvantages prevent its widespread use (28). Since the DLW method is expensive, it is usually used in studies with small sample sizes. A second downfall is that highly trained personnel are needed to implement this method and such extensive training may not be available at all facilities. Because of the cost and training required to conduct this procedure, very few physical activity questionnaires have been validated against DLW.

Heart rate monitors

Heart rate monitors are common tools used to measure physical activity. The rationale for using heart rate monitors is that a linear relationship between heart rate and oxygen consumption has been demonstrated (30,31). Janz et al. (30) concluded that heart rate monitoring is an acceptable method of measuring physical activity but also mentioned the downfalls of their use. Heart rate monitoring is not an exact method of measuring physical activity because some outside factors such as emotions and body positioning influence a person's heart rate. Those fluctuations in heart rate are independent of any changes in oxygen uptake and are unrelated to a person's activity level (30). Those false rises in heart rate can result in inaccurate estimates of subjects' physical activity and can alter data in a research study (30).

Another factor that may alter results when heart rate monitoring is used to assess physical activity is the fitness level of the participant. A person who is more physically fit will have a lower heart rate for any given activity when compared to a less fit person. Therefore, when heart rate data is reviewed, if the fitness level of each individual is not

known and accounted for in the data analysis, the data gathered will be a measure of the participant's fitness level, not their physical activity level (30,31).

Pedometers

Pedometers are a third objective measure of physical activity available for use in validation studies. Pedometers are small, low cost devices that count the number of steps taken or miles walked by measuring vertical acceleration (6). Recently, it has been determined that the newer electronic pedometers provide a reasonably accurate estimate of walking when tested in a research study, which is a significant improvement over the results seen with the older mechanical pedometers (31). Pedometers do not have the capability of storing data over a period of time, recording sedentary activities, or recording motion in the horizontal plane (6).

Accelerometers

Accelerometers are another method used when measuring physical activity in validation studies. Accelerometers are small, lightweight devices that are usually worn on a person's waistband. They can be uniaxial or triaxial, meaning that they can measure motion in either one or three planes. Uniaxial accelerometers were the most widely used motion sensors in validation studies prior to the development of triaxial accelerometers and they were found to be an acceptable tool for validating physical activity (32). Since tri-axial accelerometers measure motion in the x (mediolateral or side-to-side), y (anteroposterior or front and back), and z (vertical or up and down) planes, they are being used more frequently. The measurement of motion in three planes allows for greater sensitivity in measurements. Once data is recorded for the three planes, a vector magnitude can be calculated for each minute. Using the calculated vector magnitudes, it

is also possible to determine the energy expenditure or METs for each minute and an estimated total caloric expenditure for the day.

In a comparison study by Eston et al. (31), the ability of heart rate monitors, pedometry and accelerometry to predict energy expenditure was validated. Thirty children (both males and females) between the ages of 8.2 and 10.8 participated in this study. All subjects participated in a series of exercises while the relationship between pedometry, accelerometry (uni-axial and tri-axial), heart rate and oxygen uptake was assessed. The following exercise program was completed by all subjects: walking at 4 km/hr for 4 minutes, walking at 6 km/hr for 4 minutes, running at 8 km/hr for 4 minutes, running at 10 km/hr for 4 minutes, playing catch for 4 minutes, playing hopscotch for 4 minutes and sitting and crayoning for 10 minutes. Each subject wore three pedometers. They were secured to their ankle, wrist and waist. The pedometers kept a count of steps taken. Each subject also wore one uni-axial accelerometer and one tri-axial accelerometer. The accelerometers were programmed to measure motion in one-minute intervals. The uni-axial accelerometers were secured to the subject's left hip and the tri-axial accelerometers were secured to the subject's right hip. The heart rate monitor electrodes were attached to the subjects' chests and were programmed to record an average heart rate after every eight beats. The gas analysis was conducted using a mouthpiece to measure expired and inspired gas volumes. Gas measurements were taken every 30 seconds. All data was sent to the same watch where it was recorded and analyzed.

At the conclusion of the exercise sessions, Eston et al. (31) reviewed the data and compared the readings from all of the instruments for the various exercises. They

determined that the tri-axial accelerometers provided overall the best criterion measure of the activities. They also stated that using heart rate monitoring and accelerometry together would increase the accuracy of the results but that the results from using both would be outweighed by the additional costs and labor (31).

**Summary**

Due to the variability and heterogeneity of the activities of children and adolescents, the method of physical activity recording used in a research study needs to be validated to determine its appropriateness (7). The method of physical activity recording being validated in this study was a combination of a diary and an interview-administered recall. The objective measure of physical activity chosen to validate this method was the tri-axial accelerometer. The objectives of this study were to:

1. Validate the method of physical activity recording used in the SBS.
2. Determine how well adolescent girls classify their daily activities into three categories of intensity.

# METHODOLOGY

## Study Design

This study was designed to validate the method of physical activity recording used in the Seasonal Bone Study (SBS) at the University of Maine. Twenty-seven adolescent girls wore Stayhealthy RT3 Research Trackers (tri-axial accelerometers) and recorded their activity for 24 hours (Stayhealthy, Inc., Monrovia, CA). This study was completed during the summer of 2001. The day after the subjects kept activity records and wore the accelerometers, they reported their activity during an interview-administered recall either over the phone or in person. The reported activities were classified as either sitting, low intensity or high intensity based on the descriptions received during an unbiased interview of each subject. Activities classified as sitting corresponded to a metabolic equivalent (MET) of less than one. Activities classified as low intensity corresponded to METs between one and three, and activities classified as high intensity corresponded to METs greater than three. The METs recorded by the accelerometers were compared to the intensities reported by the subjects. The ability of the subjects to report and classify each activity into one of the three established categories was assessed.

## Subjects

### Recruitment

Twenty-seven adolescent girls between the ages of 10 and 14 years were recruited for participation in this validation study. Subjects in the SBS and those who participated in previous studies conducted by the Department of Food Science and Human Nutrition at the University of Maine were recruited through informational letters. Additional

subjects were recruited through fliers on campus, at local businesses and on the University of Maine's First Class Conference System. Refer to Appendix B for a copy of the recruitment letter and flier used to advertise the study.

To be included in this study, subjects had to be females between the ages of 10 and 14. They also had to be able to participate in activities of normal daily living, keep a written record of their daily activities, and verbally report those activities during an interview.

Consent Visit

After eligibility was determined, subjects met with the principal investigator at the University of Maine. As required by the Protection of Human Subjects Review Board at the University of Maine, the parent or guardian of each subject signed a consent form and the girls gave verbal assent. Refer to Appendix C for copies of the consent and assent forms. After consent and assent were obtained, the subjects' addresses and social security numbers were recorded. This information was used to compensate them for participation. Each subject received a check for $10.00 shortly after completing the study along with a small gift.

At the consent visit, subjects were also weighed and heights were measured. All subjects were weighed without shoes on an electronic "Detecto" physician's scale. The scale has a self-adjusting tare and was calibrated before weighing each subject. The scale has a digital readout in kilograms. All weights were recorded to the nearest tenth of a kilogram. Heights were measured on a wooden, collapsible stadiometer with an adjustable wooden headboard (Shorr Productions Olney, MD). All heights were measured without shoes and were recorded to the nearest eighth of an inch. Heights were

then converted to centimeters. Heights, weights and ages were entered into the Stayhealthy software program that accompanied the accelerometers and were used to calculate an estimation of resting metabolic rate (RMR).

