PAI MONITOR USABILITY FOR CARDIAC PATIENTS

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Chapter I

Introduction

Physical inactivity continues to be a burden on healthcare, both in America and globally. Physical inactivity is now considered the 4^{th} leading cause of death worldwide, with over 5 million deaths per year (334,000 of which are in the United States), showing that that regular physical activity (PA) is a key component of a healthier lifestyle (44). Physical inactivity alone accounts for 6% of all coronary heart disease (CHD)(1). For those who do meet recommended guidelines for PA, benefits are found in multiple facets of the individual's health. Regular PA has shown to decrease the relative risk of coronary artery disease (CAD), stroke, hypertension, osteoporosis, dyslipidemia, metabolic syndrome, depression, and Type II diabetes(2, 15, 19, 28, 44, 46). However, only 31% of individuals are currently meeting the American College of Sports Medicine's (ACSM) recommendations for PA (moderate intensity aerobic PA for a minimum of 150 minutes per week, vigorous intensity aerobic PA for 75 minutes per week, or a combination that generates energy equivalency), thereby seeing these positive results (44).

Low cardiorespiratory fitness (CRF) and physical inactivity are directly related to cardiovascular (CV) disease and all-cause mortality (19). For individuals who can only exercise at a maximum MET level of <4 (meaning, the individual can exercise at a level less than four times his or her resting metabolic rate), mortality risk is three times higher compared to those who can exercise at a level of at least 10 METS, and for every one MET improvement in CRF, an individual can see up to 20% risk reduction for heart failure (HF) (5, 10). Lee et al found reductions in cardiovascular disease (CVD) mortality of 42% in those who had improvements in CRF on follow up physical examinations an average of 6.3 years following the first examination (48). Blair et al found improvements in a similar study, with a 52% risk reduction in CVD mortality with improvements in CRF (6). These improvements in CRF and reduction in risk through PA are not only found in apparently healthy individuals, but in individuals with previous cardiac events or cardiac disease as well. Doukky et al found that individuals with chronic heart failure (HF), those who were physically active had half the risk of all-cause mortality and cardiac death compared to those who were physically inactive (56). Other cardiac patients have reported less difficulties with activities of daily living (ADL) after increasing PA levels after being diagnosed with heart disease (75). Whereas it was once thought that the risks would outweigh the benefits for those with cardiac disease performing PA, the benefits of PA for this population are now well understood.

A popular avenue for tracking PA in the past decade has been activity monitors. Sales of activity monitors have reached over 100 million units per year, and although PA monitors have emerged as a commonly used form of tracking PA, no one monitor has been accepted as the universal standard (4). Although most activity monitors do have a direct correlation with PA, there remains a large variability from brand to brand and type of monitor, with no single unit being universally accepted, leading to the conclusion that no standard exists currently for tracking PA (4, 34).

A new proposed metric for monitoring PA is the Personalized Activity Intelligence (PAI) score, which aims to eliminate subjective and self-reported measures of PA such as intensity, duration, and frequency, and instead calculate a weekly score fundamentally based on an individual's heart rate (24). An individual's score is based on the prior seven days of PA, with the goal of maintaining a PAI score of 100 for maximum health benefits.

Nes et al found that obtaining a PAI score of 100 or greater was associated with reduced risk for CVD mortality and all-cause mortality for apparently healthy individuals, regardless of age, sex, or risk factor profile (24).

Currently, there is limited evidence regarding PAI score relevance for cardiac patients, as most previous studies have excluded those with cardiac disease or previous cardiac events from study populations. However, many studies have focused on the positive impacts of cardiac rehabilitation on the health of individuals. A 31% reduction in CVD mortality has been found for those who have successfully completed cardiac rehabilitation programs (67). However, a problem that exists is that currently there is no standard measurement for PA assessment within cardiac rehabilitation programs, and individuals who are enrolled in cardiac rehabilitation programs are not getting enough PA to achieve health benefits (33, 37). In a study by Jones et al, researchers found that individuals enrolled in a cardiac rehabilitation program were classified as "low-active", with only 8% of individuals reaching a targeted goal of 10,000 steps per day (33). Along with this issue, many individuals completing monitored cardiac rehabilitation programs do not maintain being physically active, with 83% of individuals starting exercise programs after graduating from rehabilitation, but with only 37% of those individuals following through with exercise programs for at least one year (1).

With data showing the importance of remaining physically active, especially for those with cardiac disease, coupled with the lack of a universal measurement for PA, the global purpose of this study was to measure the validity of PAI scores in cardiac patients, specifically those who have graduated from a phase II cardiac rehabilitation program and joined a phase III cardiac rehabilitation program.

Aims and Hypothesis

The following aims and hypotheses were assessed in a 14-day observation of phase III cardiac patients:

Aim 1: Evaluate the usability of the PAI Health application in cardiac patients from a phase III cardiac rehabilitation program using a standardized questionnaire and focus group interview session.

Aim 2: Compare VO_2max values obtained by phase III cardiac rehabilitation patients to the amount of exercise volume performed.

- Hypothesis 1: PAI scoring and the PAI Health application will be favorably received by patients in a phase III cardiac rehabilitation program.
- Hypothesis 2: VO_2max values will be related to the amount of exercise volume performed by patients in cardiac rehabilitation.

Significance

With the lack of available data for PAI scores related to cardiac patients, as well as no universal way of assessing PA in cardiac patients, a PAI score of 100 could be a new achievable goal for cardiac patients to see maximum health benefits. However, even if a PAI score of 100 is unattainable for cardiac patients, the idea that "more is better" could show that greater PAI scores, even if less than 100, can be attributed to increased health benefits similar to the benefits seen in healthy populations (24). If participants favorably receive the PAI Health application, those who have cardiac disease and are enrolled in a cardiac rehabilitation program may have more motivation to complete exercise programs due to the added accountability of the PA monitoring. With this new form of measurement, the subjectivity currently associated with measuring PA could be eliminated. Obtaining 100 PAI may prove to be a better way to prescribe exercise and PA levels that protect against CVD and all-cause mortality compared to current PA recommendations (40). This objectivity in measuring PA for diseased populations, including those with cardiac disease, could be instrumental in providing safe exercise prescriptions that benefit the patient and give them an attainable goal through the rehabilitation process. This idea could fill the gap between PAI score research and CVD PA research, as well as present new opportunities, as most studies do not suggest a dosage of PA to reduce cardiovascular morbidity and mortality (15). Other clinical populations, such as pulmonary and bariatric patients, could see this research as transferable and begin to formulate a standard for PA within those populations as well.

