2010

Effect of a structured exercise program on physical activity patterns and assessing relationships between accelerometry and strength and running performance characteristics in male, college students

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By

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B.S. Health Enhancement, The University of Montana, Missoula, MT, 2008

Thesis

presented in partial fulfillment of the requirements
for the degree of

Master of Science
in Health and Human Performance- Exercise Science

The University of Montana
Missoula, MT

August 2010

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Effect of a structured exercise program on physical activity patterns and assessing relationships between accelerometry and strength and running performance characteristics in male, college students

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The primary purpose of this study was to determine the effect of a supervised exercise training program on physical activity (PA) patterns. A secondary objective of the study was to determine if accelerometers can predict variables associated with strength and running performance. A total of 79 adult, male, college students completed a 12 week exercise training program that consisted of pull-ups, sit-ups, push-ups, and running three hours per week. The subjects trained three days/week (Monday, Wednesday, and Friday) and conducted a performance test (PT) every Wednesday. Physical activity (average daily time spent in sedentary, light, moderate, and vigorous PA), performance strength and running variables (pull-ups, sit-ups, push-ups, and 1.5 mile run time), and body composition (BC) (weight (kg), percent body fat (PBF), fat free mass (FFM;kg), and fat mass (FM;kg)) were assessed before and after 12 weeks of the exercise training program. Results showed the 12 week exercise training program had no effect on the average daily time (min) spent in sedentary, light, moderate or vigorous activity. There were significant positive correlations between average daily time spent in vigorous PA and pull-ups (p<.05), sit-ups (p<.01), and push-ups (p<.01). There were significant negative correlations between average daily time spent in moderate (p<.05) and vigorous (p<.01) PA and 1.5 mile run times. Additionally, there were significant negative correlations between BC and weight, PBF, and FM and pull-ups, sit-ups, and push-ups (p<.01). Data showed a a significant positive relationship between weight, PBF, and FM and 1.5 mile run time (p<.01). As expected, strength and running performance significantly improved in every area (p<0 .001) with an average gain of four pull-ups, 31 sit-ups, 15 push-ups, and a mean decrease of 30 seconds on the 1.5 mile run. The structured exercise intervention significantly improved strength and running performance characteristics, which included pull-ups, sit-ups, push-ups and a 1.5 mile run time. The results from this study show that the 12 week exercise training program did not affect PA levels in the participants but PA (vigorous) and BC (weight, PBF, and FM) may be able to predict pull-ups, sit-ups, push-ups, and 1.5 mile run performance variables.

ACKNOWLEDGEMENTS

First, I would like to thank the Lord Jesus Christ for being with me each and every day. There are times during these past few years when I needed to be carried through the difficulties I was experiencing in life. I had to go through some of the hardest struggles outside of school in addition to my research and course load. I give Him all the honor and glory and this accomplishment in my life is dedicated to God!

Second, I would like to thank my beautiful family for supporting me and walking beside me on this journey. I have the most supportive and loving mom a man could ever ask for. I love her dearly and am thankful to have her in my life. I would also like to thank my baby girls Taylor, Natalie and my baby Izzy who I love deeply. They are the reason why I work so hard and continue to strive to provide for them a life I could only dream of.

I have also been blessed with an amazing advisor, co-chair of my committee, mentor, and friend in Dr. Blakely Brown. Blakely is one of the people who never stopped believing in me and worked behind the scenes to help me finish my degree. I have said this many times, but can never say it enough- thank you Blakely.

I would like to thank Dr. Brent Ruby who co-chaired my committee and gave me the opportunity to work on this project that eventually became my thesis research. Additionally, I would like to thank the entire faculty around the UM campus and my friends in the Missoula community that have supported me on this journey.

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CHAPTER 1: INTRODUCTION

Motivating individuals to change from sedentary behaviors to being more physically active is difficult. Short term interventions, however, have demonstrated some success in improving physical activity in individuals with sedentary lifestyles. Shorter physical activity (PA) interventions last anywhere from 10 weeks to 24 weeks (11, 30) and are commonly part of a structured training protocol (15, 39, 40). Structured PA interventions typically have an instructor directing the program, a training protocol that is repeated each session, specific exercises that combine strength training and/or aerobic training, and participants who repeat their prescribed training regimen every training session. The training sessions typically last 30 to 60 minutes and participants attend the exercise program an average of three days per week.

The underlying goal of conducting a PA intervention is to determine effective methods that increase physical activity, especially in populations that lack skills or discipline necessary to make physical activity part of their daily lifestyle. Data shows that structured exercise programs pose fewer challenges for novice exercisers, which may contribute to the program's success (11). Short term, structured PA interventions typically implement a high intensity training protocol with either aerobic (15) or resistance (17) training components in order to produce the greatest response from training, which may be the most challenging aspect for novice exercisers.

While structured exercise programs show promise in increasing physical activity in sedentary individuals, little is known about what types of behavioral strategies would increase a person's physical activity outside the exercise program. Individualizing the structured exercise program may be an effective approach to increasing self-selected physical activities; however, this strategy may not be conducive to working with large groups of people in a limited amount of time.

Physical activity interventions that combine aerobic and resistance training have been shown to effectively increase physical activity (11, 39, 40). These interventions have implemented resistance training strategies focused on upper and lower body large muscle groups at an intensity of eight to 20 repetition maximum (RM) (40) with either machines or free weights (39). Aerobic training strategies in these interventions consisted of cycle ergometers or treadmills for a set amount of time and intensity throughout all training sessions, (39, 40). A significant increase in PA was reported via accelerometry (40) and the International Physical Activity Questionnaire (IPAQ) (39). While these interventions were successful at increasing PA, there is no data reporting the effects of a structured aerobic and resistance training exercise program on weight bearing exercises like pull-ups, sit-ups, and push-ups or running at varied intensities. Comparing studies that motivate participants to exercise at varied intensities as opposed to exercising at one prescribed intensity (high or low) might help researchers better understand how to increase PA in sedentary populations.

Athletic performance has been predicted in a variety of ways. Common performance predictors are physiological and biomechanical variables such as speed (38), running economy (18), lactate threshold (28, 37, 42, 49), anaerobic threshold (21), power (7), and strength (4). Employing high intensity intervals in to the training program has been shown to increase VO2max (18, 28, 35, 37, 38, 41, 46, 49). Additionally, high intensity intervals have been prescribed at the velocity of VO2max, which was reported to increase running economy and running performance (3). Interval training is a good predictor of performance as it increases the lactate threshold (28, 37, 42, 49), running economy (3, 18), and reduces energy expenditure during submaximal training (38). Resistance training performance can be predicted by training that includes high repetitions, which has been shown to increase the maximal number of repetitions, maximal aerobic power, and time to exhaustion (7).

The ability to predict strength and running performance is important since the literature lacks the information needed to effectively train large populations with interventions designed to enhance these performance variables. In addition, being able to accurately predict performance may help develop PA training programs for the general population or specialized groups such as military personnel or endurance athletes. Activity monitors may be an ideal instrument for predicting performance because they can be utilized in free living conditions and possess the ability to measure multiple subjects in a single setting. These instruments can be programmed to collect data at different intervals (i.e. one second or 60 seconds) and can collect data up to 44 days. Activity monitors are also light weight, durable, and waterproof.

There are no published reports using activity monitors, specifically Actical® monitors, to predict strength and running performance variables. Activity monitors could be placed on participants before and after they participate in a structured exercise program. These data would report pre- and posttest activity counts for minutes spent in sedentary, light, moderate and vigorous physical activity. Strength performance variables, such as pull-ups, sit-ups and push-ups and running performance variables such as the 1.5 mile run could be predicted by determining a participant’s PA patterns as reported by total activity counts spent per minute in sedentary, light, moderate, and vigorous before and after the structured strength and running exercise intervention. One could hypothesize that participants spending a higher number of minutes in moderate and vigorous physical activities perform better on strength and running performance tests than participants spending a low number of minutes in moderate and vigorous physical activity.

Problem

The primary purpose of this study was to determine the effect of a supervised exercise training program on physical activity patterns. A secondary objective of the study was to determine if activity monitors can predict variables associated with strength (e.g., pull-ups, sit-ups and push-ups) and running performance (e.g., 1.5 mile run time). Lastly, the study reported on the progression or decline in strength and running performance test scores and weight, percent body fat, fat mass, and fat free mass during the 12-week, structured, exercise training program.

Hypothesis One

There will be a significant increase in the daily average minutes (min) of moderate and vigorous PA (MVPA) from pre to post training.

Justification of Hypothesis One

Studies have shown that administering a structured and supervised physical activity intervention that combines aerobic and strength training significantly increases physical activity (15, 39, 40) as measured by accelerometry and IPAQ. In addition, the literature reports that as subjects adhere to an intervention, they become more confident in decreasing their sedentary behaviors and increasing the time and intensity for regular physical activity behaviors outside a structured PA program (11).