**Activity Records**

After the anthropomeric measurements were recorded, subjects were instructed on recording activity. They were given copies of activity records, instructions, and sample activity records. Refer to Appendix D for copies of those forms. Subjects were instructed to record their activity for the day and to account for every minute during the 24-hour period, in blocks of time of five minutes or greater.

After the subjects were trained in the physical activity recording procedure, the interview-administered recall was discussed. The subjects were told that during the interview they would read each activity and the corresponding time period to the researcher. After each activity was read, the researcher would ask them if they were sitting or standing. If they were standing, they would be asked if the activity made them "breathe hard or feel tired." Activities that made subjects "breathe hard or feel tired" were classified as high intensity. Other standing activities that did not make them "breathe hard or feel tired" were classified as low intensity. During the course of categorizing activities, any sitting activities that the subjects claimed made them "breathe hard or feel tired" were also classified as high intensity. Some examples of these activities were bicycling and sit-ups.

This method of distinguishing between low and high intensity activities was modified from the method used by Bailey et al. (21) in the University of Saskatchewan Bone Mineral Accrual Study. They classified high intensity activities as "sports, games,

gym, dance, or other activities that make you breathe harder, make your legs feel tired, and make you sweat" (21).

**Objective Measurement of Activity**

Procedure

After the activity records and interview were discussed, the proper use of the accelerometers was discussed. Subjects were given written instructions for the accelerometers that were reviewed thoroughly, see Appendix E. The subjects were instructed to wear the accelerometers for a 24-hour period. They were asked to try to keep the accelerometers on while they slept, and were instructed to take them off only briefly to change clothes or shower. Subjects were also encouraged to participate in all of their usual activities except for swimming because the accelerometers are not waterproof. If swimming was necessary, they were told to take the accelerometers off, store them in a safe place and put them back on as soon as they were finished. Taking off the accelerometers was discouraged because it was desirable to have an accurate measure of the subjects' activity for 24-hours. Subjects were instructed to record any times that the accelerometers were not worn on their activity records.

Once the procedures were clearly outlined, an appointment to return the accelerometers the following day was arranged. Many people chose to return to the University of Maine in approximately 24 hours and to review the activity records in person. Others were met at convenient locations to return the accelerometers and the interview-administered recall was conducted over the phone. Whether the activity records were reviewed in person or over the phone, the same procedure was followed.

At the conclusion of the consent and training visit, the subjects' watches were synchronized to the time on the accelerometers. After their watches were set, the researchers programmed the accelerometers, attached them to the subjects' waistbands above their right or left hip and turned them on. A benefit of using this type of accelerometer is that once they are turned on, it is not possible for the subjects to turn them off until they are returned to the docking station and downloaded. This tamper-proof feature is an improvement over previously used accelerometers that had to be worn in locked bags around subjects' waists to prevent tampering (33).

<u>Stayhealthy RT3 Research Tracker Characteristics</u>

The Stayhealthy RT3 Tri-axial Research Trackers (tri-axial accelerometers) are small and lightweight and are worn comfortably in holsters clipped to the subjects' waistbands. The accelerometers weigh approximately 2.3 ounces and measure 2.8" x 2.2" x 1.1". These accelerometers measure motion in the x (mediolateral or side-to-side), y (anteroposterior or front and back) and z (vertical or up and down) planes using a sensitive piezo-electric device.

The Stayhealthy RT3 accelerometers are the most recent improvement over the commonly used TriTrac R3D accelerometers. Preliminary tests conducted by Stayhealthy, Inc., show an increase in accuracy and a decrease in inter-instrument variability with the Stayhealthy RT3 accelerometers when compared with the TriTrac R3D (Stayhealthy, Inc., unpublished data). The improvements in the Stayhealthy accelerometers are in the manufacturing practices. When the TriTrac R3D accelerometers were manufactured, three separate chips were installed into each accelerometer. Each vector (plane) was located on one chip, which was installed

separately and soldered by hand. Because the chips were installed by hand, human error may have lead to inconsistencies between accelerometers. When these newer Stayhealthy RT3 accelerometers are manufactured, all three vectors are located on the same chip cutting down on the chance for human error. They are also installed under more strict manufacturing principles.

The Stayhealthy RT3 accelerometers measure motion or kinetic energy through piezoelectricity. When the accelerometers are moved, the crystalline substance is compressed leading to the displacement of the ions in each unit cell. When the ions in each unit cell are displaced, the shape of the whole crystal changes due to the mechanical deformation. The deformation or kinetic energy (motion) is converted into electrical voltages that are displayed as accelerometer data (34). The accelerometer data is displayed in the form of activity counts per minute for each axis (x, y and z). That information is then used by the accelerometers to calculate the vector magnitudes for each minute. Vector magnitudes are calculated by the accelerometers using the following equation:

$$\text{Vector Magnitude} = \sqrt{x^2 + y^2 + z^2}$$

The accelerometers also calculate calories expended for each minute. The Stayhealthy computer software displays calories as activity calories and total calories. Activity calories are the calories expended during a minute without the effects of RMR. Activity calories reflect the net energy expenditure and are added to the calculated RMR to determine total calories. Total calories or gross energy expenditure are the sum of the activity calories and RMR. RMR is calculated by the Stayhealthy software using the height, weight and age entered for each subject.

The specificity of the data recorded by the accelerometers varies depending on how they are programmed to collect data. The following are the four modes available with the RT3 Research Trackers:

- Mod*e 1* – Samples and records all data for all three axes every second. It is possible to record data in this mode for up to three hours.
- *Mode 2* – Samples data for all three axes then calculates and records the vector magnitudes for every second. It is possible to record data in this mode for nine hours.
- *Mode 3* – Samples data for all three axes every second and calculates the average for each axis after one minute. It is possible to record data in this mode for seven days.
- *Mode 4* – Samples data for all three axes and calculates the vector magnitude every second and then averages it at the end of a minute. The vector magnitude is recorded for every minute. It is possible to record data in this mode for 21 days.

For this validation study, the accelerometers were programmed to collect data in Mode 3.

Downloading Accelerometer Data

Immediately after the accelerometers were returned, the individual data for each subject was downloaded into Microsoft® Excel 2000. The data included the activity counts for each axis per minute, the vector magnitudes for each minute, activity calories for each minute, and the total calories expended during each minute. Once the data was downloaded, any recorded activity outside of the 24-hour period reported by the subjects was deleted. Once a 24-hour period was established, the estimated 24-hour caloric expenditure for each subject was recorded.