Chapter II

Review of Literature

PA and Cardiorespiratory Fitness (CRF)

PA is defined as any skeletal contraction that results in energy expenditure above basal level (37). It is differentiated from exercise in that exercise is planned, structured, repetitive, and promotes the goal of maintaining physical fitness. Studies have shown that is an inverse relationship between PA levels and mortality risk. In a study by Stamatakis et al (n=13,726), after 8.4 years of follow up on individuals who were initially free of CVD, those who had increased levels of PA had 32% lower risk for all-cause mortality (73). In a study by Lee et al, it was determined that those individuals who met the minimal current recommendations for PA could reduce risk for CHD by 14%, type 2 diabetes by 17%, breast cancer by 33%, colon cancer by 24%, and all-cause mortality up to 48% (49). In the same study, it was determined that if physical inactivity could be eliminated, average life expectancy would increase by 0.68 years, and even if not fully eliminated, if it were decreased by 10-25%, 533,000 to 1.3 million lives could be saved annually (49).

Currently, ACSM recommendations are that adults perform 150 minutes of moderate-intensity PA, 75 minutes of vigorous-intensity PA, or a combination of the two intensities (37). However, these recommendations represent the minimum amount of PA for health benefits, and that 150 (vigorous-intensity) to 300 (moderate-intensity) minutes of PA may be required for additional health benefits and to prevent weight gain (37). In an update of Healthy People 2000 for the US Centers for Disease Control and Prevention, only 23% of individuals reported being physically active 5 or more times per week, which in itself does not take into account the volume of exercise (9). Despite these recommendations, the specific optimal volume of PA (frequency, duration, and intensity) for maximum health benefits is still unclear (85). Meanwhile, the reciprocal component of PA, physical inactivity, is a leading cause of death worldwide, with over 5 million deaths per year, 334,000 of which are domestic, confirming that that regular PA is a key component of a healthier lifestyle (44). The level of PA an individual gets, however, is a modifiable risk factor, and performing the proper amount can lead to reduction of risk for different clinical outcomes.

For individuals who have reported increased levels of PA, reductions in the relative risk of death have been found to be 20 to 35% (53, 54). In regards to specific clinical outcomes, increased levels of PA have shown to have an inverse dose-response relationship with coronary artery disease, obesity, dementia, Alzheimer's disease, stroke, hypertension, osteoporosis, dyslipidemia, metabolic syndrome, depression, Type II diabetes, (2, 15, 19, 21, 28, 44, 46, 71). In a study by Wannamethee et al (n=4,311), mortality risk ratios were calculated for groups separated into activity categories of inactive/occasionally active (1.00), light (0.61), moderate (0.50), and moderately vigorous/vigorous (0.65), and for those individuals who started the study as sedentary, if activity was increased even slightly, there were reductions in risk of up to 55% for all-cause mortality and CVD (84).

In regards to PA's relation to coronary heart disease (CHD), studies began as far back as the 1950's when Morris et al showed that individuals who had more physically demanding jobs (mail carriers versus bus conductors) had 50% lower rates in CHD than their less physically active counterparts (63). This landmark study inspired researchers to focus on PA's relationship to the reduction of risk for cardiovascular diseases. This data was confirmed in a 1977 study by Leon and Blackburn, revealing an inverse relationship between PA levels and coronary heart disease, where more active individuals were shown to have 50% of the risk a more sedentary individual has for coronary heart disease and only 33% of the risk for cardiovascular related mortality (50).

Physical inactivity alone accounts for 6% of all coronary heart disease (CHD)(1). When extended to other non-communicable diseases, such as type 2 diabetes, breast, and colon cancers, this attributable amount can be as high as 10% (49). Physical inactivity, along with cardiorespiratory fitness (CRF)(defined as the highest MET level achieved during a graded exercise test (GXT)), are directly related to cardiovascular (CV) disease and all-cause mortality (19, 78).

Generally speaking, high levels of PA have been associated with increased levels of CRF(16). For individuals who can perform maximal exercise at a MET level <4 METs, mortality risk is three times higher compared to those who can exercise at a level of at least 10 METS, and for every 1 MET improvement, an individual can see up to 20% risk reduction for heart failure (HF) (5, 10). In respects to overall mortality risk, every one MET improvement past 5 METs decreases overall mortality risk by 12% (43, 65). In a meta-analysis by Kodama et al, 33 studies comprising of 102,980 participants with 6,910 cases for all-cause mortality and 84,323 participants with 4,485 cases for CHD/CVD were evaluated. In both groups, reductions for risk for mortality were reduced by 13-15% for those individuals who were able to show an 1-MET improvement, with this improvement being associated with 7cm decrease in waist circumference, 5 mmHg decrease in systolic blood pressure (SBP), 1 mmol/L decrease in triglyceride levels, and 1 mmol/L decrease in fasting plasma glucose along with a 0.2 mmol/L increase in high-density lipoprotein

(HDL) cholesterol (42). Lee et al found reductions in cardiovascular disease (CVD) mortality of 42% in those who had improvements in CRF on follow up physical examinations an average of 6.3 years following the first examination (48), which confirmed improvements found by Blair et al in a similar study, with a 52% risk reduction in CVD mortality with improvements in CRF (6). For patients with congestive heart failure (CHF) who enroll in a cardiac rehabilitation program aimed at increasing PA, 15-30% improvements in CRF (measured by VO_2max) have been found, which is consistent with data on apparently healthy individuals(22, 26, 30, 59, 69, 81). Whereas primary prevention of CVD is the ultimate goal, secondary prevention of CVD is important, and PA and CRF play large roles in secondary prevention as well.

In a meta-analysis by O'Connor et al involving patients who were post-myocardial infarction (n=4,551), patients who increased PA levels through a cardiac rehabilitation exercise training (CRET) program had reductions in total mortality risk of 20% and CVD mortality risk of 25% (67). In a study by Joliffe et al, a 37% reduction of risk for sudden cardiac death after 1 year of individuals participating in a cardiac rehabilitation program (32). In a study of post-PCI patients by Goel et al (n=2,395), those who participated in a cardiac rehabilitation program had a reduction of risk for all-cause mortality by 45% after a 6-year follow up (20). With the decreased risk for follow-up events and better secondary prevention statistics, cardiac rehabilitation is considered essential for individuals suffering from CVD to increase exercise capacity and quality of life.

<u>History of Cardiac Rehabilitation</u>

Cardiovascular disease (CVD) has been one of the leading causes of death worldwide for many years, both domestically and globally. From 1950 to 1996, mortality from heart disease rose 37% (200,000 deaths more per year) (9). From 1990 to 2013, global CVD mortality increased 41% (47). However, cardiac rehabilitation for CVD survivors involving exercise is an established method for improving the quality of life for this population (50). However, the recommendations for PA for cardiac patients have evolved over the last 70 years. As recent as the 1950's, bedrest was considered the best option for patients in recovery from a cardiac event. In 1952, Levine and Lown took strong stances against early mobilization of cardiac patients, believing that activity works against the reparation process in any injury and that bedrest is the optimal environment for those recovering from a cardiac event (51). However, in 1953, after Morris et al found that more active ticket sellers had decreased risk for CHD than did more sedentary bus drivers, the paradigm began to shift towards having cardiac patients becoming more active (55, 63). In 1958, Hellerstein and Ford defined cardiac rehabilitation as the greatest way to return an individual to "usefulness" and to have opportunity for gainful employment (18). Klein et al agreed with this sentiment in 1965, advising that graded PA be a regular feature of treatment, both acutely and chronically, for those who have suffered a myocardial infraction (41). Saltin et al published the results from the Dallas Bed Rest and Training Study (initial study done in 1966), where five 20-year old men were subject to 3 weeks of bed rest and 8 weeks of endurance training, followed by follow-up testing on the same individuals 30 years later. Although the sample size was limited, it was determined that 3 weeks of bed rest resulted in a larger deterioration in functional capacity than did 30 years of aging, showed just how taxing physical inactivity could be on the body (55, 58, 72).

