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The Effects of Using a Nike+ FuelBand to Measure Physical Activity in a Community Based Intervention among Middle-Aged Adults

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ABSTRACT

Purpose: To examine the response of middle aged adults (age 39-64) to feedback from wearable activity sensors in a 6 month community based intervention. Participants (N = 139) were a convenient sample randomly assigned into the treatment (n = 100) or control (n = 39) group. **Methods:** All participants were surveyed about their physical activity levels during the pre, mid, and post intervention surveys. The treatment group participants were given a Nike+ FuelBand and asked to report minutes of moderate and vigorous physical activity [PA] and FuelPoints daily. **Results**: There was a significant change in moderate and vigorous PA levels from the beginning to the end of the intervention by all (treatment and control) participants when measured with self-report surveys. It was found that novice exercisers (performing <150 minutes of PA weekly) significantly increased their levels of moderate PA in a non-linear way (p = .048) when measured with pre, mid, and post intervention self-report surveys. Contradicting results were found when looking at the treatment group's FuelBand data (FuelPoints). FuelPoints did not significantly differ across the intervention (p = .084). FuelPoints also did not differ by gender (p = .857), age tertiles (p = .459), or exercise level (novice moderate (p = .573) or novice vigorous (p = .184)). **Conclusion**: Participants in a community intervention did increase their moderate and vigorous PA. This increase in moderate and vigorous PA across the 6 month intervention was seen in the control group as well as the treatment group thus it was not in response to the use of a wearable PA sensor. The current technology limitations of wearable PA sensors when used in community interventions with middle-aged adults make it difficult to obtain accurate and objective measures of PA data. Until the technology is more accurate, community based PA studies should not rely upon wearable PA sensors alone for PA data collection or for motivation of their participants to perform more PA.

Introduction

Regular physical activity (PA) has been linked to the reduced risk of: hypertension, type 2 diabetes, coronary heart disease, colon and breast cancer, obesity, mental health problems such as dementia, and depression (Booth, Laye, Lees, Rector, & Thyfault, 2007; Heath et al., 2012; Kang, Marshall, Barreira, & Lee, 2009; Lee et al., 2012; Owen, Bauman, & Brown, 2009; Tompkins, Soros, Sothern, & Vargas, 2009). Yet with all of these benefits, physical inactivity is still an increasing global pandemic (Centers for Disease Control and Prevention [CDC], 2014; Hallal et al., 2012; Health et al., 2012). The scientific community has been trying different interventions to find ways to address this growing physical inactivity pandemic (Health et al., 2012). Attempts to study physical activity are difficult because the simplest and most common method of measuring physical activity has been self-report surveys which result in biased and inaccurate estimates of physical activity (Hagströmer Oja, & Sjöström, 2007; Hansen, Kolle, Dyrstad, Holme, & Anderssen, 2012; Napolitano et al., 2010; Troiano et al., 2007).

All basic accelerometers measure step count and intensity, some companies and devices use these measures to estimate energy expenditure (Yang & Hsu, 2010). Most wearable sensors being developed and used today rely on a type of accelerometery. Advancing technology has aided in making accelerometers (activity monitoring sensors) smaller, less invasive, and able to communicate the data recorded wirelessly. This ability is enabling PA research to be conducted in real life conditions with few inconveniences to study participants (Chen & Basset, 2005). Attrition levels are high in physical activity interventions and studies (Linke, Gallo, & Norman, 2011); the use of wearable PA sensors could be one way to decrease attrition levels as measures can be taken directly from the sensors and reported to researchers.

There has been some concern by researchers about the accuracy of wearable sensors. In a series of treadmill tests (*n* = 20), it was found that the FuelBand underestimated steps at or below 2mph and was accurate at 3.5-5 mph. Energy expenditure was also measured and found the FuelBand to be accurate at 2-3.5 mph and over estimated at 5mph. As the FuelBand is a wristworn sensor, this variability could be due to the variance in arm swing at the different speeds of motion (Jupe, Faries, Jones, & Whitehead, 2013). The FuelBand has an 8% discrepancy between the number of steps it recorded when compared with a handheld mechanical clicker during a 400 meter walk around a track (Guo et al., 2013).