Each time period of reported activity for the day was then reviewed and coded as either sitting, low intensity or high intensity based on the descriptions of each activity given by the subjects and their classification of the activity. Since the objective of this study was to determine how well adolescent girls classify activity as either sitting, low intensity or high intensity, some activities were not coded and were excluded from the data analysis. Any time when the subjects reported that they were sleeping was not included because some subjects removed the accelerometer during sleep. The second type of activity that was not included was when the subjects reported that they were not wearing the accelerometers. This information was not analyzed because the motion recorded by the accelerometers was inaccurate for the times that the subjects were not wearing them. The last type of activity not included in the data analysis was when the subjects participated in activities that led to inaccurate accelerometer readings. Any motion recorded by the accelerometers that was not proportional to work performed by the subjects would result in inaccurate accelerometer readings. Therefore, the following four activities were not included in the analysis: riding in a car, bicycling, swinging in a hammock, and riding in a boat. Refer to Appendix F for the data supporting the decision to delete time spent riding in cars.

Once all of the data was coded, individual METs were calculated from the accelerometer measurements for each minute of the day using the equation devised and validated by Stayhealthy, Inc. To calculate METs with this equation, the activity calories and the subjects' weights must be known. The following equation was used to calculate METs:

$$\text{METs} = (\text{Activity Calories} \bullet 70) / \text{Subject's Weight (kg)}$$

The METs for each minute were calculated in order to make comparisons between the subjects' reported intensity and the activity counts recorded by the accelerometer. The procedure of assigning METs to activities was determined after reviewing the Compendium of Physical Activities compiled by Ainsworth et al. (26). In the Compendium of Physical Activities, both exercise and common daily activities are categorized and their corresponding METs are listed. After reviewing the list, it was determined that most of the sitting activities corresponded to a MET value of less than one. Most of the slower paced, standing activities corresponded to a MET between one and three, and faster-paced activities corresponded to a MET value greater than three. Common activities and their corresponding MET values can be found in Appendix A (26). Refer to Appendix G for a sample spreadsheet that displays the data downloaded from the accelerometers and the calculations completed using that data.

**Statistical Analysis**

Two types of data were available for use in the statistical analyses, the METs recorded by the accelerometers and the METs assigned to the activities reported by the subjects. The METs recorded by the accelerometers are referred to as "recorded METs" in the statistical analyses. The METs corresponding to the three categories of activity reported by the subjects during the activity recalls are referred to as "reported METs".

After the accelerometer data was downloaded into Microsoft® Excel 2000 and certain minutes were deleted, all activities were coded as either sitting, low intensity or high intensity based on the descriptions received during the interviews of the subjects. The data was then analyzed in two different ways.

Initially, once the recorded data was coded, it was separated based on the intensity as reported by the subjects (sitting, low intensity or high intensity). Confidence intervals were constructed for the three intensities using the mean of the recorded METs for each category as established by the subjects' reports. The purpose of analyzing the data in that way was to determine overall how well the subjects were able to classify their activities into one of the three distinct categories.

In the second data analysis, the day was broken down into sections of sitting, low intensity and high intensity data as reported by the subjects. The procedure was done the same way as in the first method of analysis. The recorded METs for those time periods were compared with the subjects' self-reports to determine how well they categorized their activity. The percentage of the total minutes that the subjects categorized their sitting, low intensity and high intensity activities correctly and incorrectly based on the accelerometer readings were determined.

# RESULTS

## Subject Results

Twenty-seven subjects between the ages of 9.8 and 14.1 participated in this validation study. Complete data was available for 24 out of the 27 subjects who began this validation study. One subject did not complete the study and the accelerometer battery failed for two subjects. The characteristics of the 24 subjects who completed the study are shown in Table 1. Their ages ranged from 9.8 – 14.1 years and the mean age ± standard deviation (SD) of the subjects was 11.7 ± 1.2 years. The means and standard deviations of the subjects' weights, heights and estimated 24-hour caloric expenditures are also displayed in Table 1.

The percent of the total reported minutes analyzed varied depending on the individual reports of activity. Between 61 and 91% of the total reported out-of-bed minutes were analyzed for the 24 subjects. Table 2 displays the reported out-of-bed minutes and the total minutes used in the analyses. The percent of reported out-of-bed minutes used in the analyses was also calculated for each subject.

In addition to variations among the subjects in the percent of out-of-bed minutes analyzed, the percent of reported minutes spent in the three intensities (sitting, low intensity and high intensity) by the subjects also varied. Refer to Table 3 for a summary of the reported minutes spent in each of the three intensities and the reported minutes that were used in the analyses after some data was deleted.

**Table 1**
Subject Characteristics

| Subject # | Age (years) | Weight (kg) | Height (cm) | Caloric Expenditure* |
|---|---|---|---|---|
| 1 | 12.3 | 40.6 | 151.8 | 1737 |
| 2 | 12.3 | 42.4 | 152.4 | 2056 |
| 3 | 11.7 | 30.2 | 151.1 | 1527 |
| 6 | 11.0 | 38.6 | 145.3 | 1985 |
| 7 | 11.8 | 40.7 | 138.4 | 2267 |
| 8 | 9.9 | 33.1 | 137.7 | 1818 |
| 9 | 10.0 | 30.1 | 142.2 | 1508 |
| 11 | 9.8 | 33.3 | 135.9 | 1733 |
| 12 | 10.8 | 49.6 | 143.5 | 2332 |
| 13 | 12.2 | 34.8 | 145.8 | 1965 |
| 14 | 12.7 | 52.1 | 163.8 | 2028 |
| 15 | 11.3 | 40.9 | 160.0 | 1778 |
| 16 | 11.4 | 34.0 | 143.8 | 1884 |
| 17 | 12.8 | 53.5 | 161.3 | 1819 |
| 19 | 10.7 | 47.8 | 142.9 | 2276 |
| 20 | 10.6 | 56.0 | 153.0 | 1668 |
| 21 | 12.5 | 62.8 | 161.3 | 2666 |
| 22 | 13.5 | 67.9 | 170.2 | 2278 |
| 23 | 14.1 | 45.0 | 149.9 | 2115 |
| 24 | 13.4 | 46.3 | 161.3 | 2631 |
| 25 | 12.6 | 49.6 | 162.6 | 2070 |
| 27 | 10.5 | 33.5 | 142.2 | 1886 |
| 28 | 11.8 | 65.2 | 1456.5 | 2682 |
| 29 | 12.0 | 64.6 | 156.2 | 2714 |
| **Mean ± SD** | **11.7 ± 1.2** | **45.5 ±11.2** | **151.2 ±9.5** | **2059 ±358** |

* Calculated from 24-hour accelerometer readings and RMR. May include time when accelerometers were not being worn (such as during sleeping and showering).