In 1975, Wilhelmsen et al reported on their study analyzing whether "supervised physical training" could reduce death and subsequent myocardial infarctions in postinfarction patients. The training group (n=158) trained three times per week and after one year of follow up, had higher physical working capacity than did the control group (n=157). During a four year follow up, there were fewer deaths and subsequent infarctions in the training group, and the training group had lower blood pressure compared to the control group (89). In 1979 in a study by Kallio et al, 375 patients who had an acute myocardial infarctions took part in a randomized trial to see the effects of rehabilitation on morbidity, mortality, and return to work. After a three year follow up period, the CVD mortality was significantly lower in the intervention group compared to the control group (18.6% versus 29.4%, p=0.02), with the greatest results showing in the first six months after the acute myocardial infarction (18.1% reduction in sudden death for the intervention group compared to 11.2% in the control group) (36). Concurrent with this study were studies looking as length of stay for myocardial infarction patients and mobilization after myocardial infarction.

In a study by McNeer et al, 33 of 67 patients suffering an acute myocardial infarction with no complications within the first four days were discharged after one week, with the remainder of patients having a mean hospital stay of 11 days (60). Thornley and Turner were interested in having patients who had suffered acute myocardial infarction become "rapidly mobilized". In a study of 127 men under the age of 65 who suffered an acute MI, the mean amount of bed rest was only 5.4 days before mobilization. This mobilization led to early discharge for patients, as well as "eliminating the need for physiotherapy" (79). This emphasis on increased PA and cardiac rehabilitation from the 1970s continued on into the 1980s.

In 1985, in a study by Hammond et al, 59 men with CHD underwent one year of what was labeled “supervised aerobic exercise”. In the study, over 60 variables were tested for an association with the training program, including baseline oxygen uptake, anthropomorphic measures, and ejection fraction (EF). After the training period, an average estimated maximum oxygen consumption increased by 15% (23, 27).

Moving into the 1990s, the total length of stay in inpatient care for cardiac patients had decreased from prior decades. For individuals under the age of 70, the mean length of stay was 8.5 days, and for those 70 years of age or older, the mean length of stay was 11.6 (38). In a study done at Brigham and Women’s Hospital, even with an increase of volume in cardiac surgeries, there was a 15% decrease in the total length of stay for cardiac patients, with patient satisfaction increasing to 95% (11). In a meta-analysis in 2001 by Jolliffe et al, 32 separate trials were evaluated concerning the effectiveness and benefits of cardiac rehabilitation programs following an MI. Consistent with previous studies, a 27% reduction in all-cause mortality for exercise-only cardiac rehabilitation programs (32, 74). In the same year, a study by Hedbäck et al showed that those who completed a cardiac rehabilitation program had an 18% rate of a repeated cardiovascular event after 10 years of follow up compared to the 35% rate for those who did not participate in a cardiac rehabilitation program (29, 74). The increased emphasis throughout the decade also brought with it more reductions in the length of hospital stay, as well as improved cardiac risk factors (91). The U.S. Center for Medicare and Medicaid Services supported the notion that cardiac rehabilitation is necessary following an MI, coronary artery bypass graft (CABG), stable angina pectoris, PCI, heart valve surgery, or heart transplant (32, 86, 87).

Exercise Intensity Measurements and Evaluation

It is common for exercise to be prescribed on the basis of intensity level. Two classical ways of prescribing exercise based on intensity level have been using a percent of VO_2max ($\%VO_2max$) or percent of HR_{max}($\%HR_{max}$)(57). Both of these values can be determined through GXT or calculated from predictive models. Calculated HR_{max} from GXT is especially important in individuals with CVD due to medications lowering HR_{max}, thereby making prediction equations irrelevant. However, using these two methods does not take into account the variability of resting metabolic rates for specific individuals; two individuals with the same maximal heart rates and VO_2max values can have drastically different resting values. Thus, it has become increasingly more common to use an individual's reserve values (both $\%VO_{2Reserve}$ and $\%HR_{Reserve}$), which will place individuals at an intensity level percentage above resting values (57). Although it is common for both values to be used in prescribing intensity, it is important to note that a 1:1 relationship may not exist between $\%VO_{2Reserve}$ and $\%HR_{Reserve}$. In a study by Cunha et al, the stability of the relationship of both $\%VO_{2Reserve}$ and $\%HR_{Reserve}$ and $\%VO_2max$ and $\%HR_{Reserve}$ were observed, and it was determined that the relationship between $\%VO_{2Reserve}$ and $\%HR_{Reserve}$ garnered from maximal exercise tests did not apply to prolonged continuous exercise bouts at 60%, 70%, and 80% of VO_2R. The greatest difference between the two variables was found at 80% $VO_{2Reserve}$, which would be considered vigorous intensity by ACSM guidelines (12). It is reasonable to use individual aerobic threshold data in order to individualize exercise prescription and intensity levels, but the challenges of determining thresholds in most individuals could partially explain why $\%VO_{2Reserve}$ and $\%HR_{Reserve}$ are commonly used as surrogates (57). Currently, HR is not common to use in the prediction of energy expenditure (EE) due to factors that influence the HR-VO_2 relationship such as current fitness level, prescription medication, age, gender, and outside environmental factors (88). In a study by Wicks et al, the reported effects of these variables were limited by calculating net HR (HR_{net}) which takes absolute HR ($HR_{absolute}$) divided by RHR. In addition, HR index (HR_{index}), which equals $HR_{absolute}$ divided by HR_{rest}, was used to determine the relationship of HR to VO_2max and predicted EE in a cohort of 11,257 eligible participants. It was determined that, while determining the HR-VO_2 relationship, HR_{index} explained most of the variation at 99.1%, and that because of the ability to predict VO_2 (thereby EE) independent of testing method, HR_{index} could be important for clinical use (88).

PAI monitoring has determined that moderate-intensity activity is at approximately 75% of HRR and vigorous-intensity activity is at approximately 85% of HRR, which are considerably higher than ACSM guidelines for moderate-intensity (40%-59% VO_2R or HRR) and vigorous-intensity (60%-89% VO_2R or HRR) (24).