Hypothesis Two

The average daily time (min) spent in MVPA is an accurate predictor of running performance (1.5 miles).

Justification of Hypothesis Two

Activity monitors have been shown to accurately and reliably detect running speeds of up to 10 km/hr (34, 45) and 11 km/hr (5), which would be recorded as moderate to vigorous physical activity. If a subject has a high amount of their average daily PA (min) in these categories, it can be assumed they are physically active and possibly participating in high intensity aerobic training prior to the study. Therefore, if this assumption is accurate, then their pre training PA data will be a good predictor of aerobic performance on the 1.5 mile run.

Hypothesis Three

The average daily time (min) spent in MVPA will not be a strong predictor of the strength performance variables pull-ups, sit-ups, and push-ups.

Justification of Hypothesis Three

Several studies have reported that activity monitors can accurately and reliably document PA patterns (2, 6, 12, 32, 44, 47, 51). Each of these studies included an aerobic component that incorporated running or similar exercises. Other studies have implemented a training protocol primarily focused on strength training exercises. For example, Lemmer et al. (30) administered a PA intervention exclusive to strength training (ST). The author reported a decrease in PA from pre to post training, which was attributed to the activity monitors' inability to accurately detect the intensity of strength training. Previous research has documented the inability of accelerometry to accurately detect PA during stationary activities such as strength training (31, 40). Perhaps the lack of change in PA may also be due to the duration of the study, (e.g., 24 weeks) which may indicate the intervention needed to be prescribed for a longer period of time to have an impact on changing physical activity.

If accelerometry does not accurately detect the intensity of strength training, then our study could expect results similar to Lemmer et al. (30). For example, subjects who limit their exercise exclusively to weight training before the intervention will most likely score high on the program's strength exercises (pull-ups, sit-ups, and push-ups) in the initial performance test. Participants, however, who train and score well on the strength tests may have low moderate to vigorous activity (MVPA) counts because activity monitors may not be able to accurately measure strength training intensity levels.

Significance of the study

This study will determine the effect of a PA intervention that combines pull-ups, sit-ups, push-ups, and running at varied intensities on PA patterns. To our knowledge, no studies exist that have administered a PA intervention (combining strength and aerobic training) on college males (mean age 23 years) and measured PA pre and post training. Research that has measured PA before and after a PA intervention reports that combining aerobic and strength training is an effective way to increase PA in older (mean age 66 years), inactive subject populations (39, 40) and populations with mental illness (39). The current study will also determine if activity monitors can predict strength and running performance variables, which are pull-ups, sit-ups, push-ups and the 1.5 mile run.

Rationale of the study

The results of this study could inform the implementation of a structured strength and running PA intervention for military personnel or specialized populations needing to pass rigorous performance test (PT) requirements. In addition, the study outcomes could open up new avenues of research that use activity monitors to predict objective performance measures like pull-ups, sit-ups, push-ups and the 1.5 mile run. Although prior research has shown that activity monitors can accurately depict PA behaviors in free living populations (2, 6, 12, 32, 47, 51), no study to date has used PA patterns documented by activity monitors to predict strength and running performance test variables in similar settings.

Limitations

i/ Physical condition of the subjects: Subjects entered the study at different levels of physical fitness. To correct this, the training protocol on Monday was individualized. The subjects completed strength training that was calculated from the outcome of their previous PT. All of the subjects trained at the same relative intensity on the other training day.

ii/ Non-randomized samples: The subjects were not randomized to the study. . The subjects were recruited by email, classroom presentations, and posters around the UM campus. All subjects volunteered to participate in this study.

iii/ Instrumentation: There is inherent error with all instrumentation. The only instrument that needed calibration was the hydrostatic weighing tank.

iiii/ Honesty of subjects: The subjects each had a partner that counted the amount of strength training exercises completed on the PT. The amount of exercises performed was documented by their partner. To correct this, the instructors watched closely during every PT to make sure the subjects were completing the exercises with technique and the partners were counting honestly.

v/ Subject enrollment: The training protocol did not begin until 2 weeks in to the academic semester. At that time, students were still being recruited and able to register for the class. Some subjects registered and were allowed in to the class after training began. Therefore, their Actical® data was collected during training and may not accurately reflect their normal behavior. Therefore, it could be assumed that certain subjects logged PA in the vigorous (min) and moderate (min) categories that could be attributed to the training.

Delimitations

i/ Age of subjects: Only subjects in the age of 18- 40 were used for this study.

ii/ Gender: Only enrolled male students at the University of Montana could participate in the study.

Definition of Terms

Physical Activity: Mean time (min) spent in sedentary, light, moderate, and vigorous PA during four complete days.

Body Composition: Mean body weight (kg), percent body fat (%BF), fat free mass (FFM; kg), and fat mass (FM; kg).

Percent Body Fat: The percent of body fat that is an individual has in proportion to muscle mass.

Fat Free Mass: The amount of muscle mass on the body, determined in kilograms (kg).

Fat Mass: The amount of fat mass on the body, determined in kilograms (kg).

Sedentary Physical Activity: Resting in one spot without any movement or expending energy.

Light Physical Activity: Determined to be at an intensity that is equivalent to walking around the UM campus.

Moderate Physical Activity: Determined to be at an intensity that is equivalent to a brisk walk or light jog.

Vigorous Physical Activity: The highest level of physical activity that is equivalent to lifting heavy weights or running at a high intensity.

Performance: Individual mean test scores in push-ups, sit-ups, pull-ups, and 1.5 mile run (min).

Pull-ups: Starting from a position with arms extended, the ability to pull the upper body up above the bar holding legs completely still, and slowly lowering the body all the way down extending the arms completely in one motion.

Sit-ups: Starting from a position lying flat on the mat, the ability to flex the torso, touch the elbow to the knees, and lower the upper body down until the back is flat on the mat in one complete motion.

Push-ups: Starting from a position with arms extended and back straight, the ability to bend the arms at a 90˚ angle while touching the ground with the chest and maintaining a straight back, and then completely straighten out the arms in one fluid motion.

1.5 mile run: The ability to run 1.5 miles at an all out pace.

Accelerometer/Activity Monitor: These two terms are used interchangeably. This instrument collects data on the amount of physical activity an individual completes in a 24 hour period.

Hydrostatic Weighing: A method of determining body composition that requires and individual to submerge themselves in a tank full of water and exhale all the air in their lungs. Data is collected taking in to account residual lung volume and the measures include body weight, fat free mass, fat mass, percent body fat, body mass index, and residual lung volume.

CHAPTER 2: REVIEW OF LITERATURE

A. The impact of physical activity interventions on self-selected activity behaviors

This section of the literature review describes interventions focused on increasing PA in participants who were sedentary or novice exercisers. These studies are similar to our intervention because they contain one or more of the following elements 1) have a structured PA intervention with the intent to increase PA, 2) measure PA at pre and post intervention time points with the Actical® activity monitor 3) have an intervention period lasting at least 10 weeks, and/or 4) have an intervention that includes aerobic training, resistance training, or both.

Opdenacker, J. et al. (40) conducted a structured and supervised PA intervention for 11 months. The protocol included aerobic and strength training, which is similar to our study. Study participants included older sedentary adults (mean age 66 years) who volunteered to participate. The subjects trained 3 days/week for 90 minutes. Physical activity was measured over a 5-day period at baseline (week 1) and at 11 months with the RT3 acceleromer. The 11-month supervised PA intervention study resulted in a 150% increase in (average) weekly PA in the participants. These data suggest that a long-term supervised, aerobic and strength training PA intervention can significantly increase average weekly PA in older sedentary adults.

A study conducted by Dawson & Brawley (11) recruited college students to participate in a structured physical activity intervention lasting 10 weeks. An intervention specialist facilitated all training sessions and subjects were encouraged to train on their own outside the structured class training sessions.

The subjects came to the class two to three times per week, with each session lasting 45 minutes. The intervention included aerobic and strength training with the intent to predict the frequency and intensity of PA from surveys that measured self efficacy and goal influence. The variables were measured at baseline and week five in order to predict the PA measures. Frequency was measured by attendance that the subjects recorded on a wall chart. Intensity was measured by a 14-point Rating of Perceived Exertion (RPE) scale. The authors reported that self efficacy, which was defined as having confidence within themselves to complete each exercise and the ability to schedule exercise in to their daily routine (subjects lacked both factors at the beginning of the study), was significantly related ($p<.03$) to exercise intensity. The longer the subjects adhered to the intervention, the more confident they became that they could exercise on a regular basis at high intensity.

In a study done by Oeland (39), subjects were recruited to participate in a 20 week supervised and structured PA intervention. The subjects were included if they met the criteria of having a depressive and/or anxiety disorder. The authors did not state the physical fitness of the subjects, but it was imperative that the intervention increased PA in this special population to determine the effects of PA on these types of disorders (depression and/or anxiety).