**Table 2**
Minutes Reported by the Subjects Versus the Minutes Used in the Analyses

| Subject # | Out-of-Bed Minutes Reported | Total Minutes Used* | Percent of Reported Minutes Used |
|---|---|---|---|
| 1 | 767 | 697 | 91 |
| 2 | 911 | 792 | 87 |
| 3 | 758 | 647 | 85 |
| 6 | 870 | 708 | 81 |
| 7 | 970 | 730 | 75 |
| 8 | 862 | 668 | 77 |
| 9 | 878 | 701 | 80 |
| 11 | 805 | 698 | 87 |
| 12 | 869 | 774 | 89 |
| 13 | 932 | 779 | 84 |
| 14 | 767 | 708 | 92 |
| 15 | 855 | 738 | 86 |
| 16 | 780 | 607 | 78 |
| 17 | 830 | 725 | 87 |
| 19 | 884 | 805 | 91 |
| 20 | 760 | 551 | 73 |
| 21 | 795 | 680 | 86 |
| 22 | 910 | 808 | 89 |
| 23 | 932 | 858 | 92 |
| 24 | 836 | 511 | 61 |
| 25 | 969 | 901 | 93 |
| 27 | 855 | 637 | 75 |
| 28 | 801 | 662 | 83 |
| 29 | 798 | 674 | 84 |
| **Mean ± SD** | **850 ± 65** | **711 ± 90** | **84 ± 8** |

* Total reported minutes minus the times when the subjects were not the wearing accelerometers and/or readings were inaccurate (such as riding in cars, riding in boats, swinging in hammocks and bicycling).

**Table 3**

Minutes Reported by the Subjects in the Three Intensities Compared to Minutes Used in the Analyses

| Subject # | Sitting Minutes Reported | Sitting Minutes Used | % Sitting Minutes Used | Low Minutes Reported | Low Minutes Used | % Low Minutes Used | High Minutes Reported* | High Minutes Used | % High Minutes Used |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 530 | 469 | 88 | 228 | 228 | 100 | 9 | 0 | 0 |
| 2 | 368 | 249 | 68 | 349 | 349 | 100 | 194 | 194 | 100 |
| 3 | 561 | 453 | 81 | 157 | 155 | 99 | 40 | 39 | 97.5 |
| 6 | 651 | 441 | 68 | 236 | 236 | 100 | 45 | 30 | 67 |
| 7 | 591 | 382 | 65 | 290 | 259 | 89 | 89 | 89 | 100 |
| 8 | 516 | 349 | 68 | 316 | 289 | 92 | 30 | 30 | 100 |
| 9 | 696 | 544 | 78 | 470 | 145 | 31 | 12 | 12 | 100 |
| 11 | 555 | 462 | 83 | 170 | 156 | 92 | 80 | 80 | 100 |
| 12 | 579 | 500 | 86 | 290 | 274 | 94 | 0 | | |
| 13 | 460 | 307 | 67 | 472 | 472 | 100 | 0 | | |
| 14 | 566 | 536 | 95 | 175 | 155 | 89 | 26 | 17 | 65 |
| 15 | 664 | 571 | 86 | 94 | 70 | 74 | 97 | 97 | 100 |
| 16 | 431 | 258 | 60 | 349 | 349 | 100 | 0 | | |
| 17 | 738 | 661 | 90 | 92 | 64 | 70 | 0 | | |
| 19 | 545 | 467 | 86 | 299 | 299 | 100 | 40 | 39 | 98 |
| 20 | 537 | 443 | 82 | 104 | 59 | 57 | 119 | 49 | 41 |
| 21 | 465 | 447 | 96 | 222 | 175 | 78 | 108 | 58 | 54 |
| 22 | 633 | 598 | 94 | 210 | 210 | 100 | 67 | 0 | 0 |
| 23 | 580 | 509 | 88 | 265 | 265 | 100 | 84 | 84 | 100 |
| 24 | 473 | 227 | 48 | 284 | 284 | 100 | 80 | 0 | 0 |
| 25 | 757 | 747 | 98 | 148 | 110 | 74 | 64 | 49 | 77 |
| 27 | 448 | 279 | 63 | 200 | 151 | 76 | 207 | 207 | 100 |
| 28 | 267 | 147 | 55 | 311 | 292 | 94 | 223 | 223 | 100 |
| 29 | 627 | 559 | 89 | 95 | 90 | 89 | 76 | 25 | 33 |
| **Mean±SD** | **549±113** | **442±145** | **79±14** | **243±107** | **214±104** | **88±17** | **70±65** | **66±68** | **72±38** |

*Seventeen of the 24 subjects who completed the study reported spending time in high intensity activities during their 24-hour activity-recording period.

**Accelerometer Results**

Recorded METs

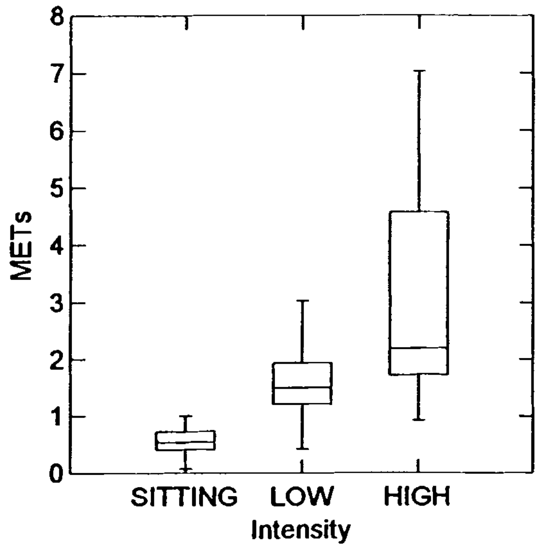
The mean ± SD of the METs recorded by the accelerometers during the time that the subjects reported that they were sitting was 0.61 ± 0.25 METs. The mean ± SD of the METs recorded by the accelerometers when the subjects reported low intensity activity was 1.61 ± 0.66 METs, and the mean ± SD of the METs recorded by the accelerometers for the times the subjects reported high intensity activity was 3.20 ± 2.04. Refer to Table 4 for the values for every subject.

The range of the mean of the METs recorded by the accelerometers for the three intensities as reported by the subjects is shown in the box plots in Figure 1. The box plots in Figure 1 show the minimum and maximum means of the METs and the median recorded by the accelerometers.

**Table 4**
Mean of the Recorded METs for Each Category of Activity as Reported by the Subjects

| **Subject #** | | **Reported Categories** | |
|---|---|---|---|
| | **Sitting METs** | **Low METs** | **High METs** |
| 1 | 0.36 | 1.49 | |
| 2 | 0.69 | 1.13 | 2.17 |
| 3 | 0.24 | 1.94 | 1.85 |
| 6 | 0.97 | 1.14 | 4.57 |
| 7 | 0.38 | 0.74 | 2.22 |
| 8 | 0.77 | 1.50 | 3.85 |
| 9 | 0.50 | 1.25 | 0.93 |
| 11 | 0.64 | 2.32 | 1.73 |
| 12 | 0.98 | 2.05 | |
| 13 | 0.70 | 2.18 | |
| 14 | 0.52 | 1.04 | 6.18 |
| 15 | 0.41 | 1.51 | 1.98 |
| 16 | 1.02 | 1.83 | |
| 17 | 0.28 | 1.03 | |
| 19 | 0.62 | 1.57 | 7.03 |
| 20 | 0.52 | 1.21 | 1.50 |
| 21 | 0.71 | 1.89 | 4.76 |
| 22 | 0.41 | 1.45 | |
| 23 | 0.19 | 1.35 | 6.60 |
| 24 | 0.81 | 3.02 | |
| 25 | 0.46 | 2.07 | 1.15 |
| 27 | 0.47 | 0.42 | 1.12 |
| 28 | 0.89 | 1.27 | 2.18 |
| 29 | 0.98 | 3.22 | 4.50 |
| **Mean** | **0.61** | **1.61** | **3.20** |
| **SD** | **0.25** | **0.66** | **2.04** |
| **Pre-determined Ranges** | **< 1 MET** | **1-3 METs** | **> 3 METs** |

**Figure 1**
Range of the Mean Recorded METs




<u>Confidence Intervals</u>

The mean MET values recorded by the accelerometers during the time periods that the subjects reported sitting or low intensity activity fell within the pre-determined ranges for MET values when 99% confidence intervals were constructed. The 99% confidence interval for recorded sitting METs was 0.46-0.75 METs and the 99% confidence interval for the recorded low intensity METs was 1.2-2.0 METs. Therefore, the reported METs and the METs recorded by the accelerometers for sitting and low intensity activities were not significantly different.