PA Monitors

PA monitors have become increasingly popular among those track PA. In 2016, global sales of PA monitors reached approximately 100 million units, with PA monitors having an increased role in healthcare systems(4). Many commercial devices cost within $50-$100 USD, display immediate feedback on a number of metric including step count, calories burned, stairs climbed, distance travelled, etc, and offer social network interaction/application interaction, making them catalysts for behavior change (17). However, although there exists a demand for PA monitors, variability among PA monitors continues to grow.

Three general types of PA monitors exist: pedometers, accelerometers, and integrated multisensory systems (82). Pedometers generally estimate the number of steps an individual takes, accelerometers detect acceleration in 1-3 directions, and integrated multisensory systems combine accelerometry with other data such as heart rate or skin temperature (82). Although almost all monitors have a direct correlation with PA, variability exists between monitor feedback, leading to the belief that there may not be a true gold standard for activity monitors (70).

Swartz et al examined the validity of PA monitors in assessing energy expenditure in normal, overweight, and obese adults by having participants wear three different activity monitors throughout the duration of a sub-maximal treadmill test (77). The test comprised of six 5-minute stages that began at 1.5 mph and increased 0.5 mph at the conclusion of every stage while maintaining a 0.0% grade. The researchers concluded that none of the monitors assessed energy expenditure accurately for the normal BMI or obese BMI groups. Although monitors improved accuracy of estimating energy expenditure as speed increased, lower speed treadmill walking led to inaccurate measures of energy expenditure throughout the groups (77).

Step counts are generally referred to as the most commonly used output parameter for activity monitors, due in part to the World Health Organization's (WHO) recommendation for individuals to reach 10,000 steps per day (66). A study was performed by Storm et al, where researchers compared seven commercially available activity monitors in terms of step count detection accuracy. Sixteen individuals without impairment or morbidity that could interfere with assessment were participants in the study who wore the seven different monitors simultaneously. Accuracy of the monitors was measured under different walking conditions that included walking a 20m straight line, descending 24 steps, free outdoor walking, and ascending 24 steps. Statistical analysis showed significant differences in step counts between three walking speed conditions, with some monitors overestimating step counts and some monitors underestimating step counts. Researchers noted that although seven individual monitors were used in the study, a portion of the monitors were originally developed for running, while a portion of the monitors were designed for clinical use, which may have partially explained the variance among monitors (76). In a similar study, researchers compared the output of five different activity monitors in relation to step counts. Participants wore activity monitors throughout multiple activities that included activities of daily living, cycling, and rowing. Results showed that all five activity monitors reported a significant number of false positive steps throughout one or more of the different activities, which could negatively impact the consumer's estimated of individual activity performed (66).

Hagstromer et al compared the subjective PA garnered from the International PA Questionnaire (IPAQ) with objective PA data garnered from an Actigraph accelerometer for 980 participants over the course of a 7 day period. The results of the study showed significant low (Rs = 0.07-0.36) between the 2 methods, with participants reporting significantly higher values for sitting time and vigorous intensity activity time on the IPAQ compared to what was calculated from the accelerometer (25). This overestimation of PA by the subjective measure of an IPAQ proves that more objective forms of calculation, such as in the form of an activity monitor, is likely needed to calculate an individual's true amount of PA, especially related to intensity levels.

Many PA monitors also seek to estimate intensity levels of PA performed. In a study by Ferguson et al, researchers had 21 healthy adult participants wear seven consumer-level activity monitors and two research-grade accelerometers throughout daily life in free-living conditions. Validity relative to moderate to vigorous PA (MVPA) was quantified, and absolute differences were large for MVPA (26-298%), with trends being difficult to determine due to the lack of explicit MVPA reporting for consumer-level activity monitors (17).

Along with assessment of PA in healthy populations, a new trend has developed for measure PA in those with chronic disease or comorbidities. In a review study by Van Remoortel et al, healthy adults and those with whom inactivity is considered a contributor to morbidity (COPD, HF, diabetes type II, pulmonary hypertension, obesity, etc) were included, where participants wore activity monitors and had outcomes compared against a criterion method such as indirect calorimetry. Forty activity monitors were validated against indirect calorimetry in adults with chronic disease (12% of the studies), and researchers concluded that due to less accuracy of activity monitors at slow walking speeds and a lack of information about validated activity monitors in chronic disease populations, proper validations studies are needed in order to include these populations in clinical trials (82).

In a study by Vogel et al, researchers investigated outcomes of cardiac rehabilitation patients wearing PA monitors synced through smart phones. 29 patients were assigned to either the study group (n=13) or control group (n=16), where participants performed cardiac stress tests at baseline, the middle (6 weeks/end of cardiac rehabilitation), and the end of the study (12 weeks), and results showed that those who wore PA monitors not only maintained performance level at week 6, but they improved performance at the end of the study (week 12). Studies such as these show the impact of wearing PA monitors in regards to maintaining health in clinical populations, especially those with established CVD (83).

Personal Activity Intelligence (PAI)

Personal Activity Intelligence (PAI) was created in an attempt to make quantifying the amount of PA an individual gets per week simpler (90). Researchers have found that obtaining a PAI score of 100 or greater delays premature mortality from CVD and all causes, independently of whether or not the individual is meeting currently PA recommendations and guidelines (24, 39, 90). This scoring system is meant to provide clear feedback to individuals, removing subjectivity from step counts, intensity levels, and arbitrary units used by many PA monitors (24). The model was designed to be implemented on devices, such as the MIO Slice, where heart rate can be monitored continuously, primarily on the wrist (24).

The derivation cohort for development of the PAI algorithm was comprised of participants in the HUNT Fitness study, where 4,631 healthy subjects completed treadmill VO_2peak tests, where VO_2peak and HR_{max} were determined (3, 24, 45). The validation cohort was comprised of 70,535 apparently healthy participants 20 to 74 years older from the first three years of the HUNT Fitness study (1984-1986). Those with worse CV risk profile, as well as those > 74 years of age were excluded (24). Results from the study showed that participants with ≥ 100 PAI, equating to either 40 minutes of high-intensity (~85% HRR) or 60 minutes of moderate-intensity (~75% HRR) activity in a week, had better health profiles than those not reaching 100 PAI, with individuals have lower instances of hypertension, smoking, and obesity (24). Men reaching ≥ 100 PAI had 17% decreased risk of CV disease mortality, and women had 23% reduced risk of CV disease mortality. Men reaching ≥ 100 PAI had 13% risk reduction for all-cause mortality, and women had 17% reduced risk for all-cause mortality. Reduction of risk for CV disease mortality based on PAI score was true independently when accounting for obesity (22% for men and 39% for women), smoking status (21% for men and 42% for women), and hypertension (26% for men and 37% for women), with similar reductions of risk for all-cause mortality (24). Ultimately, researchers observe that those who obtained < 100 PAI lost an average of 4.7 years of life compared to participants obtaining ≥ 100 PAI (24).