The subjects underwent an aerobic and strength training regimen two times/week for the duration of 90 minutes. Physical activity (PA) was measured pre intervention, post intervention, and 12 weeks after the intervention concluded with the International Physical Activity Questionnaire (IPAQ). IPAQ results showed PA increased by 120 minutes per week. The authors attributed the change in PA to the presence of the instructor, since the instructor was present at all times during the intervention and the improvement stopped after PA was measured at the end of the 12 week intervention. The authors further suggest that supervision is needed in order for the subjects to sustain sufficient levels of physical activity during the intervention period.

Lemmer et al. (30) examined the effects of a whole body resistance training program and how this mode of training affects physical activity. The participants were healthy, sedentary men (mean age 25 years) and women (mean age 26 years). The subjects trained three days per week for 24 weeks and the intervention focused on all the major muscle groups of the body. Physical activity was assessed at the beginning and end of the intervention by an accelerometer for four consecutive days (two weekdays and two weekend days). Results showed the PA intervention did not affect physical activity. The authors attributed these results to the activity monitors inability to accurately detect the intensity of strength training or the intervention was too short to elicit a change in physical activity.

Dunn and colleagues (15) recruited sedentary individuals to a supervised and structured PA intervention that only included aerobic training. The intervention lasted six months and progressively increased in duration and intensity over the course of the intervention. Accelerometers collected PA data at baseline and post intervention for seven consecutive days. The intervention resulted in a significant increase in daily PA, with a 2 fold increase in vigorous physical activity.

Collectively, these studies are similar in that they all implemented structured and supervised interventions to either increase physical activity or resistance training activities, or both. The one study reviewed determining the effect of a resistance training program on physical activity behaviors (30) showed a decrease in these behaviors at the end of the intervention. Other studies, however, combining aerobic and resistance training activities reported increases in PA behaviors at the end of the intervention. These data suggest the combination of aerobic and resistance training approaches may be more effective than strength training alone on increasing PA behaviors in sedentary individuals, special populations, or college students. Whether or not these exercise programs increased self-selected physical activity behaviors in the participants was not determined.

More research is needed to determine the most effective training protocol to increase and maintain physical activity behaviors outside/beyond the structured exercise programs.

B. Activity Monitors

Activity monitors have been used to estimate the amount of physical activity of individuals in free living populations. The validation of activity monitors has made it easier for researchers to collect data on large samples providing quantitative data on estimated activity counts, energy expenditure, time (min), and the percentage of time an individual spends in each intensity category (sedentary, light, moderate, and vigorous) on a daily period. The use of activity monitors has expanded because of their accessibility to subject populations and ease of application by attaching them to the wrist, ankle, or hip. Activity monitors can be programmed to collect data at different intervals (i.e. one second or 60 seconds) and can collect data up to 44 days. These instruments are light weight, durable, and waterproof.

.There is no published studies using activity monitors to predict strength and running performance. However, some investigators have used activity monitors in their research to predict variables associated with physical activity and performance such as physical activity energy expenditure (PAEE), running speed, and body fatness (6, 20, 23). These variables (e.g., PAEE, running speed, and body fatness) are similar to ones examined in our study.

This section of the literature review describes studies similar to ours that 1) use accelerometers to predict physiological variables associated with physical activity and performance, and 2) use activity monitors to determine PA patterns in populations in free-living conditions (e.g., non-laboratory-based research settings).

B1. Using accelerometers to predict variables associated with physical activity and performance in adult populations

Heil (23) used the Actical® activity monitor to predict activity energy expenditure (AEE) in adults when attached to ankle, wrist, or hip. Volunteers reported to the lab for a single 1.5 hour visit and performed a series of 10 activities ranging from resting to jogging with an activity monitor strapped to their ankle, wrist, and hip. Heil summarized that the Actical® activity monitor can validly predict AEE whether worn at the ankle, wrist or hip. These results, however, were limited to a lab-based setting and needed to be validated under free living conditions.

Melanson et al. (34) conducted one of the early studies validating the CSA accelerometer using EE determined by indirect calorimetry as the criterion measure when worn at three different sites: ankle, hip, and wrist. Fifteen males and 13 females performed walking (4.8 km/hr), fast walking (6.4 km/hr), and jogging (8.1 km/hr) at 0%, 3%, and 6% grades on a treadmill for 8 minutes. The investigators found that the CSA accelerometer can discriminate changes in treadmill speed, but could not differentiate treadmill grade. Regression models revealed that mean EE could be accurately predicted using CSA counts and body mass as predictors.

Fudge et al. (20) explored the "leveling off" of accelerometer counts using 4 different activity monitors at running speeds as high as world-record marathon pace and the feasibility of generating VO2max prediction equations in the process. They experienced biomechanical limitations in 3 out of the 4 accelerometers at record speeds, but found the use of accelerometers to predict VO2max was enhanced when applied in conjunction with heart rate, as opposed to using either predictor alone.

Nichols et al. (36) compared laboratory data to data gathered outdoors to see the validity of using the laboratory prediction equations for use in the field. Sixty subjects (30 men and 30 women) were fitted with CSA accelerometers on the right and left hips. In the laboratory, each participant ran on a treadmill at speeds of 3.2, 6.4, and 9.7 km/hr at 0% grade and 6.4 km·h at 5% grade for 5 minute bouts with 1 minute rests in between. Using the same procedure (with the CSA monitors), the participants completed walking, brisk walking, and jogging around a 400m track for 5 minute bouts. The investigators found that the laboratory data cannot be directly applied to field data.

Eston et al. (16) compared the accuracy of HR monitoring, triaxial accelerometry, uniaxial accelerometry, and pedometry to predict oxygen uptake in children while they performed different activities (walking [4 and 6 km/hr], running [8 and 10 km/hr], hopping, catching, and sitting and crayoning) for 4 min (except the sitting and crayoning lasted 10 min). Thirty children were fitted with three pedometers (on the ankle, hip, and wrist), one uniaxial accelerometer (on the left hip), one triaxial accelerometer (on the right hip), and a HR monitor while they performed the different activities. The investigators concluded that the best predictor of oxygen uptake was the triaxial accelerometer (accounted for 71.8% of the variance) and the pedometer worn at the hip was the second best predictor (accounting for 64.8% of the variation). When two measures were used, the best model contained the triaxial accelerometer and HR (R^2 = .849).

B2. Using activity monitors to assess physical activity patterns and body fatness in adult populations

Buchowski et al. (6) examined the variations in the amount and patterns of PA in a free living population in the Southern United States . One hundred and twenty subjects participated in a six to eight day trial wearing the Tritrac-R3D activity monitor attached to their right hip. The study found that the amount and variability of PA was negatively associated with body fatness and 95% of the study population led a sedentary lifestyle. There was also evidence that subjects who performed at least one minute of vigorous PA had a significantly lower amount of body fat than those who did not.

Matthews et al. (32) looked at using an accelerometer to quantify the major sources of variance and to estimate the number of days required to quantify PA behaviors reliably in a sample of 122 healthy adults, age 18- 79. The participants wore a uniaxial accelerometer for three weeks on their right hip. The researchers reported that the major sources of variance in PA was between subjects and accounted for the majority (55-60%) of the variance observed. In addition, 3-4 days of monitoring revealed 80% reliability in quantifying PA behaviors in this population.

Dinger et al. (12) used 14 cohorts ranging from 12 to 15 participants each and spanned eight months. The study examined college students' PA patterns using an accelerometer. The activity monitors were placed over the subjects' right hip and worn for seven days. Results of the study found that few participants accumulated enough vigorous PA to meet the American College of Sport Medicine (ACSM) PA recommendations, but that almost half of the students engaged in sufficient amounts of moderate PA. Overall, participants were more active during the week than on weekends and males were more active than females.

Behrens et al. (2) looked at examining college students' physical activity (PA) and gender differences in PA participation with a Yamax Digiwalker Model 200 pedometer. Thirteen females and 18 males participated in this study. The subjects were instructed to wear the pedometer for seven consecutive days on their waist at the anterior mid-line of the right leg. Similar to the study by Dinger et al (7), the investigators found the participants to be more active during the week than on the weekend, however, unlike Dinger study, there were no differences in PA between genders.

C. Aerobic and strength training protocols

The following studies describe interventions testing the effect of a structured exercise program on performance measures similar to ours (e.g., pull-ups, sit-ups, push-ups, and the 1.5 mile run). For instance, one study examined the relationship between physical activity and performance. Other studies determined the effect of training protocols on changes in body composition and strength and running performance variables. Collectively, these studies informed the implementation of our study and collection and analysis of outcome measures.