With the advances in technology, researchers have begun to use physical activity monitors, like pedometers and accelerometers, as an objective and accurate way of gathering detailed physical activity data (Bock, Jarczok, & Litaker, 2013; Chen & Bassett, 2005; Hagströmer et al., 2007; Intille, Lester, Sallis, & Duncan, 2012; Kang et al., 2009; Toriano et al., 2007). The advances in cell phone technology have also aided the wearable physical activity sensors by providing a wireless digital platform to log and transfer data. Some cell phones are now even used as physical activity sensors themselves (Consolvo et al., 2006; Patel et al., 2012; Valentin & Howard, 2013). A meta-analysis of physical activity interventions showed that interventions that used pedometers have a high effect size (0.68) showing that these interventions have a significant effect on physical activity behavoir (Heath et al., 2012). There are limitations to what activities PA sensors can measure. For example, biking is difficult to measure if the sensor is worn on the hip or wrist, also many PA sensors are not waterproof and cannot be worn while swimming (Chen & Bassett, 2005; Pärkkä et al., 2006).

With physical activity monitors becoming smaller and more accessible their use in PA interventions has increased but their use has been predominately focused on children, adolescents, college-age students, adult sub-groups and older adults (65 years and older) (Burnet & Sabiston, 2010; Bock, Jarczok, & Litaker, 2011; Chen, Janz, Zhu, & Brychta, 2012; Hansen et al., 2012; Murphy, 2009; Taraldsen, Chastin, Riphagen, Vereijken, & Helbostad, 2011; Valentin & Howard, 2013). Middle aged adults (ages 40-64) are often incorporated in other PA studies that measure a much wider age range (Brunet & Sabiston, 2010) but there is not much data on physical activity interventions focused on this specific age demographic alone. This stage of life should not be forgotten when demographics are taken into consideration, as this time of life is a key time to be establishing or maintaining patterns of PA. Midlife PA modifications have fewer health risks than PA modifications later in life (Ayotte, Margrett, and Hicks-Patrick, 2010; Ziegelmann, Lippke, & Schwarzer, 2006).

Researchers ask as to whether or not wearing an accelerometer is enough to influence physical activity behavior and participants' reporting in research studies (Napolitino et al., 2010). The purpose of this study was to examine the response to feedback from a wearable activity monitor worn by middle aged adults (age 39-64) in a community based intervention. It was hypothesized that middle aged adults would change and modify their physical activity behavior in response to the feedback from wearable activity sensors; that novice exercisers would increase their physical activity level above those who were regularly exercising before the Gray Matters Pilot study began; and that the response to feedback from wearable technology would differ between men and women, and that PA levels would decline with age.

METHODS

Subjects. The participants in this study were also participants in the larger Gray Matters Alzheimer's Prevention Community Pilot Study. The sample was a convenient sample of middle aged adults from Cache County, Utah. Participants for the Gray Matters Pilot study were recruited in various ways: potential participants were contacted through Utah State University email lists, a promotional booth was stationed at each of two health fairs at a local hospital, posters were circulated in various locales throughout the community, a newspaper article advertising the study was published, and the local health department also assisted in recruitment. The inclusion criteria for the participants were: being between the ages of 40-64, living in Cache County, Utah, having a smartphone or tablet, and having no medical contraindications. The exclusion criteria included: dementia, unmanaged diabetes, untreated current major depression, pregnancy, and a BMI greater than 41. The participants' (N = 139) were randomly assigned to either the treatment (N=100) (see Table 1) or the control group (N = 39) (see Table 2), with the exception of spouses, who were assigned together. The Gray Matters participants were predominantly white and had high levels of education, all of the participants had some college and most (81%) have completed college or a graduate degree. A university Institutional Review Board (IRB) approved the study protocol and all participants were provided and signed an informed consent form. The entire sample completed the pre, mid, and post surveys, these surveys were taken and returned by $n_{survey1}$ = 145, $n_{sruvey2}$ = 138, and $n_{survey3}$ = 125 participants respectively. Our treatment sample consisted of 100 individuals, 35 men and 65 women (see *Figure 1)* who were given and reported FuelPoints from the Fuel Bands over the six months of the study (see Table 3).