In a cross-sectional study by Zisko et al, associations between sedentary behavior and CVD risk factors were studied along with the modifying effect of obtaining a PAI score of 100 or greater in apparently healthy individuals. All apparently healthy individuals from the HUNT study were included, with those with a history of heart disease, stroke, diabetes mellitus, or regular use of blood pressure medication were excluded (90). Ultimately, analysis showed that those obtaining 100 or more PAI per week were less likely to present CVD risk factors clustering associated with sedentary behavior (90). Individuals who were 44 years of age or younger, had a PAI score of less than 100, and sat 7 hours or more a day had an OR of 2.09. For those aged 45-59 with the same PAI score and who sat the same amount of time, the OR was 2.21, and for those aged 60 or greater with the same PAI score and who sat the same amount of time had an OR of 2.29. However, if individuals obtained 100 PAI or more weekly, even if they sat for 5 or more hours, ORs were non-significant across all age categories (90).

Literature regarding PAI scores related to those with cardiac disease is limited to retrospective studies. In a study by Kieffer et al, a total of 3,133 patients with CVD were followed from the date of participation in the HUNT Study (between January 1, 1984 and February 28, 1986) until the date of the participant's death or the end of follow-up (December 31, 2015). After 12.5 years of follow-up, there were 2,936 deaths that included 1,936 of those deaths being attributable to CVD. After PAI scores were calculated for those individuals with CVD, it was determined that participants who had PAI scores 100 or greater 36% lower risk for CVD mortality and 24% lower risk for all-cause mortality compared to participants who were deemed inactive (40). The risk reduction found from PAI scores held true regardless of whether or not individuals met current PA recommendations, the participant's sex, and age. Risk reductions were held true for those who were diagnosed as hypertensive, those who were clinically overweight (BMI 25.0-29.9), and those with poor self-health ratings. However, different from previous studies concerning PAI scores related to risk reduction, there were no significant risk reductions for those with CVD who had PAI scores of 100 or greater and were smokers or had diabetes (40).

Chapter III

Methods/Design

Design and Setting

The research design used a mixed-methods approach to examine the perceived usability of the PAI Health application technology designed to increase PA and promote a healthier lifestyle. The research was conducted at the Ball State University Clinical Exercise Physiology Laboratory and the Ball Memorial Hospital Cardiopulmonary Rehabilitation Center. User acceptance of the application through focus group interview was assessed according to the consolidated criteria for reporting qualitative research (61, 80). The usability questionnaire was developed and based on the Technology Acceptance Model (TAM) (13). The TAM suggests that if participants in a study have perceived usefulness and perceived ease of use about a technology, they will be more likely to adopt the technology into daily living (13).

Three assumptions were made for the study population: (1) the population being assessed (cardiac patients enrolled in phase III cardiac rehabilitation) would benefit from higher levels of PA; (2) most individuals in cardiac rehabilitation programs are not currently wearing PA monitors; and (3) PA monitors, specifically the PAI Health application in conjunction with the Mio Slice, have the potential to increase PA in this population.

Participants

Ten phase III cardiac rehabilitation patients were recruited through face-to-face interactions to participate in the study. Participants were recruited by a member of Ball Memorial Hospital's cardiopulmonary rehabilitation staff, with the only criteria for acceptance into the study being inclusion and exclusion criteria. Upon obtaining written informed consent, participant anthropometrics were assessed. Inclusion criteria required that participants be ≥ 18 years of age, English speaking, have a primary diagnosis of myocardial infarction (MI), coronary artery bypass grafting (CABG), percutaneous coronary intervention (PCI), heart valve replacement, stable angina, or heart failure with an ejection fraction (EV) of 35% or less. Participants were required to own a smartphone or tablet in order for the application to sync properly with the Mio Slice provided, must be in normal sinus rhythm (NSR) in order to accurately assess heart rate, and must have had no changes in heart rate altering medications since the last time they performed an exercise stress test. Those who had prior injuries, musculoskeletal conditions, or medical conditions that limit the ability to exercise, have implanted pacemakers, or have abnormal heart rhythms that might interfere with heart rate assessment were excluded from the study.

Exercise Test

Participants performed an exercise stress test under medical supervision to determine maximal heart rate. The purpose of this test was to have a measured maximum heart rate (HR_{max}) for participants, as well as have a measured VO_2max for participants. Participants performed the exercise stress test at the Clinical Exercise Physiology Laboratory at Ball State University, where after explanation of the test, were monitored through electrocardiogram (ECG) and a metabolic cart for indirect calorimetry. This provided researchers with HR_{max} and VO_2max values for the participants. Results from individual exercise tests are presented in Table 1. All participants were supervised by faculty from the Clinical Exercise Physiology Laboratory, as well as a cardiologist.

Orientation Visit

Participants underwent an orientation visit in which they were provided the PA monitor (Mio Slice) and guidance on using the device and the phone/tablet application, charging protocol, and synchronization of the activity monitor with the application for data transfer. Participants also received standard instructions that come with each Mio Slice package. Research staff assisted in activating the device, setting up a user profile which included the participant's height, weight, and peak heart rate acquired during the exercise stress test. Research staff requested participants record PA and exercise totals for the observation period of the study.

Observational Period

Participants wore the PA monitor for 14 days during all hours of the day and night, except for activities that required water submersion (i.e. swimming) and when charging the device. Participants were asked to follow regular daily routines and were encouraged to attend phase III cardiac rehabilitation at least 3 days of the week per standard clinical recommendations and practice.

Follow Up Visit and Usability Questionnaire

Participants received a follow up visit within 3 days of completing the 14-day period. After completion of the observation period, participants were asked to complete a usability questionnaire to describe overall satisfaction with the PAI Health application and Mio Slice, which included a 19-item questionnaire developed using Technology Acceptance Model, which assesses external variables, usefulness, ease of use, attitude towards the technology, likelihood of future use, and system use (13, 61). Participants were then be invited to a focus group visit to discuss their experiences with the device, which allowed participants to go into great detail about individual experience with the application and PA monitor. The group of participants was led through a series of 10 questions and encouraged to give open-ended feedback. No pre-conceived theories about PA monitors were identified prior to collection on the usability or usefulness of PA monitors for those enrolled in cardiac rehabilitation programs. Recorded transcripts and participants' notes were used in the analysis of the activity monitor.

Data Analysis

Data analysis was performed using SPSS Statistics 24 (SPSS Inc., Chicago IL). Data was represented as means, and a correlation analysis was performed to examine the relationship between VO_2max values and PAI scores. Descriptive statistics were used to categorize participants.