Knapik et al. (27) measured the performance of U.S. army conscripts with a performance test (PT) consisting of push-ups, sit-ups, and a 3.2 km run. The subjects completed a questionnaire that assessed the duration and frequency of physical activity completed outside of army combat training (ACT). The researchers were interested in the relationship between physical activity and performance as measured by the questionnaire and the performance tests. The findings showed that subjects with an increase in duration and frequency of physical activity outside of ACT scored higher on the PT's compared to their sedentary counterparts. The investigators provided correlation coefficients that described the relationship between each performance variable: push-ups and 3.2 km run -0.49, sit-ups and 3.2 km run -0.51, and push-ups and sit-ups 0.62 (p= <.001).

Drystad et al. (14) conducted a study on 107 military personnel with an average age of 19.2 years. The subjects completed a 10 week training program in addition to basic training (BT) that included a control group and an intervention group. The control group was required to complete one hour of strength training and one hour of endurance training (in two separate training sessions) in addition to BT. Consequently, the intervention group was required to complete two times this amount, with two hours of strength training and two hours of endurance training (in four separate training sessions) in addition to BT. The training was assessed with a performance test (PT) that included push-ups, sit-ups, pull-ups, and a 1.8 (3km) mile run at baseline and the conclusion of 10 weeks. The PT was not timed; the subjects completed each exercise until exhaustion. The results of the study showed a significant difference ($p < 0.05$) between baseline and post measures of sit-ups and push-ups. The study did not provide data for the subjects' 1.8 mile time at post assessment.

Woodruff et al. (52) assessed the effectiveness of a Basic Exercise Program (BEP) on improving performance and body composition. The BEP was a 24 week physical conditioning program designed to improve cardio respiratory endurance, muscular strength, and reduce body fat. One hundred eight subjects with a mean age of 28.6 were required to attend the intervention at least three days/week. The duration of scheduled meeting times was not specified. Training included upper body strengthening, abdominal strengthening, and aerobic conditioning (the exact upper body exercises and the duration and intensity of aerobic training was not specified). The program was evaluated by its effectiveness to improve Navy personnel's score on a Physical Readiness Test (PRT) that included push-ups (2 min), curl-ups (2 min), and a

1.5 mile run at maximum velocity. The program was evaluated and compared between two different naval bases in the San Diego area. The BEP showed a significant improvement in the PRT, but failed to reduce body fat. Additionally, all Navy personnel were required to attend the BEP 3 days out of the week and no association exists between attendance and increased performance or attendance and reduced body fat.

Hortobagyi et al. (24) studied the effects of a 13 week intervention on a circuit training program that was specifically aimed to increase upper and lower body strength measures in 28 college males (US Army ROTC) with a mean age of 20.8 years. The training was assessed with a physical fitness test pre and post training that included push-ups, sit-ups, and a two mile run. The subjects were randomized to either low resistance (LR), high resistance (HR), or control group (no training). The groups trained three days/week for 40 minutes. The training included high intensity resistance training focusing on large muscle groups of the upper and lower body. A two mile run immediately followed the resistance training component. Study results found that the type of training the subjects completed significantly improved the performance of each one of the physical fitness variables (p=0.05) in the LR and HR groups. There was no difference in physical fitness performance variables in the control group.

Collectively, the studies described in this chapter focused on the following aspects which are similar to our study: 1) the effect of structured physical activity interventions on physical activity patterns, 2) studies using activity monitors to collect information on performance variables including PAEE, running speed, and body fat and, 3) studies that implemented an exercise training protocol similar to ours and determined the effect of the intervention on various exercise performance and body composition variables. These studies helped inform our study design, implementation, data collection and analysis.

CHAPTER 3: METHODS

A sample of 79 male, undergraduate college students at the University of Montana (UM) aged 18- 40 years old were recruited for this study. The participants were recruited via email, flyers around campus, and classroom presentations at the beginning of the academic semester (spring and fall 2009). All subjects were asked to sign informed consent documents. The procedures were approved by UM's Internal Review Board.

Experimental Protocol

After each participant was registered for the class, they were given an Actical® (Mini-Mitter Co., Inc., Bend, OR) PA monitor to wear for one week to assess their physical activity (PA) patterns. During the week of activity monitor data collection, body composition (BC) was assessed by underwater weighing in the Health and Human Performance laboratory. At the end of the week, the subjects returned their accelerometer and participated in their initial performance test (PT). The PT consisted of pull-ups, sit-ups, push-ups, and a 1.5 mile run (in that order). This occurred 3 weeks in to the beginning of the semester. The following week training began in which the subjects trained every Monday, Wednesday, and Friday for the remaining 12 weeks of the semester. The subjects were assigned to a strength, running, or a running and strength training group.

The strength training group completed only strength training exercises consisting of pull-ups, sit-ups, and push-ups every Monday and Friday. The running group completed only running every Monday and Friday. In addition, the strength and running group completed pull-ups, sit-ups, push-ups, and running every Monday and Friday. All subjects completed the same PT every Wednesday.

Monday's training consisted of easy training at a light intensity. Wednesday was PT's, and Friday's were interval training. All training sessions consisted of pull-ups, sit-ups, push-ups, and running. The intensity and duration was dependent on the day of the week and how many weeks the subjects had been training (every four weeks the intensity of the protocol progressively increased). At the conclusion of the 12 week training program, the initial procedures of collecting PA and BC were repeated.

Hydrostatic Weighing

Body composition (BC) was assessed at baseline and at the end of the intervention in the underwater weighing (UWW) tank at the Health and Human Performance laboratory (HHPL). The UWW procedure is based upon Archimedes's Principle where the change in weight of an object when submerged in water is equal to its volume (25, 26). Estimated residual lung volume (liters; RV) was calculated with the equation: 1.310 x Ht. (meters) + 0.022 x Age – 1.232 (50). During this study, the water in the UWW tank was kept at 38˚c, so water density was calculated to be 0.99299 (entered in to the last part of the BD equation). Body density (BD) was then converted to PBF with the equation: (495/BD) – 450 (48).

Actical Data

The Actical® (Mini-Mitter Co., Inc., Bend, OR) PA monitor is a small omnidirectional accelerometer, which senses motion primarily in a single plane (uniaxial) and is less sensitive to other planes (triaxial) (23). The Actical® detects low frequency (0.35 Hz to 3.5 Hz) common to human movement (23). The Actical® used in this study is water resistant, lightweight (0.56 ounces), small (1.14 in. x 1.14 in. x 0.43 in.) and easily attached to the wrist with a plastic band.

The Actical® was calibrated to record at 1 min epochs, which is calculated to collect data for a total of 1440 min/day. The Actical® has the capability to record data for 44 days on this setting. The data was collected in the total number of activity counts per minute in sedentary, light, moderate, and vigorous PA (43). The data was logged using the measurement of min/day based on the previously validated research by Cuddy et al. (10) to analyze work output by different intensities, which was critical to determining hypothesis 2 and 3.

The first week of the study, every subject was fitted with an Actical® that was attached to their wrist with a plastic band. The subjects wore the Actical® for six days. The subjects were given information about the durability and water proof capability of the Actical® and instructed not to take them off for any reason. If the subjects had problems with the band (skin irritation, broken band, etc), the subjects were instructed to report to the Work Physiology Exercise Metabolism (WPEM) laboratory to get fitted with a new band.

After the six day data collection period, the Actical's® were collected at the beginning of class. Subjects that enrolled late or did not show up on the day when the Actical's® were disbursed, an activity monitor was distributed to the participant for a period that was equal to six days and then collected after the subsequent data collection period (six days).   The Actical's® distribution was carefully documented to ensure each subject was credited with the actual monitor that was allocated. Each Actical® contained a number and when a subject was assigned their activity monitor, they were assigned the specific number listed on the Actical®. This number was recorded and each subject was assigned the same Actical® at pre and post assessment.

After all the Actical's® were collected, the data was downloaded via Actical® software (Actireader PC serial port interface, Mini-Mitter Co., Inc.). The data collection was for a period of six days, but only four complete 24 hours days were used in the analysis. The first and last day of data were omitted. Two weekdays and two weekend days were included in the analysis to get the most accurate description of PA patterns. The decision to include only four days of data collection was contingent on prior research conducted by Masse et al. (31) that determined four days of data collection was sufficient to accurately reflect PA patterns when the analysis included two weekdays and two weekend days and when the epoch period is set for 1 min. Each individual assessment period (pre and post) included four complete 24 hour days (31), which equaled 5,760 total minutes for four days and 1,440 minutes in one day. The mean time (min) in each PA category (sedentary, light, moderate, and vigorous) was calculated and entered in to the analysis.

After the subjects completed 12 weeks of training, post intervention PA patterns were collected via the procedures outlined above. Prior to distributing the activity monitors spring and fall semesters, every Actical® was checked for battery life and maintenance was administered according to the need. All Actical's® were approved and distributed contingent upon their feasibility of collecting data for the entire week.