The mean of the recorded high intensity METs for all subjects was >3 METs, but when 95% confidence intervals were constructed, the mean did not fall within the pre-determined range of >3 METs. The 95% confidence interval for recorded high intensity METs was 2.1-4.2 METs.

Percentages

A second analysis was conducted to determine how many minutes the subjects reported time in the three intensities (sitting, low intensity and high intensity) accurately and inaccurately when compared to the METs recorded by the accelerometers. These results are shown in Table 5.

**Table 5**
Percent of Accelerometer Readings for Each Category of Reported Activity

| **Intensity** | **Percent of Recorded METs** |
|---|---|
| **Sitting <1 MET** | **80** |
| Sitting >1 MET | 20 |
| **Low 1-3 METs** | **38** |
| Low <1 METs | 46 |
| Low >3 METs | 16 |
| **High >3 METs** | **38** |
| High <3 METs | 62 |

Items in bold are the percentages of accelerometer readings that fell within the three pre-determined categories for METs (Sitting <1 MET, Low Intensity 1-3 METs, and High Intensity >3 METs).

## DISCUSSION

Twenty-seven adolescent girls between the ages of 9.8 and 14.1 years wore Stayhealthy RT3 Research Trackers (tri-axial accelerometers) and recorded their activity for 24 hours. They were instructed to record activity in intervals of at least five minutes. The subjects reported their activity during an interviewer-administered recall the following day. Reported activity was divided into three categories: sitting, low intensity or high intensity and was assigned metabolic equivalents (METs) (sitting < 1 MET, low intensity 1-3 METs, and high intensity >3 METs). The METs corresponding to the reported activity were compared to the METs recorded by the accelerometers.

The sample means of the recorded METs for the three intensities fell within the pre-determined ranges. When confidence intervals were constructed, the METs for sitting and low intensity fell within the pre-determined ranges of <1 MET and 1-3 METs respectively. The confidence intervals for the recorded high intensity METs did not fall within the pre-determined range of >3 METs. It included values below 3 METs.

### Reported Activity versus Recorded Activity

#### Sitting

On average, good agreement was seen between accelerometer readings and reported METs for sitting. One reason adolescent girls were successful at reporting activities as sitting when the accelerometers recorded METs of less than one was because of the homogeneous nature of sitting activities. There are fewer types of activities in the sitting category than in the low intensity or high intensity categories. Also, there is less variation in the motion of the body during sitting activities.

Other researchers have found that accelerometers are a useful tool in measuring sedentary activities, identifying periods of inactivity, and distinguishing between more active versus less active people (35).

Low Intensity

Greater variation existed between reported low intensity activity and recorded METs than reported sitting activity and recorded METs. Refer to Table 5 (page 43) for the percent of accelerometer readings within each category of reported activity. This variation could be due to some of the downfalls associated with accelerometer use, less accurate reporting of low intensity activity by the subjects, the study design, or an increase in the heterogeneity of low intensity activities.

The low intensity category was designed to include standing, normal or slow-paced activities. Subjects were asked to classify periods of time by the average activity level. An activity classified as low intensity in this validation study is shopping. Since shopping involves walking and standing still, the accelerometers may record METs <1 during the times when the subjects were standing still. Those low accelerometer readings could decrease the mean METs for the time period resulting in lower recorded METs.

During 46% of the minutes that the subjects reported low intensity activity, the accelerometers recorded METs <1. It has been reported in previous studies that tri-axial accelerometers significantly underestimate daily energy expenditure and under-predict the metabolic cost of several activities (35). If the accelerometers in this study under-predicted the metabolic cost of certain activities, that would explain the lower recorded METs observed when low intensity activities were reported.

When the low intensity time periods were broken down on a minute-by-minute basis, many of the accelerometer readings were <1 MET but the mean of the METs was still between the pre-determined range of 1 to 3 METs and the confidence interval was also within that range. Therefore, adolescent girls were capable of classifying blocks of time as low intensity.

High Intensity

The mean recorded METs for reported high intensity activity was >3 METs. When the confidence intervals were constructed, the lower end of the confidence range included values below 3 METs. This could be due to the increased heterogeneity of activities that are classified as high intensity, the over-estimation of time spent in high intensity activities by adolescent girls, or the low rate of participation in high intensity activity.

Because high intensity activities are very heterogeneous, meaning that the motion is variable and a steady pace is usually not maintained for long periods of time during high intensity activities, the standard deviation of the recorded METs is quite high. An example of an activity in the high intensity category is softball. A subject may report playing softball on her activity record and may classify the whole block of time as high intensity. During that block of time, the accelerometers would record some periods of higher accelerometer readings and some periods of lower readings. As a result, the average METs may be below the range of greater than 3 METs.

In addition, not all subjects reported participating in high intensity activity. Seventeen out of the 24 subjects reported high intensity activity, see Table 3. The lower

amount of data in this category may also increase the standard deviation and the range of the confidence interval.

Research has been conducted studying the ability of children and adolescents to report activity. Welk et al. (36) reported that pre-adolescent children participate in short, 15-second bouts of activity throughout the day, and that tremendous variability within one minute is observed. The behavior of children is very sporadic. Therefore, within the course of one minute, all of their sporadic high intensity activity would be averaged with the rest breaks and the total minute may be classified as lower recorded activity because the METs recorded during the rest breaks will bring down the average METs for the minute. As a result, periods of high intensity activity within the minute may be overlooked because the mean recorded METs for a minute may be less than 3 METs. Those findings are applicable to this validation study because the accelerometers were programmed to average activity counts for each second's reading and record the mean activity counts for each minute.

Another issue pertaining to the study design that would affect the reports of high intensity activity was the way in which high intensity was classified in this study. Subjects were asked if an activity made them "breathe hard or feel tired." That classification is subjective and would vary depending on the fitness levels of the subjects. As a result, a subject with a low fitness level may report that an activity made them "breathe hard or feel tired" when a lower MET value was recorded by the accelerometers.

Other possible times when accelerometers may under-estimate the intensity of activity are during changes in gradient or when subjects carry heavy objects. In a study examining the effects of backpacking on accelerometer readings, DeVoe and Dalleck

(37) examined the effects of changes in terrain on accelerometer readings. It was found that the tri-axial accelerometers were sensitive to speed changes but not to gradient changes. It was also determined that the accelerometers significantly under-estimated caloric expenditure when compared to indirect calorimetry. In this study, subjects may have reported that an activity made them "breathe hard or feel tired" when gradient changes were occurring. Because tri-axial accelerometers are not capable of detecting gradient changes, lower METs may be recorded, reducing the mean recorded METs for the reported high intensity activity.