Chapter IV

Results

The primary purpose of this study was to assess the usability of the PAI Health application, synced with the Mio Slice watch, for patients enrolled in phase III cardiac rehabilitation at IU Health – Ball Memorial Hospital. Ten patients between the ages of 60 and 76 years (mean 70 $\pm$ 5.6 years; Table 1.0) enrolled in phase III cardiac rehabilitation participated in this investigation. One individual declined to participate in the study after the orientation visit due to declining maximal exercise testing, thus was not included in the dataset. Of the ten individuals included in the study, all ten completed a maximal graded exercise treadmill test to determine VO_2max and completed the 14-day trial period wearing the Mio Slice watch and completing the usability survey

Subject Characteristics

Table 1.0 provides subject characteristics and maximal exercise test data at baseline. Anthropometric values of sex, age, and weight were included, as well as data from the maximal exercise test, which included total test time, absolute maximal VO_2, relative maximal VO_2, peak VO_2 (ml/kg/min), maximal respiratory exchange ratio (RER), expired minute ventilation (VeBTPS), respiratory rate (RR), maximal treadmill MPH, maximal treadmill grade (%), VE/VCO_2 slope, resting end-tidal carbon dioxide pressure ($PETCO_2$), warm-up $PETCO_2$, maximal $PETCO_2$, ventilatory threshold (VT), HR at VT, maximal systolic blood pressure (SBP), maximal diastolic blood pressure (DBP), recovery HR, exercising ectopic beats, recovery ectopic beats, and reported exercise volume (minutes per week).

Usability Questionnaire

Table 2.0 provides average user scoring for the 19-item questionnaire provided to participants at the end of the 14-day trial period of the study, as well as a percentage of individuals rating low scores (a score of 1 or 2 on a given question) and individuals rating high scores (a score of 4 or 5 on a given question). All participants in the study provided feedback via the usability questionnaire. 6 of the 10 participants in the study attended the focus group interview session. Of the four that did not attend, one was out of the country, two were visiting different states, and one did not communicate as to the reason for being absent.

<u>User Perceptions – Thematic Analysis</u>

In this study, overarching themes emerged from the usability questionnaire and focus group interview to described the usability of the PAI Health application and Mio Slice for individuals enrolled in phase III cardiac rehabilitation. Based on average scoring from the questionnaire and the focus group interview session, the first theme that arose was that participants quickly became comfortable wearing the Mio Slice, but they had issues using and interpreting the PAI Health application. The second theme was that participants were encouraged to perform more PA based on constant feedback from the study, evidenced as well by exercise volume. The third theme was that participants felt that the HR monitor in the Mio Slice was inaccurate, leading to inaccurate PAI scores. The fourth theme was that participants wanted more focus on other aspects of the application, specifically the sleep time and wanted more compatibility with other programs and applications.

<u>Theme 1: Comfortability</u>

Although there may exist a perception that individuals within this age range struggle to adopt new technologies in regards to PA monitoring, this was not the case in the present study. Questions 7-10 and 18 of the questionnaire related specifically to the ease of use of the application, asking questions concerning ease of learning how to operate the activity tracker (score of 3.7), how clear and understandable the tracker was (score of 4.0), flexibility of working with the tracker (score of 3.3), overall ease of use (score of 3.6), and how comfortable the watch was to wear (score of 4.5). Comments throughout the focus group interview supported these scores.

Prior to this study, only 17% of those attending the focus group interview session had used PA monitors in the past. By the end of the study, 83% of those involved in the focus group interview session reported being comfortable with using the PA monitor, and all individuals reported being comfortable with wearing the PA monitor. For those that were not comfortable wearing the PA monitors, a few issues arose, mainly around not being able to understand or interpret the feedback being presented.

- *The biggest problem I had was remembering to put on the watch since I have not worn a wrist watch of any kind in any years. I stopped wearing a wrist watch when I retired.* [Male, 74]
- *The biggest reason I was uncomfortable with wearing the PA monitor and not finding it easy to use was the fact that I constantly had to seek advice from other people on how to even keep it functioning.* [Male, 76]
- *I'm still trying to figure mine out. I can kind of understand the numbers on my watch, but honestly, trying to go into the application to understand what was being thrown*

at me was tough. I stopped looking at the application itself after about the 2nd day of the study. [Female, 74]

Instructions were given to individuals at orientation as to how to use the PA monitor, but no physical instructions were provided to participants in this study. TAM notes that a lack of instructions is a barrier to individuals adopting new technology due it being a barrier to *actual system use* (13).

Despite not always finding the application easy to use, no individuals reported that they stopped using the PA monitor before the end of the 14-day study. All participants reported total completion of the 14-day study.

Theme 2: Motivation for PA

TAM emphasizes *behavioral intention to use* as one of the biggest assets for adoption of new technology. Prior to the 14-day observational period, participants informed research staff that they were very eager to begin as to help motivate them to become more physically active, and this was evidenced post-observational period by participant answers on the questionnaire and the focus group interview session. Questions 2-5 in the usability questionnaire dealt with the issue of motivation in regards to PA monitoring, asking questions concerning how the tracker helped set activity goals (score of 3.9), if the tracker helped reach activity goals more (score of 3.6), if the activity tracker helped individuals be more active (score of 4.1), and if using the activity tracker made it easier to be more active (3.4).

All participants had favorable dispositions towards the PAI Health application and Mio Slice's ability to encourage them to be more active.

- *I really liked the fact that you actually had some data go to by, and it actually encouraged me to be more active*. [Male, 68]
- *The PA monitoring created a "friend competition" between individuals in my peer group, which was actually a lot of fun*. *We all wanted to see who could do the most PA in a certain amount of time.* [Female, 74]
- *I actually found myself doing different exercise just to see what I could do with it and how PAI score would change from activity to activity. This made my exercises just a little more fun.* [Male, 74]

Overall, participants were appreciative of the motivation being a part of this study gave them to become more active throughout the 14-day observational period and beyond.

- *Although I've lost the consistency already for wearing the monitor, it created in me a greater overall awareness for my own PA time, and because of this, I think I have become more physically active on a day to day basis*. [Male, 76]
- *It was nice to see how my intensity related to my PAI score, and if nothing else, I have upped the intensity of the workouts I was already doing when I came to cardiac rehab*. [Male, 68]

Theme 3: Inaccuracy

A pervasive theme throughout the questionnaire and focus group interview was that participants in the study perceived the HR monitor within the Mio Slice to be inaccurate. Whereas patients with chronic ectopy and atrial fibrillation were excluded from the study due to irregular heart rates, even those with seemingly regular heart rates reported the HR monitoring as inaccurate. Question 19 dealt with the perceived accuracy of the watch and received an average score of 3.2 from the questionnaire. During the focus group interview session, the accuracy of the watch was debated by many within the session.

- *The same activity didn't always elicit the same response, so I didn't always feel comfortable wearing the monitor because I wasn't sure how accurate the monitor was.* [Male, 74]
- *The accuracy was inconsistent. When I did certain activities such as cutting down trees, it didn't rate my intensity as high even though I knew I was working really hard. However, when I would do lighter activities such as walking, it would sometimes rate my intensity higher than I know it was, so that was frustrating.* [Male, 71]
- *Inconsistency seemed to be the biggest issue. My score and heart rate didn't always correlate with how tired certain activities made me feel.* [Female, 74]

Although there was a general consensus that individuals enjoyed wearing the Mio Slice and using the PAI Health application, this sentiment was contradicted by the perceived lack of accuracy displayed by the watches linking to the PAI Health application.