Training: Monday Class Session

Strength and Running Group

Before any training was incurred, the subjects participated in an initial performance test (PT). PT's were conducted every Wednesday during the 12 wk training program. Based upon their PT score, each participant was assigned to complete two times the amount of pull-ups, sit-ups, and push-ups that was completed during the initial performance test. For example, if a subject was able to complete 20 pull-ups, 60 sit-ups, and 50 push-ups during the initial PT, the following Monday they would come in to the gym and complete 40 pull-ups, 120 sit-ups, and 100 push-ups at a self selected intensity. During this phase of training, the subjects were monitored by the instructors and honesty was encouraged. Every Monday afterward during the 12 weeks of training, the subjects were assigned two times the amount of muscular strength exercises based on their PT from the previous week.

The second phase of training was running. After everyone completed their muscular strength exercises, the subjects went outside and ran together as a group for 17 minutes. The instructors ran with the subjects on a trail alongside the UM campus.

The procedure consisted of running down the path away from the gym for approximately 8 min 30 sec and then turning around and running back to campus. The intensity of this run was a light jog.

Strength Group

The same procedures as the strength and running group were followed with the strength group, except at a higher volume. Before any training was incurred, the subjects participated in an initial performance test (PT) and based upon their PT score, each participant was assigned to complete four times the amount of pull-ups, sit-ups, and push-ups that was completed during the initial performance test. For example, if a subject was able to complete 20 pull-ups, 60 sit-ups, and 50 push-ups during the initial PT, the following Monday they would come in to the gym and complete 80 pull-ups, 240 sit-ups, and 400 push-ups at a self selected intensity. During this phase of training, the subjects were monitored by the instructors and honesty was encouraged. Every Monday afterward during the 12 weeks of training, the subjects were assigned four times the amount of muscular strength exercises based on their PT from the previous week. The subjects in the strength group did not complete any running.

Running Group

The subjects assigned to the running group completed 34 minutes of running at an easy intensity. The subjects went outside and ran together as a group accompanied by the instructors alongside a trail by the UM campus. The procedure consisted of running down the path away from the gym for approximately 17 min and then turning around and running back to campus. The intensity of this run was a light jog. The running group did not complete any strength training.

Wednesday Class Session: Performance Tests

Every Wednesday the subjects completed performance tests (PT) consisting of pull-ups, sit-ups, push-ups, and 1.5 mile runs (in that order). The pull-up test lasted for 1 minute or till exhaustion, and the sit-up and push-up tests were completed at 2 minutes or till exhaustion. Between the pull-up and sit-up test was a 4 minute rest period and between sit-ups and push-ups a 3 minute rest period. Only technical pull-ups, sit-ups, and push-ups were counted. The objective of each exercise was for the participants to complete as many of each exercise as possible in the allotted time or until exhaustion.

A technical pull-up was defined by the finding the appropriate spacing between the hands while underneath the bar (length between hands will be dependent upon the participant). The participants were instructed to pull their upper body up until their chin is raised above the bar and their legs were held completely still, and slowly lower their body all the way down extending the arms completely in one complete motion to count one pull-up. A technical sit-up was achieved by locking their fingers across the posterior section of the head, bending their knees approximately 90 degrees (their partner will be holding their feet) with their feet flat on the ground, and touching their knees with their elbows. For one sit-up to be counted with their backs flat on the mat, the subjects were required to flex their torso, touch their elbow to their knees, and lower their upper body down until their backs were flat on the mat in one complete motion. A technical push-up was achieved by bending their arms at a 90˚ angle while touching the ground with their chest and maintaining a straight back. The participants will have to completely straighten out their arms in one fluid motion for one complete push-up. Any break in technique and the participant was disqualified for that specific exercise. Additionally, if a participant quit or repositioned their hands (pull-ups and push-ups only), they were disqualified for the specific exercise in which the breach occurred.

After the muscular strength test was complete, the subjects were escorted down to a running trail alongside the University for the 1.5 mile run. Every participant lined up at the starting line and the investigators gave a verbal cue to start the race. The course was measured half the distance one way (¾ mile), and the subjects ran to a designated point where an instructor stood directing the subjects to turn around and run back to the finish.

Every class session, (Mondays were up to the discretion of the participant) the participants completed their exercises with a partner who counted and recorded each exercise performed (pull-ups, sit-ups, and push-ups). Everyone was advised to practice honesty when counting and performing the PT. Additionally, the investigators observed all testing sessions and watched for participants that did not complete the exercises as described above. Strength exercises that were not completed through the full range of motion were not included in the participants' overall score for that day.

Friday Class Session: Interval Training

Strength and Running Group

Every Friday the strength training protocol consisted of high intensity intervals. The participants performed pull-ups for one minute and sit-ups and push-ups for two minutes continuously (in that order). A 30 second break was given between pull-ups and sit-ups, and a one minute rest was given between sit-ups and push-ups, and push-ups and pull-ups (in between the end and beginning of a new set). The training program began with one set of each strength training exercise for the first four weeks of the semester. Every four weeks thereafter, the training program increased to two sets (weeks 5-8) and then three sets (weeks 9-12) of strength training exercises.

The subjects were encouraged to work as hard as possible only stopping when needed and they were permitted to perform unconventional exercises as long as they keep working within the prescribed time period. To strengthen camaraderie and confidence, the subjects were allowed to help one another complete an exercise. For example, if a participant could not complete pull-ups continuously for the duration of one minute, then their partner held their legs and assisted them in working until the prescribed time period ended. In addition to creating confidence and camaraderie, the subjects receiving help were also stimulating the muscles that were needed to complete the task, thus increasing strength. After the subjects completed their sets of strength training exercises (the number of sets were contingent upon the number of weeks in to the semester), they were escorted outside to run intervals for 17 minutes.

The protocol for the running component of this workout consisted of alternating easy running and intervals. The instructors ran with the participants and timed the runs each week. The group started out with a warm-up run of approximately 4 minutes (time it takes to get from the gym to the running trail), an interval training session, and a cool down back to the gym.

The first 4 weeks the subjects completed three sets of two minute intervals with a two minute recovery period in between. The subjects were given the choice between an active recovery (light jogging) or walking between intervals. During weeks 5-8, the protocol progressed to one set of four minutes and one set of two minutes with a two minute recovery period in between. During weeks 9-12 the subjects completed one interval of six minutes.

Strength Group

Every Friday the strength group completed high intensity intervals, which consisting of a procedure that included pull-ups for one minute and sit-ups and push-ups for two minutes continuously (in that order). A 30 second break was given between pull-ups and sit-ups, and a one minute rest was given between sit-ups and push-ups, and push-ups and pull-ups (in between the end and beginning of a new set). The training program began with two sets of each strength training exercise for the first four weeks of the semester. Every four weeks thereafter, the training program increased to four sets (weeks 5-8) and then six sets (weeks 9-12) of strength training exercises. The strength training group did not complete any running on Friday.

Running group

Every Friday, the running group completed a procedure that included high intensity intervals. The instructors ran with the participants and timed the runs each week. The group started out with a warm-up run of approximately 4 minutes (time it takes to get from the gym to the running trail), an interval training session, and a cool down back to the gym.

The first four weeks, the subjects completed six sets of two minute intervals with a two minute recovery period in between. The subjects were given the choice between an active recovery (light jogging) or walking between intervals. During weeks 5-8, the protocol progressed to three sets of four minute intervals with a two minute recovery period between each interval. During weeks 9-12 the subjects completed two intervals of six minutes with a two minute recovery period in between each interval. The running group did not complete any strength training.

Statistical Analysis

A 2-tailed dependent *t*-test was used to assess pre and post differences in PA, BC, and performance measures. Pre to post differences in PA were determined by the mean total minutes per day (four days total) in sedentary, light, moderate, and vigorous PA. Body composition (BC) was assessed in mean weight (kgs), fat free mass (FFM; kg), percent body fat (PBF), and fat mass (FM; kg). Performance was assessed with individual mean test scores in pull-ups, sit-ups, push-ups (mean number completed), and 1.5 mile run times (min). The level of significance was set at $p \leq .05$.

A Pearson-product moment correlation coefficient was used to determine if the Actical® PA monitor can predict performance. The pre training PA data in minutes per day in sedentary, light, moderate, and vigorous PA was correlated with the initial PT (If a subject did not participate in the initial PT, the PA data was then correlated with their first PT test recorded). Although sedentary and light PA is included in the analysis, the variables of interest are moderate and vigorous physical activity.

The association between each individual PA variable (time (min) in each of the sedentary, light, moderate, and vigorous categories) and the mean of each performance variable (pull-ups, sit-ups, push-ups, and 1.5 mile run) were determined with the pearson-product moment correlation coefficient. The statistical results are presented as mean ± standard deviation (SD) and bivariate correlation models. Statistical significance was set at $p<0.05$.

CHAPTER 4: RESULTS

Physical Activity

Decriptive characteristics of all the subjects are shown in Table 1. The mean daily PA levels recorded by the Actical® PA monitior are shown in Table 2. The average daily time spent in each PA category was the same pre and post training. There were no significant differences in any PA category from pre to post training ($p>0.05$).