Jakicic et al. (35) compared the energy expenditure recorded by tri-axial accelerometers and indirect calorimetry for several activities. Twenty subjects between the ages of 18 and 35 years participated in walking, running, stepping and sideboard exercise. It was concluded that as workload increased, the amount of under-estimation from the tri-axial accelerometers also increased. They did not find that the recorded METs for the different workloads increased proportionally when the workload was increased (35).

Based on these findings, the ability of adolescent girls to report high intensity activity is unclear. The results regarding high intensity activity are inconclusive primarily because accelerometers tend to under-estimate activity and it is unknown whether adolescent girls over-reported the amount of time spent in high intensity activity or whether the accelerometers under-estimated high intensity activity.

**Conclusions**

Based on the findings of this validation study, adolescent girls were capable of classifying physical activity into the categories of sitting and low intensity when activity

diaries and interviewer-administered recalls were used. Since good agreement was seen between reported sitting and low intensity activity and recorded METs, and the mean for the recorded high intensity METs was above three, this combination of a diary and an interviewer-administered recall is an appropriate tool to measure broad categories of physical activity in adolescent girls. More research should be conducted to determine the ability of adolescent girls to self-report periods of high intensity physical activity. This method of physical activity recording developed for use in the SBS at the University of Maine has proven to be a reasonable way to record and classify general physical activity patterns in adolescent girls.

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# APPENDICES

**APPENDIX A**

METs Corresponding to Common Activities

**Table A1**

METs Corresponding to Common Activities

| Activity | METs |
|---|---|
| **Sleeping** | 0.9 |
| **Lying quietly** (reclining, watching TV) | 0.9 |
| **Standing quietly** (waiting in line) | 1.2 |
| **Standing** (shopping, making bed) | 2.0 |
| **Standing** (getting ready for bed) | 2.5 |
| **Walking** (2.5 mph, downhill, flat surface) | 3.0 |
| **Walking** (3.0 mph or faster, brisk) | 4.0 |
| **Dancing** (aerobic or ballet) | 6.0 |
| **Basketball** (non-game, general) | 6.0 |
| **Kickball** | 7.0 |

Table adapted from: Ainsworth BE, Haskell WL, Leon AS, Jacobs DR, Montoye HJ, Sallis JF, Paffenbarger RS. Compendium of physical activities: classification of energy costs of human physical activities. *Med Sci Sports Exerc*. 1993;25(1):71-80.

**APPENDIX B**

Recruitment Letter and Flyer

June 15, 2001

(name)
(address)

Dear (parent):

Summer is upon us and we are planning another small research project here at the University of Maine. A graduate student, Alison Camesano, and I are looking for 30 girls between the ages of 10 and 14 years to participate in this study and your daughters are eligible. The purpose of the study is to test the method of physical activity recording that we are using in the Seasonal Bone Study. We will be asking the girls to keep an activity record for one day this summer and to wear an accelerometer for 24 hours. The accelerometer is a beeper-size device worn around the waist to measure motion and activity. It is safe and comfortable to wear. We will compare accelerometer readings to the written reports of activity.

If your daughter would like to be in this study, she will need to come to the University of Maine with a parent or guardian for a brief consent visit and to pick up the accelerometer. She will also need to meet with us one or two days later to return the accelerometer and review their activity records. She can use the activity record as one of the four that she needs to keep for the Seasonal Bone Study this summer. She will be paid an additional $10.00 for being in this one-day study. If you daughter does not wish to participate in this additional study, she is free to decline and it will not affect participation in the Seasonal Bone Study. Please contact me if she expresses an interest and would like more information about this short study. Have a great summer!

Sincerely,

Susan Sullivan
581-3130

June 15, 2001

(Name)
(Address)

Dear (parent):

Summer is upon us and we are planning another small research project here at the University of Maine. A graduate student, Alison Camesano, and I are looking for 30 girls between the ages of 10 and 14 years to participate in this study and your daughter is eligible. The purpose of the study is to test the method of physical activity recording that we are using in the Seasonal Bone Study. We will be asking the girls to keep an activity record for one day this summer and to wear an accelerometer for 24 hours. The accelerometer is a beeper-size device worn around the waist to measure motion and activity. It is safe and comfortable to wear. We will compare accelerometer readings to the written reports of activity.

If your daughter would like to be in this study, she will need to come to the University of Maine with a parent or guardian for a brief consent visit and to pick up the accelerometer. She will also need to meet with us one or two days later to return the accelerometer and review her activity record. She will be paid $10.00 for being in this study. Please call me if she expresses an interest and would like more information about this short study. Also feel free to mention this research to any friends that might be interested. Have a great summer!

Sincerely,

Susan Sullivan
581-3130

# Are you looking for something different for your daughter to do this summer?

- The Department of Food Science and Human Nutrition at the University of Maine is looking for girls between the ages of 10 and 14 to participate in a physical activity study.
- Participants must be able to record their activity and report it back to the researchers during an interview.
- All participants will receive $10 for being in the study.

Alison Camessano
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**APPENDIX C**
Informed Consent and Assent Forms

**Informed Consent**

**Participant's Name** ______________________________

**Project Title: Validation of Physical Activity Recording in Adolescent Girls**

Alison Camesano and Susan Sullivan, a graduate student and assistant professor in the Department of Food Science and Human Nutrition at the University of Maine, have asked my daughter to participate in a research study on physical activity in adolescent girls. The purpose of this study is to test a method of recording physical activity. Thirty girls between the ages of 10 and 14 will be participating.

**1. Explanation of the Procedure**

My daughter will wear an accelerometer for one day around her waist. An accelerometer is a lightweight device that will measure activity and motion. While wearing the accelerometer, my daughter will be asked to record her physical activity on the forms provided. She will be trained in filling out the forms. My daughter is encouraged to participate in all of her usual activities during this 24-hour period except swimming. This is because the accelerometer is not waterproof. If it is absolutely necessary for my daughter to take off the accelerometer, she will record the activity and put the accelerometer back on as soon as she is done. The same procedure should be followed when showering. Swimming is discouraged because the researchers are looking for an accurate measure of my daughter's activities and the accelerometer will not be measuring activity if she is not wearing it.

The next day my daughter and I will meet the researchers to return the accelerometer and my daughter will report her physical activity to them.

**2. Risks to Subject**

There are no risks associated with wearing an accelerometer greater than those of everyday living. The accelerometers are small, lightweight and comfortable to wear.

**3. Responsibility of the Participant**

I will encourage my daughter to keep her accelerometer on at all times during the 24-hour period and to record her activity as accurately as possible. If she removes the accelerometer, she will report this on her activity form.

My daughter does not have to disclose information on her activity record that she wishes to keep private.

**4. Benefits to the Subject**

My daughter will receive $10 for participating in this study. She may also benefit from receiving information about her caloric expenditure.

**5. Contact Information**

Alison Camesano and Susan Sullivan are available to answer any questions you may have about this procedure. They can be reached at 581-3130, or via email at Alison.Camesano@umit.maine.edu or Susan.Sullivan@umit.maine.edu.