Theme 4: Other Features/Incompatibility

Although many of the participants were excited about the PA monitoring to be done in this study, many were interested in the sleep time and were disappointed with the lack of explanation and/or focus on sleep time tracking.

- *I don't usually sleep with a watch on due to being uncomfortable, but I was interested in the feedback on sleep time, so I wore it. However, now I don't know what to do other than to just know how much I am sleeping*. [Male, 68]

- *I was interested in the sleep as well, so I tried to remember to leave it on at night*. *I wear a CPAP, so I was interested in how the watch would rate my sleep during the night.* [Female, 74]
- *The graph on the sleep time seemed to be pretty accurate, but I didn't know exactly how to interpret the graph or other graphs included on the application*. [Male, 71]
- *The sleep count seemed to be somewhat inaccurate, as I know some nights I received more sleep than what was reported and vice versa. I also wish there was some more focus on accelerometry from the watches.* [Male, 72]

Question 15 dealt with the topic of how well the activity tracker was to use in conjunction with other systems and applications, and this question had an average score of 2.8. Although participants felt comfortable with using the application itself, they did not seem to be able to apply it or sync the data with other applications, systems, or technologies.

- *I wish I could sync the watch and/or the app with other apps such as my Weight Watchers app. I know a lot of people in my group have FitBits, and I was not able to sync my watch up the same way that they were.* [Female, 74]
- *I will probably be switching back to my FitBit only because I know that the technology can integrate with other devices, and I am not sure about the Mio Slice and PAI Health Application. It was fun to use, but the FitBit seems to be a bit more universal than does the technology that we used in this study.* [Male, 68]

Chapter V

Discussion

Due to the increased amount of physical inactivity and its correlation with increased risk of CVD and overall mortality, it is of utmost importance to encourage individuals to become more physically active and make PA a more routine part of daily living, thereby creating more individual awareness of individual PA levels. PA monitors, such as the Mio Slice and the corresponding PAI Health application, are becoming increasingly popular and can increase motivation to become more physically active. Recently, research into mobile technology and its support for health care and health interventions has been rising, and with the amount of smartphone health and fitness applications growing from roughly 7,000 in 2010 to over 40,000 in 2013, one can expect this area of research to continue to expand (7, 35, 52, 62). The primary findings of this study were participants in a cardiac rehabilitation program can quickly acclimate to using the PAI Health application and Mio Slice device, that the technology encourages and motivates them to become more physically active, that they perceive the HR monitoring ability of the technology to be inaccurate, that they prefer more information on other metrics measured such as sleep counts, and that synchronization with other technology and applications, such as Weight Watchers and FitBits, would be ideal for this technology.

Previous studies have looked at the usability of different PA monitors for those with known disease and apparently healthy populations. However, this is the first known study to look at the usability of the Mio Slice watch in conjunction with the PAI Health application. In a study by Deka et al, patients with heart failure participated in a study to determine the usability of the Fitbit® Charge HR (FCHR), a wrist-worn activity monitor that similarly syncs with a smartphone app and tracks PA in real-time, recording date, time, HR, step-count, and energy-expenditure (14). In the study, researchers found similar themes to the current study, with participants having to seek out advice on properly installing and running software, that the device itself was not hard to use but that data were hard to interpret, and that wearing the monitor encouraged them to be more physically active (14). Researchers noted that one of the benefits and distinct advantages of using the FCHR was having participants being able to sync the hardware and software themselves, leading to data that can be accessed by researchers in longitudinal studies at any time (14). This novelty is also found through the PAI Health application, with data being able to be stored through secure cloud-based services, allowing researchers to access data collected at a later time.

In a study by Ormel et al, patients undergoing cancer treatments participated in a study looking at the feasibility of using the RunKeeper smartphone app and if it increased reported PA (68). Researchers found that sedentary time decreased by 19% during the first six weeks of the trial and 27% during the second six weeks of the trial, and that the overall usability was rated as “good” through questionnaire (68). Participants reported frustrations with the data reported by the application, suggesting more tailored and detailed reporting of individual data, similarly to theme four in the present study (68). In the current study, participants were unclear on the interpretation of sleep time, step counts, and the overall algorithm of PAI scoring.

A study by Boeselt et al looked at the usability of PA monitors in patients with chronic obstructive pulmonary disease (COPD). In the study, daily activity time was increased, with participants in the study being especially appreciative of the interface of specific activity monitors (8). This idea contrasts with the current study, as participants found the data being reported hard to interpret, troubles accessing the application, and finding the data on the Mio Slice hard to read and cycle through.

An issue arising from a combination from the first theme (comfortability) and fourth theme (other features/incompatibility) is that participants in the study were only instructed on how to use the PAI Health application (from a smartphone or table) in conjunction with the Mio Slice. Many participants voiced that they were weary of using such an application on their phones or tablets, as they were not fully comfortable with this type of technology. Individuals quickly became comfortable with the technology and wearing of the Mio Slice, as evidenced from the questionnaire and focus group interview session. However, participants voiced that they wished more focus was placed on the other metrics such as sleep time, and that the data were compatible with other products they own that focuses on health and PA. This could largely be due to the fact that the Mio Slice was provided to the participants, and participants were only trained on using the Mio Slice for this study. Recently, devices such as the Apple Watch have successfully integrated the HR monitoring technology that the Mio Slice does, and these devices might possess a greater potential for synchronization with other technologies and applications that could alleviate the perceived notion that the PAI Health application is not compatible with other technologies.

The PAI Health application collects and reports data on current HR, daily PAI score, weekly PAI score, step counts, sleep time, calories burned, and distance traveled if walking or running. The application goes somewhat further into detail on the intensity of activity, as well as breaking sleep time into “Deep Sleep”, “Light Sleep”, and “Awake” time.

However, explanations and information on these metrics seem to be lacking, and further exploring these metrics could become more motivational for those using the PAI Health application and monitors synced with it. Participants in the study were given a brief orientation on PAI scoring, yet the intricacies of exactly how PAI score is accumulated outside of the basic principles was left out. With the focus on PAI scoring being the main goal of the PAI Health application, one might consider step counts as an arbitrary measure that, although motivation may be increased, could be deemed as unnecessary if the goal of the PAI Health application is to create a universal metric for PA or if the individual is doing any type of exercise that would not typically be measured through accelerometry (cycling, swimming, rowing, etc.).

Participants in the study reported favorably that being a part of this study encouraged and motivated them to be more physically active. However, it is possible that the Mio Slice and PAI Health application generated motivation stemming from users who already did or already wished to make PA an integral part of their lives (31). Inclusion criteria for this study requested that participants already be attending a cardiac rehabilitation program three days per week, which could potentially create a bias for those already with increased levels of PA. For those who are already aware of healthy behaviors, extrinsic motivators such as PA monitors may have a greater effect, whereas for those who do not seek out healthier lifestyles that include greater amount of PA, PA monitors may not lead to significant motivation to become more physically active.