Relationship between Physical Activity and Performance: Pre Training

The pre training associations between PA and performance are shown in Table 3. There were significant positive correlations between average daily time spent in vigorous PA and pull-ups ($p<.05$), sit-ups ($p<.01$), and push-ups ($p<.01$). There were also significant negative correlations between average daily time spent in moderate ($p<.05$) and vigorous ($p<.01$) PA and 1.5 mile run times.

Relationship between Body Composition and Performance: Pre Training

Table 4 shows the relationship between the BC variables and performance prior to training. There were significant negative correlations between weight, PBF, and FM and pull-ups, sit-ups, and push-ups ($p<.01$). Data reported a significant positive relationship between weight, PBF, and FM and 1.5 mile run time ($p<.01$).

Performance Tests

The performance test (PT) scores of all subjects are shown in Table 5. There were significant improvements in pull-ups, sit-ups, push-ups, and 1.5 mile run time ($p<0.001$). On average, the subjects improved by four pull-ups, 31 sit-ups, 15 push-ups and 30 seconds in the 1.5 mile run.

Body Composition

Table 6 illustrates the pre and post training effects of training on body composition (BC). There were no differences in weight and fat free mass (FFM) from pre to post training ($p>.05$). However, a significant decrease was observed in fat mass (FM) and percent body fat (PBF) from pre to post training ($p<.001$).

Table 1. Average Body Composition Characteristics of the Subjects

	Anthropometric Data			
Parameters	**n**	**Mean**	**±**	**SD**
Age	79	23.6	±	5.0
Height (cm)	79	180.4	±	16.1
Weight (kg)	79	83.5	±	15.5
PBF (%)	79	18%	±	8%
FFM (kg)	79	67.6	±	9.1
FM (kg)	79	15.8	±	9.4

PBF= percent body fat; FFM= fat free mass; FM= fat mass

Table 2. Averge Physical Activity on Week 1 and After Week 12 of Training

		Pre PA			Post PA			
Parameters	**n**	**Mean**	**±**	**SD**	**Mean**	**±**	**SD**	***p***
Sed (min)	79	772.9	±	126.6	782.3	±	140.1	0.42
Light (min)	79	518.6	±	99.2	512.3	±	106.5	0.51
Mod (min)	79	141.0	±	55.3	137.8	±	51.8	0.54
Vig (min)	79	7.3	±	9.1	7.5	±	5.8	0.87

PA= physical activity; Sed= sedentary; Mod= moderate; Vig= vigorous

Table 3. Relationship Between Physical Activity and Performance on Week 1 Prior to Training (n= 79).

Performance Parameters		Sedentary PA	Light PA	Moderate PA	Vigorous PA
		Activity Monitor Parameters			
Pull-ups	Pearson Correlation	-0.13	0.05	0.18	0.23*
	p -value	0.24	0.69	0.11	0.04
Sit-ups	Pearson Correlation	-0.20	0.12	0.16	0.53**
	p -value	0.08	0.30	0.17	0.00
Push-ups	Pearson Correlation	-0.08	0.00	0.13	0.34**
	p -value	0.48	0.99	0.25	0.00
1.5 Mile Run Time	Pearson Correlation	0.19	-0.05	-0.26*	-0.47**
	p -value	0.10	0.65	0.02	0.00

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed)

PA= physical activity

Table 4. Relationship Between Body Composition and Performance on Week 1 Prior to Training (n=79).

Performance Parameters		Weight	PBF	FFM	FM
		Body Composition Parameters			
Pull-ups	Pearson Correlation	-0.459**	-0.623**	-0.11	-0.597**
	p -value	0.00	0.00	0.34	0.00
Sit-ups	Pearson Correlation	-0.319**	-0.505**	-0.004	-0.472**
	p -value	0.00	0.00	0.98	0.00
Push-ups	Pearson Correlation	-0.289**	-0.471**	0.01	-0.440**
	p -value	0.01	0.00	0.91	0.00
1.5 Mile Run Time	Pearson Correlation	0.595**	0.796**	0.12	0.791**
	p -value	0.00	0.00	0.29	0.00

**. Correlation is significant at the 0.01 level (2-tailed).

PBF= percent body fat; FFM= fat free mass; FM= fat mass

Table 5. Average Performance Test Scores on Week 1 and Week 12 of Training

		Pre Performance			Post Performance			
Parameters	**n**	**Mean**	**±**	**SD**	**Mean**	**±**	**SD**	***p***
Pull ups	79	7	±	5	11	±	6	<0.001
Sit ups	79	46	±	18	77	±	22	<0.001
Push ups	79	29	±	11	44	±	16	<0.001
1.5 mile run (min)	79	12.0	±	2.5	11.5	±	2.3	<0.001

Table 6. Average Body Compostion Scores on Week 1 and After Week 12 of Training

		Pre Training			Post Training			
Parameters	**n**	**Mean**	**±**	**SD**	**Mean**	**±**	**SD**	***p***
Weight (kgs)	79	84.1	±	14.0	82.9	±	16.8	0.35
PBF (%)	79	19%	±	8%	17%	±	8%	<0.001
FFM (kgs)	79	67.5	±	7.4	67.7	±	10.6	0.85
FM (kgs)	79	16.6	±	9.5	15.1	±	9.3	<0.001

PBF = percent body fat; FFM= fat free mass; FM= fat mass;

CHAPTER 5: DISCUSSION

Purpose

The primary purpose of this study was to determine the effect of a supervised exercise training program on physical activity patterns. A secondary objective of the study was to determine if accelerometers can predict variables associated with strength (e.g., pull-ups, sit-ups and push-ups) and running performance (e.g., 1.5 mile run time). Lastly, the study reported on the progression or decline in strength and running performance test scores and weight, percent body fat, fat mass, and fat free mass during the 12-week, structured, exercise training program.

Effect of the structured exercise program on PA patterns

We orginally hypothesized the structured, exercise training program would significantly increase daily minutes of moderate and virogous physical activity. There was, however, no effect of the intervention on sedentary, light, moderate or vigorous PA patterns. Suttle, but nonsignificant (p>0.05) changes were observed in each category, with an increase of 10 minutes spent in sedentary PA, and decreases of six minutes spent in light PA, and four minutes spent in moderate PA. There were no increases in minutes spent in vigorous physical activity.

These results suggest providing more supervision for a structured exercise program than we had in our study may be important to increase PA levels. For example, Oeland et al. (39) suggest that the prescence of an instructor is needed for subjects to sustain (or increase) PA levels. In addition, the convenience of participating in a gym setting with a structured protocol may have contributed to maintaining adequate levels of physical activity. Dawson and Brawley (11) implemented a PA intervention similar to our study that included supervision and structure. The authors report that this type of intervention presents novice exercisers with fewer challenges and require fewer planning and scheduling strategies in order to successfully adhere.

For example, every Monday the subjects were prescribed two times the amount of strength training exercises (pull-ups, sit-ups, and push-ups) they completed the week prior during the performance test (the prescribed amount changed each week based upon the PT score). The subjects were required to complete the prescribed amount at their own speed and intensity before the subjects and instructor(s) went outside and ran as a group. Although the instructors were present at all times while they completed these exercises, we did not count every pull-up, sit-up, and push-up for each subject individually. Therefore, it would have been easy for a participant to dishonestly report that they completed every strength training exercise when in fact they did not. In addition, during interval training on Friday, the subjects were allowed to rest while they completed pull-ups, sit-ups, push-ups and running and may not have put forth maximum effort during each training session.

Our findings that the exercise program did not change PA patterns in the participants contrasts other studies. For example, Oeland et al. (39) conducted a 20 week PA intervention that included aerobic and strength training and reported a 120 minutes per week increase in physical activity. Opdenacker et al. (40) implemented an 11 month aerobic and strength training intervention and observed a 150% increase in physical activity. Dunn et al. (15) reported a significant increase ($p<0.01$) in PA with a 2 fold increase in vigorous PA, but only prescribed aerobic training at an intensity of 50-

85% max power. Similar to our methods, the latter two studies both measured PA with accelerometry.

A possible explanation for the different results reported in our study compared to Opendacker et al. (40), Dunn et al. (15), and Oeland et al. (39) may be attributed to the subject population. Opdenacker et al. (40) recruited a sedentary subject population with a mean age of 66 years. Dunn et al. (15) recruited sedentary men and women with a mean age of 45 years. Additionally, Oeland and colleagues (39) included sedentary subjects with a mental illness, but did not provide data on age or gender. The subjects in our study were healthy, college age males with a mean age of 23 years. According to our results, it appears that participation in a strength and running exercise program has no effect on college males' (mean age 23 years) PA patterns outside of the intervention compared to previous reports (15, 39, 40) using older populations.