**6. Confidentiality**

My daughter will be assigned a number identifier that will be used to process all data. All data will be stored in a locked office. Only the investigator and faculty sponsor will have access to her personal information. My daughter's name will not be used in any publications describing this research. As soon as all data is collected, the key that links subject names to specific data will be destroyed.

**7. Freedom of Consent**

Permission to allow my daughter to participate in this study is voluntary. My daughter is free to stop participation at any time. I have read this information and my daughter wishes to participate. I give consent for my daughter to participate in this study.

__________________________________ __________________________________

Parent's Signature date Investigator's Signature date

**Assent Form**
**Participant's Name** ______________________________________________

**Project Title: Validation of Physical Activity Recording in Adolescent Girls**
Alison Camesano and Susan Sullivan, a graduate student and assistant professor in the Department of Food Science and Human Nutrition at the University of Maine, have asked me to participate in a research study on physical activity in adolescent girls. Thirty girls between the ages of 10 and 14 will be participating.

I am being asked to wear an accelerometer for 24 hours around my waist. An accelerometer is small and light. It will measure my physical activity. I will also write down everything that I do while I am wearing the accelerometer. The researchers will give me the forms and show me how to fill them out.

The accelerometer should not get wet during the 24 hours that I am wearing it. If I take a shower during this day, I should take the accelerometer off and put it back on as soon as I am done. I should write that activity on my activity form.

Also, since the accelerometer should not get wet, the researchers have asked me not to go swimming during this 24 hours. If it is necessary that I take off the accelerometer, I will follow all procedures for taking the accelerometer off and recording my activity. I will put the accelerometer back on as soon as I am finished. They are asking me not to swim because they want accurate information about my physical activity and the accelerometer will not measure activity when I do not have it on.

The next day, I will report my activity to the researchers and we will meet so I can give back the accelerometer.

There are no risks from wearing an accelerometer. The accelerometer will be worn in a "holster" around my waist and is comfortable to wear.

I do not have to write down an activity on my activity record that I want to keep private.

I will be given $10 after I complete this study.

I do not have to do this study of I don't want to. I can stop at any time.

The researchers will not tell anyone that I am participating in this study. They will not tell anyone information about me.

I understand everything that I have been asked to do. I would like to be in this study. Discussed with subject. Assent received on ______
Date

# APPENDIX D
Activity Records and Instructions

## Physical Activity Study

### Instructions for Keeping Your Activity Record:

- Please keep a record of your activity for one day. The day after you keep your record, we will meet with you to get the accelerometer back. We will either talk about your record then or we will call you on the phone later that day.

### *Activity Worksheet*

- Using your "Activity Worksheet," keep track of what you do during each hour of the day. Make sure to record things like watching TV, using the computer, eating lunch, playing outside, or specific activities like riding a bike, jumping rope, walking your dog, driving in the car, and so on.

- You do not have to write down activities that you want to keep private.

- When we call you on the phone the next day, we will ask you if any of your daily activities made you breathe hard or feel tired. We will also ask which of your activities were mostly sitting down.

- For each activity you do, write down when you started and when you finished the activity, but only if you did the activity for 5 minutes or more. Sometimes during activities you may stop and do something different, such as resting or waiting in line. For example, you walked around your neighborhood from 10:30 am until 11:47 am, but during that time you stopped and sat down to talk to a friend from 11:03 am until 11:10 am. So, on your activity worksheet, write down:

| | |
|---|---|
| 10:30 am - 11:03 am | walked around neighborhood |
| 11:03 am - 11:10 am | sat talked with a friend |
| 11:10 am - 11:47 am | walked back home |

**See sample "Activity Worksheet" on back of this page.**

*Sample Activity Worksheet*

| Time of Day | Activity |
|---|---|
| 8:00 am - 8:18 am | Got up, got dressed |
| 8:18 am - 8:45 am | Ate breakfast |
| 8:45 am - 9:00 am | Made bed |
| 9:00 am - 9:30 am | Watched TV |
| 9:30 am - 9:43 am | Drove to supermarket with mom |
| 9:43 am - 10:30 am | Shopped in supermarket with mom |
| 10:30 am - 10:40 am | Drove from supermarket to home |
| 10:40 am - 11:00 am | Helped mom put away groceries |
| 11:00 am - 11:05 am | Walked to friend's house |
| 11:05 am - 12:15 pm | Sat and talked with friends |
| 12:15 pm - 12:20 pm | Walked home |
| 12:20 pm - 1:23 pm | Ate lunch outside on our deck |
| 1:23 pm - 2:20 pm | Played computer games |
| 2:20 pm - 3:20 pm | Played softball with friends in my backyard |
| 3:20 pm - 4:05 pm | Sat and ate a snack with friends |
| 4:05 pm - 5:00 pm | Played softball with friends |
| 5:00 pm - 5:20 pm | Took shower with accelerometer off |
| 5:20 pm - 5:30 pm | Drove to Grandma's house |
| 5:30 pm - 6:30 pm | Ate dinner at grandma's |
| 6:30 pm - 7:15 pm | Helped clear table and clean up |
| 7:15 pm - 7:45 pm | Walked the dog |
| 7:45 pm - 7:55 pm | Drove home |
| 7:55 pm - 9:10 pm | Played a game with brother and sister |
| 9:10 pm - 10:20 pm | Watched TV |
| 10:20 pm - 10:38 | Got ready for bed |
| 10:38 pm | Went to bed |

* Be sure to record any time that you are not wearing the accelerometer!! *

## Physical Activity Study

***Your Activity Worksheet***

*Please Record any time that you are not wearing the accelerometer!!*

| Time of Day<br>EXAMPLE | Activity<br>EXAMPLE |
|---|---|
| 9:00 am -<br>9:30 am | Ate breakfast |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |

## APPENDIX E
Accelerometer Instructions

# Accelerometer Instructions

1. Start recording your activity as soon as you put the accelerometer on.
2. If you have to shower, take off the accelerometer, write down the activity and time. Put the accelerometer back on as soon as you are done. Please write down on the activity form that you did not have the accelerometer on.
3. Try to keep the accelerometer on while you sleep. If it gets in the way, take it off and leave it near your bed until you wake up. Make sure you put it back on as soon as you get up.
4. Please treat this equipment very carefully. If you must take it off, please leave it in a safe place. Never leave it in a hot car or out in the sun.
5. You can stop writing down your activity at ______________________ tomorrow. You can take the accelerometer off then.
6. We will meet at ____________________________________________ so you can give back the accelerometer.
7. Call us if you have any questions!! (Alison Camesano or Susan Sullivan: 581-3130)

**THANK YOU!!!**

**APPENDIX F**

Accelerometer Driving Study: Methods and Results

## Accelerometer Driving Study

### Rationale

This study was designed to determine the accuracy of accelerometer readings when research subjects report riding in moving vehicles. Significant research has been conducted to determine the accuracy of accelerometers when recording different types of physical activity, but to our knowledge, no studies have been conducted to determine the accuracy of accelerometers in field studies where subjects are passengers in cars (36,37,38). The objective of this study was to determine whether the motion generated by cars affects accelerometer readings, leading to a higher estimated energy expenditure than if a subject was sitting in a non-moving vehicle.