Measurement of Physical Activity. Physical activity for the GM study, and the present study, was recorded in three different ways. First, all of the participants (control and treatment) were given the same pre, mid, and post treatment surveys which asked about current physical activity levels. Second, the treatment group also recorded their PA level on a daily basis with the GM smart phone application. The smart phone application asked the participants in the treatment group to slide a scale over to the number of minutes of moderate and vigorous PA performed each day (see *Figure 2).* Third, the treatment group was also given a Nike+ FuelBand, a tri-axial accelerometer that is worn on the wrist. The FuelBand is water resistant but not water proof so participants were asked to wear the FuelBand during waking hours with the exception of bathing and swimming. The FuelBand measures physical activity in FuelPoints which are proprietary measures of PA. According to controlled environment lab studies, the Nike+ FuelBand had abount an 8% discrepancy between the actual steps taken and the number of steps recorded (Jupe, Faries, Jones, & Whitehead, 2013). More specifically, it was found that the FuelBand underestimated steps at ≤ 2mph, was accurate at 3.5-5 mph and overestimated energy expenditure at or above 5mph (Guo, Li, Kankanhalli, & Brown, 2013).

As noted above, survey data were collected from both the control and the treatment group at three different time periods throughout the study. Time 1 was the first survey the participants took before any intervention began, Time 2 was given out after three months of the intervention, and Time 3 was given after the conclusion of the intervention at six months. The dates when participants took the three (pre, mid, and post) surveys were quite variable as each survey was sent out at the same time but completed at the participant's convenience. Before analyzing the data, researchers organized each participant's survey into groups: the participant's first survey equaled Time 1, their second survey equaled Time 2, and their third survey equaled Time 3.

As previously mentioned, Nike+ FuelPoints were also collected from our participants on a daily basis via the smart phone application, these data points were collected and weekly averages were computed for each participant. Regression lines were calculated with these weekly values for each participant, it is with these regression slopes that our analyses are computed.

Survey Analysis. All data analyses were conducted in SPSS 22.0 with the assumption of a two-sided alpha level of $p < 0.05$. Not all of the participants took all of the surveys. In order to ensure correct measurement of each participant, the first survey the participants completed was titled Survey 1, the second survey was Survey 2, and the final survey was Survey 3. An example of this is if a participant did not take Survey 1 but took Survey 2 and 3, their data for survey 2 was moved to Survey 1 as it was their first measure and their Survey 3 was moved to Survey 2 was it was their second measure. In order to use as many of the data points as possible, Mixed Linear Models were chosen for the analysis of these data.

FuelBand Analysis. FuelPoints from the FuelBands were entered into the smart phone application on a daily bases, each night the values were collected and stored. As not all participants submitted their FuelPoints each night the weekly average was taken for each participant and used in these analyses. Upon examining the data there were many drastic outliers (400 FuelPoints per day above the next lowest value) found amongst our participants as many of our participants were achieving well above the CDC's recommended 150 minutes of moderate and 75 minutes of vigorous PA each week (CDC, 2015). These individuals were removed from further analyses (see Table 2). After removal of the outliers, novice exercisers were categorized for this study as those achieving less than the CDC's recommended weekly values; for moderate PA a novice would be considered anyone performing less than 150min of PA per week, and a vigorous PA novice would achieve less than 75 minutes of vigorous PA per week (see *Figure 3)*.

RESULTS

The one of the purposes of this study was to examine the change in physical activity levels over the course of the intervention; the results showed that the treatment group's self-reported FuelPoint values from the beginning to the end of the study showed no significant differences, $t(99) = 1.75$, $p = .084$. Next examined was the hypothesis that novice exercisers (<150min PA/week) would have a larger increase in their activity levels than the regular exercisers (<150min PA/week) over the course of the intervention (CDC, 2014). This analysis was divided up by novice moderate ($n = 63$) and novice vigorous ($n = 87$), again no significant differences were found for either novice moderate, $t = 1.006$, $p = .317$, or novice vigorous, $t = -1.338$, $p = .184$, in reported FuelBand points.

An independent samples t-test was run to examine if the change in FuelPoints over the intervention varied by gender. No significant differences were found between FuelPoints recorded between men and women, $t(98) = .181$, $p = .857$.