Participants in the study achieved an average VO_2max of 22.73 ml/kg/min $\pm$ 5.33, which placed individuals at an average FRIEND Registry Percentile (%) of 35.33 $\pm$ 20.98. The FRIEND Registry, which examines $VO2_{max}$ normalized standards for apparently healthy adults, was adapted to improve upon previous regression formulas for normalizing VO_2max standards in relation to maximal treadmill testing (64). This VO_2max correlates to a MET-level of 6.49, which leaves great room for improvement in regards to decreased mortality risk (every 1-MET level increase past this could lead to a 12% reduction in mortality). With CRF being such a strong predictor for overall health and mortality, being able to link this metric with PAI scores would be a valuable asset in exercise prescription for patients with decreased cardiac function and with known cardiac disease.

One the biggest limitations of the current study is the lack of PAI score availability from the 14-day observational period from the patients in cardiac rehabilitation. Whereas participants could report and monitor daily and weekly PAI scores throughout the study, official and final numbers were stored in a cloud based service inaccessible to the research staff conducting the study. In the future, this data will be available and will be important in determining the feasibility of patients from a cardiac rehabilitation program reaching a PAI score of greater than or equal to 100. From that, future studies can be done on the mortality risk and risk of future cardiac events for those with variable PAI scores. All participants in the study reported exercise volumes that exceed the minimum recommendations from ACSM (207.4 ± 59.16 compared to the 150 minutes of moderate intensity PA recommended by ACSM), yet no correlation to the PAI scores from participants in the study is currently available. Whereas participants reported levels of PA acceptable by ACSM standards, the average VO_2max was only 22.74 ml/kg/min $\pm$ 5.33, which would place the collective group at a FRIEND Registry percentile of 35.33% $\pm$ 20.98. This may be attributable to decreased cardiac function found in patients with known cardiac disease, as well as a marker of training programs not having high enough intensities to elicit responses in VO_2max. In future studies, being able to relate PAI scores to exercise volume and VO_2max in clinical populations could be beneficial in providing adequate feedback for training programs in this population. In a perspective study (to compare with recent retrospective studies concerning this topic), knowing the feasibility of cardiac rehabilitation patients to achieve PAI scores greater than or equal to 100 would be of great importance to understand the mortality risk and health outcomes for this population. The data could potentially help prescribe exercise and change recommendations for those with cardiac disease in order to achieve greater health outcomes, and this represents the biggest area of future research.

Conclusions

This study shows that participants using the PAI Health application to track PA and its corresponding PAI score can adapt to the technology quickly and are motivated by the technology, yet find the HR monitoring ability of hardware such as the Mio Slice to be inaccurate, wish more emphasis was placed on other metrics such as sleep time, and that the application was more compatible with other health and fitness applications. Generally, the PAI Health application was received favorably. However, adequate PA in the sample did not equate to increase VO_2max values, and having PAI scoring data available might help in the prescription of exercise for patients in a cardiac rehabilitation program in an effort to increase cardiorespiratory fitness.

Table 1.0 Subject Characteristics and Maximal Exercise Test Data

Sex (Male/Female)	8/2
Age (years)	70 ± 5.63
Weight (kg)	89.61 ± 13.92
Test Time (min)	10.27 ± 2.29
Max VO_2 (L/min)	2.04 ± 0.50
Max VO_2 (ml/kg/min)	22.74 ± 5.33
Peak VO_2 (ml/kg/min)	23.82 ± 5.38
Max RER	1.07 ± 0.07
VE_{btps} (L/min)	67.81 ± 15.76
RR (breaths/min)	29.53 ± 4.76
Max speed (mph)	3.73 ± 0.62
Max Grade (%)	14.73 ± 1.38
VE/VCO_2 Slope	28.11 ± 4.07
Resting $PetCO_2$	19.89 ± 2.85
Warm Up $PetCO_2$	21.89 ± 2.67
Max $PetCO_2$	29.44 ± 3.57
VT (ml/kg/min)	16.43 ± 2.95
HR at VT (beats/min)	105.60 ± 6.19
Max SBP (mmHg)	167.20 ± 20.09
Max DBP (mmHg)	75.60 ± 9.65
Max RPE	17.60 ± 1.35
Resting HR (beats/min)	62.30 ± 9.82
Max HR (beats/min)	138.30 ± 8.03
Recovery HR (beats/min)	118.90 ± 11.37
Exercise Test Ectopic Beats	6.00 ± 5.68
Recovery Ectopic Beats	1.30 ± 1.25
Reported Exercise (min/week)	207.4 ± 59. 16
FRIEND VO_2 Percentile (%)	35.33 ± 20.98

Data is presented as mean ± SE
Max VO_2 = Maximal oxygen uptake
RER = Respiratory exchange ratio
VE_{btps} = Expired minute ventilation
VT = Ventilatory threshold
$PetCO_2$ = End-tidal carbon dioxide pressure
FRIEND = Fitness Registry and the Importance of Exercise National Database

Table 2.0 Participant Experience Questionnaire Averages

Question	Average Score	Percent of Low Scores (%)	Percent of High Scores (%)
Overall, I was satisfied with the activity tracker.	3.9 ± 0.57	0	80
Using the activity tracker helped me set activity goals.	3.9 ± 0.57	0	80
Using the activity tracker helped me reach my activity goals more	3.6 ± 0.52	0	60
Using the activity tracker helped me to be more active.	4.1 ± 0.42	0	80
Using the activity tracker made it easier to be more active	3.4 ± 0.97	20	50
Using the activity tracker supported me in managing my health problems.	3.5 ± 0.53	0	50
I found it easy to learn to operate the activity tracker.	3.7 ± 0.82	0	50
I found the activity tracker to be clear and understandable to use.	4.0 ± 1.15	20	80
I found the activity tracker to be flexible to work with.	3.3 ± 0.48	0	30
Overall, the activity tracker was easy to use.	3.6 ± 0.70	0	50
People who influence my behavior would think I should use the activity tracker.	3.5 ± 0.85	10	50
People who are important to me would think I should use the activity tracker.	3.5 ± 0.97	10	40
I have the technology necessary to use the activity tracker	4.5 ± 0.53	0	100
I have the knowledge necessary to use the activity tracker.	3.7 ± 0.48	0	70
The activity tracker was compatible to use with other systems I use.	2.8 ± 0.92	50	30
I am very knowledgeable about my PA needs.	4.1 ± 0.48	0	80
I understand how to use PA to manage my health problems.	4.0 ± 0.67	0	80
The activity tracker was comfortable to wear.	4.5 ± 0.53	0	100
The activity tracker accurately tracked my PA.	3.2 ± 0.79	20	40

Data is presented as mean ± SE
Low scores determined as a rating of 1 or 2; High scores determined as a rating of 4 or 5

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