In addition to the subject population, the measurement of PA may also contribute to the contrasting results. Dunn et al. (15) was the only study that reported using accelerometry (tritrac accelerometer) and measuring PA outside of the study (pre to post intervention). Oeland et al. (39) measured PA with the IPAQ during the PA intervention at pre and post assessment periods. Opdenacker et al. (40) indicated that PA was measured with the RT3 accelerometer, but did not include whether or not PA was measured outside of the study (pre and post intervention). Although Dunn et al. (15) measured PA at similar time points, the intervention only included aerobic training and further distorts the comparison to our study since the protocol included strength and running exercises.

Another possible explanation for the descrepency between our study and others is the duration of our intervention, especially for the aerobic training component. Our study prescribed an aerobic training for a duration of 17 minutes, two days per week and one day where the time spent in aerobic training was based upon the amount of time it took them to complete 1.5 miles during the performance test.. The studies that reported an increase in PA prescribed aerobic training for a duration of 40 minutes, three days per week (40), 30 minutes, two days per week (39), or 60 minutes, five days per week (15). Two out of the three studies (39, 40) included some form of strength training exercise, and employed the use of accelerometry to measure PA (15, 40). The literature has documented the limitations of accelerometry to accurately detect PA patterns during strength training exercise programs (30, 31, 40) and the increased duration of aerobic training in other studies compared to ours may have contributed to the significant increase in PA reported in these studies (15, 39, 40).

Another possible explanation for the nonsignificant changes in PA reported in our study could be attributed to the subjects' level of physical fitness and inability to schedule PA in to their daily lives. The majority of the subjects enrolled in the study because they wanted to get in shape or achieve a higher level of physical fitness, which suggests our participants were novice exercisers. The prospect of participating in a structured training program with other college males was likely a motivating force for many of the subjects. During the intervention, some of the subjects verbally stated that the only time they particpated in PA was during class time. Although the 12 week structured exercise training program did not change PA patterns, PA patterns were maintained. These results suggest subjects consistently participated in the structured

PA strength and running activities during the structured exercise program class times, but may have been primarily sedentary outside the class times.

The volume and rigor of course work and work schedules may contribute to college students physical activity patterns. For example, to be considered a full-time student, a person must register for 12 credits, which is equivalent to four classes. Many students also have to work part-time in order to support themselves financially. The activity monitor data illustrated a non-significant increase of 10 minutes in sedentary PA and no change in vigorous PA from pre to post training. The post data assessment was recorded during week 12 of training, which was finals week at the university. The time taken to study in addition to working (for some of the subjects) may have dictated whether or not the subjects had any time to engage in PA outside of class and may have contributed to the non-significant increase in sedentary behavior at post assessment.

The PA patterns in Table 2 show non-significant increases in sedentary PA by 10 minutes, and non-significant decreases in light PA by six minutes and moderate PA by four minutes. The pre training PA patterns were collected via activity monitor during the first two weeks of the semester and before any intense training began. During this time, the researchers were still recruiting subjects to participate. Subjects were allowed to enroll in the study even after training began 3 weeks in to the semester. All subjects in the study had their post PA patterns collected during the last week of training and this was included in the post assessment.

The students were required to register for the study as they would for any class at the university. Intense training did not start until the third week of classes, so the subjects had one less class to attend and could use this free time to engage in sports or recreational activities. Additionally, at the beginning of the semester, professors typically outline the class by discussing the syllabus and introductory material the initial two weeks. During this time, the subjects would have less homework and more free time. This may explain why they had 10 minutes less sedentary activity at the beginning of training.

At the end of the semester, the non-significant (p>0.05) increase of sedentary PA (10min) and non-significant (p>0.05) decrease in light and moderate PA (six min and four min) could be attributed to students focusing on preparing for final exams and presentations (e.g., primarily sedentary behavior activities) and not getting daily exercise during the post-test measurement time period. Additionally, most undergraduate students are not good at time management and do not make PA a priority in their life (12), which would greatly decrease the likelihood of structuring a workout into their daily class and study time routines .

Relationship between PA and Performance

The data collected from the Actical® activity monitor and the initial performance test (PT) was to determine if accelerometers could predict strength and running performance variables. There were weak to moderate correlations between each PA category (mean min/day in sedentary, light, moderate, and vigorous) and the performance variables (pull-ups, sit-ups, push-ups and a 1.5 mile run). The strongest correlation was between vigorous PA (mean min/day) and sit-ups at 0.53 (p<0.01); all other correlations fell below this value. These data show that sedentary, light, and moderate PA (mean min/day) are weak, accurate predictors of performance. Vigorous PA (mean min/day) may be a useful indicator of performance. Vigorous PA was significantly correlated with pull-ups ($p<0.05$), sit-ups ($p<0.01$), push-ups ($p<0.01$), and 1.5 mile run ($p<0.01$) compared to the correlations between sedentary, light, and moderate PA (mean min/day) and the study's strength and running performance variables.

We hypothesized that moderate and vigorous PA (mean min/day) would predict running performance, as measured by the 1.5 mile run. We also hypothesized that moderate and vigorous PA (mean min/day) would not predict strength performance as measured by pull-ups, sit-ups and push-ups. The results indicated a significant correlation between moderate and vigorous PA (mean min/day) and 1.5 mile running performance. In addition, vigorous PA was significantly correlated with the pull-ups, sit-ups, and pull-ups strength performance variables. Moderate PA (mean min/day) however, was not significantly correlated with any of the strength or running performance variables.

The significant relationship between moderate and vigorous PA (mean min/day) and running could be attributed to the accelerometers' documented ability to accurately detect aerobic activity. The Actical® accelerometer is probably more sensitive to aerobic training than strength training (11, 31, 40), which would explain why aerobic training produced two (moderate and vigorous PA) significant predictors of performance rather than one significant predictor (vigorous PA) of performance with strength training.

The data also revealed some interesting correlation patterns. The strength training variables (pull-ups, sit-ups, and push-ups) demonstrated a negative association with sedentary physical activity. This would indicate that the subjects who spent most of their time sedentary did not complete very many strength training exercises when completing the strength performance tests. In contrast, as the intensity increased in category from light, moderate, and then to vigorous PA (mean min/day), the associations became positive and increased in correlative strength. The increase in the correlative strength was gradual and did not reach a value greater than 0.53 (Table 3). Although the strength and PA correlations were weak to moderate, the patterns suggest that the more time each subject spent being physically active, (specifically in moderate and vigorous PA), the greater amount of strength exercises the subject was able to complete when participating in the strength portion of the performance test.

The findings reported in Table 3 showed a similar pattern between PA patterns and the 1.5 mile run, but with an inverse relationship. The correlation strengthened and became negative as it moved from light, to moderate, and then to vigorous PA (mean min/day). The data suggests that when subjects entered the study and then spent time becoming more physically active, mostly in the moderate and vigorous PA categories, the less time it took them to complete the 1.5 mile run when participating in the performance test at the end of the study.

As mentioned earlier, accelerometers may not be able to accurately detect stationary strength exercises (30, 31, 40). Perhaps this mechanical deficiency in the instrumentation contributed to the weak to moderate correlations between PA and strength performance variables reported in our study. Lemmer et al. (30) administered a whole body strength training intervention and measured PA at baseline and post intervention with an accelerometer. The outcome reported that PA decreased from pre to post intervention by 12,531 ± 6,589 counts/day. The authors attributed the decrease in PA to the accelerometers inability to detect strength training performance variables. Perhaps the weak to moderate correlations between PA and strength performance in our study could be explained by the same occurrence.

Relationship between Body Composition and Performance

The results in Table 4 indicate that the body composition (BC) variables weight, percent body fat, and fat mass may be strong indicators of strength and running performance. Each of these variables showed significant, positive or inverse relationships with pull-ups, sit-ups, push-ups and a 1.5 mile run time. The most significant, positive relationship was forPBF and the 1.5 mile run (0.796) and the most significant, inverse relationship was between PBF and pull-ups (-0.623). Fat free mass (FFM) was not significantly associated with any of the strength and running performance variables. Our data indicate that weight, PBF, and FM may play a vital role in predicting strength and running performance characteristics, whereas FFM may not be able to predict these performance outcomes.

The results from BC and strength and running performance measures suggest that lighter body weight is ideal for optimum performance, especially during running and body weight bearing strength exercises. The moderate to strong and significant relationships ($p<0.01$) between these variables in Table 4 illustrate this relationship. Prior research has reported on the increased benefits of lighter body weight (and associated variables) on running and strength performance (body weight bearing) measures. Coetzer et al. (9) reports that elite distance runners typically have a smaller body mass compared to average runners. Laurenson et al. (29) found the same relationship between elite triathletes and club level triathletes. Additionally, superior performance was reported with a lighter body weight on performance tests consisting of pull-ups, sit-ups, and push-ups compared to their heavier counter parts (8).