### Methods

#### Study Design

In this study, three Stayhealthy RT3 Research Trackers (tri-axial accelerometers) were secured to three different objects of varying weights and were driven in two different vehicles over two different road conditions. To test the effects of differences in vehicles, a minivan and a pick-up truck were driven. To test the effects of different road conditions data was collected on both a country road and a highway. To determine the effects of human motion on the readings in a vehicle, the accelerometers were securely attached to a 100 pound bag of gravel (inert object) or to the driver's waistband.

#### Procedure

All of the driving was completed on either the same stretch of country road or highway under the same weather conditions. Once the driver reached the desired speed of 45 mph or 65 mph on the country road and the highway respectively, the driver

pressed the start flag on the three accelerometers to signal the beginning of the data collection. Before slowing down, the driver pressed the stop flag on the three accelerometers to signal the end of the data collection period. Immediately after the driving was completed, all data was downloaded into Microsoft® Excel 2000 to be coded and analyzed. The data was coded and separated based on road conditions, vehicle, and placement of the accelerometers. Vector magnitude, activity calories and METs were calculated by the accelerometers in the same way as in the validation study. After all data was downloaded, one-way ANOVA was conducted (Microsoft® Excel 2000) to determine if there was a difference between the readings of the three accelerometers within each driving condition. The three accelerometer readings from each driving condition were then averaged together.

**Results**

None of the accelerometers was statistically significantly different than the others within any of the driving conditions. Statistical significance was determined by a p-value of $p < 0.05$. Table 7 contains a summary of the results obtained.

**Table F1**
Driving Data Summary

| **Vehicle** | **Road Condition** | **Minutes of Driving** | **Placement of Accelerometers** | **Mean (SD) Recorded METs*** |
|---|---|---|---|---|
| Minivan | Country Road | 34 | Inert Object | 1.1(0.1) |
| Pick-up Truck | Country Road | 26 | Inert Object | 2.7(0.17) |
| Minivan | Country Road | 27 | Driver | 1.1(0.13) |
| Minivan | Highway | 16 | Inert Object | 0.56(0.09) |

* Average of the three accelerometers.

The recorded METs were within the pre-determined category for sitting (<1 MET) during the time that the van was driven on the highway. For the other three conditions, the METs recorded by the accelerometers were within the pre-determined range for low intensity activity (1-3 METs).

**Discussion and Conclusions**

After reviewing the data, it was determined that the mean METs recorded by the accelerometers varied depending on the road conditions and the vehicle driven. These variations were presumably greater than the difference in energy expenditure of an individual riding in these cars. The results from the truck illustrated that the METs recorded by the accelerometers were greater than that which would have been expended by subjects riding in the vehicle. Because of the great variation in the recorded METs between the driving conditions, it would not be possible to determine the exact road conditions during each time period that the subjects reported being in cars. Therefore, any time periods when the subjects reported riding in moving vehicles were deleted from the data analyses.

## APPENDIX G
Sample Microsoft ®Excel Spreadsheet of Accelerometer Data

Sample Microsoft® Excel Spreadsheet of Accelerometer Data

| Date | Time | Total kcal | Activity kcal | VM[a] | ActCnts X[b] | ActCnts Y | ActCnts Z | METs[c] | Intensity[d] |
|---|---|---|---|---|---|---|---|---|---|
| 08/20/2001 | 20:14:00 | 1.4088 | 0.5138 | 415.514 | 242 | 258 | 218 | 1.1 | H |
| 08/20/2001 | 20:15:00 | 1.8053 | 0.9103 | 736.877 | 358 | 490 | 418 | 1.9 | H |
| 08/20/2001 | 20:16:00 | 3.8309 | 2.9359 | 2377.435 | 1521 | 1254 | 1329 | 6.2 | H |
| 08/20/2001 | 20:17:00 | 4.0335 | 3.1385 | 2541.236 | 872 | 1339 | 1976 | 6.7 | H |
| 08/20/2001 | 20:18:00 | 2.8206 | 1.9256 | 1558.908 | 707 | 859 | 1092 | 4.1 | H |
| 08/20/2001 | 20:19:00 | 2.9614 | 2.0664 | 1672.737 | 376 | 756 | 1444 | 4.4 | H |
| 08/20/2001 | 20:20:00 | 2.4056 | 1.5106 | 1222.678 | 488 | 811 | 774 | 3.2 | H |
| 08/20/2001 | 16:26:00 | 2.5723 | 1.6773 | 1358.083 | 218 | 471 | 1255 | 3.6 | L |
| 08/20/2001 | 16:27:00 | 3.5802 | 2.6852 | 2173.522 | 1200 | 1158 | 1394 | 5.7 | L |
| 08/20/2001 | 16:28:00 | 1.7731 | 0.8781 | 710.624 | 148 | 369 | 589 | 1.9 | L |
| 08/20/2001 | 16:29:00 | 2.2092 | 1.3142 | 1064.315 | 214 | 353 | 981 | 2.8 | L |
| 08/20/2001 | 16:30:00 | 1.2754 | 0.3804 | 308.315 | 92 | 163 | 245 | 0.8 | L |
| 08/20/2001 | 16:31:00 | 1.4569 | 0.5619 | 454.793 | 154 | 265 | 336 | 1.2 | L |
| 08/20/2001 | 16:32:00 | 1.2951 | 0.4001 | 324.005 | 163 | 199 | 197 | 0.8 | L |
| 08/20/2001 | 21:21:00 | 0.9419 | 0.0469 | 38.471 | 0 | 6 | 38 | 0.1 | S |
| 08/20/2001 | 21:22:00 | 1.04565 | 0.1506 | 122.004 | 24 | 70 | 97 | 0.3 | S |
| 08/20/2001 | 21:23:00 | 1.0815 | 0.1865 | 151.212 | 35 | 102 | 106 | 0.4 | S |
| 08/20/2001 | 21:24:00 | 1.2284 | 0.3334 | 269.641 | 144 | 169 | 153 | 0.7 | S |
| 08/20/2001 | 21:25:00 | 0.9901 | 0.0951 | 76.792 | 24 | 61 | 40 | 0.2 | S |
| 08/20/2001 | 21:26:00 | 1.0123 | 0.1173 | 94.81 | 40 | 75 | 42 | 0.2 | S |

[a] VM = Vector Magnitude
[b] ActCnts X = Activity counts measured on the x plane
[c] METs recorded by the accelerometers
[d] Intensity reported by the subjects

## BIOGRAPHY OF THE AUTHOR

Alison Camesano was born in Utica, New York on June 18, 1976. Alison was raised in Whitesboro, New York and graduated from Whitesboro High School in 1994. Alison received her Bachelor's degree in Nutrition from Russell Sage College in Troy, New York in May of 2000.

Alison is a member of Phi Tau Sigma and Kappa Omicron Nu Honor's Societies. Upon completion of her thesis research, Alison will begin her Dietetic Internship. Alison is a candidate for the Master of Science degree in Food Science and Human Nutrition from The University of Maine in December, 2002.