The correlations between BC and performance show patterns similar to the correlations between PA and strength and running performance measures. The difference is strength and running performance variables in our study found an inverse relationship with BC compared to physical activity. Weight, PBF, and FM all had weak to strong, negative correlations with strength performance (pull-ups, sit-ups, and push-ups) variables. These data suggest that having a lower body weight is associated with increased strength performance. In addition, weight, PBF, and FM all had strong, positive associations with the 1.5 mile run time. The correlation between BC and run time suggests that the greater the body composition, the more time it takes to complete 1.5 miles, which would be expected.

Strength and Running Performance Variables

A small component of this study was to report the effect of the 12 week training program on strength and running performance variables and body composition. Strength and running performance significantly improved in every area (p<0 .001) with an average gain of four pull-ups, 31 sit-ups, 15 push-ups, and a mean decrease of 30 seconds on the 1.5 mile run. The significant improvement and large gains in performance may be explained by the physical conditioning of the subjects at the beginning of the study. The response to training is expected in a sedentary population (13, 22). We may not have seen the significant effects in the strength and running performance variables if the subjects had been in superb physical condition when the study began.

Previous research has confirmed that subjects entering a training study in poor physical condition have been shown to respond with significant gains to strength and running performance variables. Hanson et al. (22) implemented a study that targeted strength, power, and body composition. The authors reported a significant increase in 1RM bench press of 22 ± 1kg to 28 ± 1kg, leg press 88 ± 3kg to 96 ± 3kg, 279.7 ± 17.7 watts to 330.2 ± 18.6 watts, and 49.8 ± 1.4kg to 50.4 ± 1.5kg. Donges and colleagues (13) conducted a resistance and aerobic training intervention in addition to a fitness test at baseline and post assessment. The resistance training program produced a significant improvements ($p<0.05$) in 10RM upper-body strength by 46.5% ± 21.9% and 10RM lower-body strength by 56.6% ± 23.3%, and a 20.9% ± 8.6% improvement in aerobic performance. The large gains in these studies were attributed to the sedentary condition of the subjects, which was characteristic of our subjects as well.

Another explanation for the significant improvement in the strength and running performance variables is the specificity of training. The training was specific to the pull-ups, sit-ups, push-ups, and running performance measures. The subjects complete a performance test (PT) every Wednesday during the intervention to determine how many performance exercises they could complete and training was designed to help the subjects improve on the performance tests. The training protocol focused specifically on pull-ups, sit-ups, push-ups, and running. Prior research on strength training suggests that in order for an athlete to achieve the greatest improvements in athletic performance, the resistance training program must be adapted to meet the specific demands of their sport (19). Additionally, the training consisted of aerobic interval training, which has been proven to enhance running economy (38) and increase performance (18, 28, 35, 37, 41, 46, 49). The sedentary condition of the subjects at the beginning of the study in conjunction with the specific training protocol contributed to the significant improvement in performance.

No study to date has administered the type of training protocol used in our study. Other studies have implemented different training approaches, but measured the same performance variables used in our study. Woodruff et al. (52) employed a similar type of protocol and found significant improvements in (p=0.05) sit-ups 7.8, push-ups by 8.2, and 1.5 mile run time by 0.8 min. Additional PA interventions measuring the same variables have reported improvements of 14.2 push-ups, 10.8 sit-ups, and 2.4 min on the 2 mile run (24) and 16 sit-ups, 8 push-ups, and 0.3 pull-ups (14). Although there is variation in the training protocol and outcome of each study, our results can be compared to these studies because they were exercise training programs implemented to improve strength and running performance outcomes in college males (US Army ROTC) military personnel.

Body Composition: Fat free mass, Fat mass and Percent Body Fat variables

The training produced mixed results on body composition. After 12 weeks of training, body weight (BW) decreased by one pound and was not significantly different from pre to post training. The exercise program had no effect on changes in fat free mass. The intervention did produce a significant improvement (p<0.01) in FM and PBF with a 2 kg and 2% decrease respectively.

These data indicate that although the PA intevention did not change BW, there were changes in various measures of body composition. Our results for no change in body weight are consistent with previous research by Woodruff et al. (52) and Drystad et al. (14). Both studies did not find a change in body weight ($p>0.05$) after administering a PA intervention similar to ours.

Although body weight and FFM did not change, FM and PBF significantly decreased ($p<0.01$) by the end of the study. Prior research by Matilla et al. (33) reported similar results after conducting a PA intervention. The authors observed a 3.17 kg decrease in FM and a 3.23% decrease in percent body fat. Additionally, there was an increase in FFM of 1.16kg, data which is similar to ours.

The outcome reported by Matilla (33) do not align verbatim to our study, but there are similarities in the changes in body composition. Perhaps the resemblance between the outcome of BC in each study may be attributed to the type of training prescribed during the interventions. Matilla's training protocol closely aligns with our training protocol, which consisted primarily of pull-ups, push-ups, sit-ups, and running (combining resistance and aerobic exercise). Combining strength training specific to pull-ups, sit-ups, and push-ups in conjunction with aerobic training may be an effective way to target FM and PBF, and thus having no effect on body weight but changing body composition.

A possible explanation for no change in body weight and FFM may be due to the subjects building or maintaining muscle mass and at the same time decreasing body fat. This would explain why there was no change in body weight, but there was a change in body composition. Similar findings were reported by Fleck et al. (17) who conducted a three day per week, 14 week resistance and aerobic PA intervention The subjects significantly increased FFM by 2.2% and significantly decreased total percent body fat by 1.4%.

Our body composition study outcomes indicate that a PA intervention combining strength training in the form of pull-ups, sit-ups, and push-ups in conjunction with running produces positive effects on FM and PBF, but does not affect fat free mass. Perhaps the differences in body composition outcome variables can be explained by the mode of training prescribed in our study. Fat free mass is gained by providing the muslce with a stimulus that elicits hypertrophy. Hypertrophy is typically achieved by overloading the muscle and lifting heavy weight with low repititions (strength training). The intervention that the subjects completed was the exact opposite and more specific to endurance training rather than strength training. The training response may have been restricted to the hormonal level and did not produce big gains in muscle mass and would be a likely reason why FFM did not change. Prior research (1) has shown that the hormones associated with muscle growth are stimulated within the first 14 weeks of training and are dependent upon the training volume. The training regimen the subjects completed (pull-ups, sit-ups, push-ups, and 1.5 mile run) may need to be administered more than three days per week and for a longer duration to impact a change in fat free mass.

Conclusion

The results from this study revealed that a PA intervention combining aerobic and strength training did not produce an increase in PA from pre to post intervention. A multitude of variables could have contributed to this finding, but perhaps the most meaningful explanation is the rigorous schedules and work load demanded of college students during the semester creates barriers to engaging in daily physical activity. In addition, our results suggest that accelerometers may be able to predict some strength and running performance variables. Every body composition variable (weight, PBF, and FM) except FFM showed a significant (p<0.01) and moderate to strong correlation with performance (pull-ups, sit-ups, push-ups, and 1.5 mile run time). It appears that BC may also have the potential to provide insight into predicting strength and running performance test scores.

The subjects significantly improved in pull-ups, sit-ups, push-ups, and 1.5 mile run time from pre to post intervention. Although the intervention did not change PA patterns, it was successful at improving strength and running performance variables. The training also significantly decreased FM (2 kg) and PBF (2%), but did not change weight or fat free mass.

This study suggests that supervision may be key to changing PA patterns although our study design did not specifically test the effect of a supervised versus non-supervised exercise intervention on PA levels. Future studies may want to test the effect of varying levels of supervised exercise programs on PA patterns, and strength and running performance variables to fully determine if supervision is the key to changing PA levels and associated performance measures.

Areas for Further Research

Previous studies that combine aerobic and resistance training have been successful at increasing PA from pre to post intervention (11, 39, 40). Future research in the area of PA interventions should take into account the type (aerobic, strength, or combined) and intensity of training and how that may affect PA levels. Additionally, it is of interest to explore how participating in performance tests during the middle of a school week r at the end of a semester effects PA outcomes.

Accelerometers have been used in research to predict a variety of variables (16, 20, 34, 36). This study used the Actical® PA monitor to predict strength and running performance. Our results revealed weak to moderate associations between PA and strength and running performance measures. However, prior research has confirmed that activity monitors may not accurately detect stationary exercises like strength training (30, 31, 40), which may partially explain our study results for strength performance variables and accelerometry. Future studies should explore if able accelerometry can detect strength training PA and if different activity monitor placement (i.e. wrist, ankle, or hip) affects these study outcomes.

Practical Applications

The PA intervention administered in this study utilized a military like, exercise training protocol. The subjects focused on pull-ups, sit-ups, push-ups, and running, which are drills that the military enforces daily on their soldiers. The performance test used in our study was derived from the Air Force. The outcome of this study suggests that the training protocol was effective in significantly ($p<0.01$) increasing strength and running performance (pull-ups, sit-ups, push-ups, and 1.5 mile run) and may be useful in improving these performance variables in the military population. Thus our exercise protocol may be useful for soldiers that have been denied full access in to the military as a consequence of their inability to pass the performance test.

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