Past studies have shown that PA tends to decrease with age (Aoyagi & Shephard, 2012). To examine the next hypothesis that FuelPoints will decline as age increases a one way ANOVA was run to examine the effect of age on FuelPoints. The treatment group participants were divided into three age groups with approximately the same percentage of participants in each group 39-51 (31.5 %), 52-58 (36.3%), 59-64 (31.5%), The results of this one-way ANOVA showed that there was no statistically significant change in any one of the age group's FuelPoints across the intervention, $F(2,97) = .784$, $p = .459$, (see *Figure4)*.

A multiple correlation analysis was run between the daily reported FuelPoints and the daily reported minutes of moderate and vigorous physical activity. This analysis showed no correlation between the self-reported FuelPoints and the self-reported PA levels, $r = -.002$, $n = 97$, $p = .985$, indicating that this very weak correlation was due completely to chance. With there being no correlation found, one-sample t-tests were run on the daily reports of FuelPoints and minutes of moderate and vigorous PA to determine if there was a change over time. These tests showed a significant difference in PA levels across the intervention for self-reported moderate, $t(98) = 9.910$, $p < .001$, and vigorous $t(97) = 5.376$, $p < .001$, PA levels. The one-sample t-test with FuelPoints, $t(99) = 1.748$ $p = .084$, was not found to be significant. These data support the finding that there is no correlation between the self-reported FuelPoints and the self-reported amount of PA performed on a daily basis. This finding is not one that was expected as PA sensors are typically more accurate measure of PA and would be expected to correlate with self-reported PA survey data.

The pre, mid, and post intervention surveys when analyzed with a Mixed Linear Model showed a significant difference in pre and post exercise levels for the treatment and the control group in both moderate and vigorous physical activity levels. Physical activity levels significantly changed for all participants (treatment and control) over the course of the 6 month intervention in a non-linear fashion for both moderate ($p = .002$) and vigorous ($p = .003$) PA regardless of treatment or control group status. When further analyzed, a significant non-linear difference was found in the treatment group when looking at moderate PA novices (Estimate = -71.942, $p = .048$) (see *Figure 5)*. These data show that novice moderate exercisers in the study increased their levels of PA more than the regular moderate exercisers. We used an unstructured covariance structure, when compared to the autoregressive 1 using the restricted maximum likelihood [REML] ratio test, the more complicated structure was justified ($\chi^2(4) = 65$, $p < .001$). Although there was a significant difference in vigorous PA seen across the intervention for all participants, the treatment group with the FuelBands ($p = .202$) were not statistically different from the control group (see *Figure 6)* in final PA level.

It was found that middle-aged adults in Cache Valley, Utah do change and modify their moderate and vigorous physical activity as measured by self-report surveys. It was also found through survey data that middle-aged treatment group novice exercisers significantly increased their physical activity across the intervention. In contradiction, it was found that these middle-aged adults did not change or modify their PA levels when measured by a physical activity sensor (Nike+ FuelBand). It was also found that the response to feedback from the PA sensors did not significantly differ by gender, age groupings, or exercise status (novice or regular as stated at the beginning of the study).

DISCUSSION

The lack of correlation between the daily reported FuelPoints and daily reported minutes of moderate and vigorous PA for the treatment group, and the pre, mid, and post intervention survey for the entire sample leave no clear answer to our research questions. According to the FuelPoint data, the participants did not significantly change their PA behaviors, however according to the participant reported levels of PA, there was a change. This increase in PA could be associated with feedback from wearing a PA sensor, the intervention spanning the summer months, increased motivation from participating in an intervention, and added knowledge about PA from the intervention's PA aspect, such as the Gray Matters Pilot study hypothesis that PA, along with other lifestyle modifications, can prevent or delay Alzheimer's Disease.

Physical activity was one of the six major domains studied in the larger Gray Matters Alzheimer's Prevention Pilot Study. As PA was only one part of the larger Gray Matters intervention, no PA inclusion or exclusion criterion was included and as such our participants for this study began with varying levels of PA. Some participants began at, and maintained, very high levels, causing outliers and a ceiling effect in the results but even with the ceiling effect removed no significance was found (see Table 4). Participants were also able to select the specific domain of the GM's study that they wanted to focus on during the intervention. Not all of our participants selected PA as a domain to work on during the intervention and yet were included in this study. Future studies to test our research questions would benefit from a more homogenous sample, starting with less PA variation and having PA as a focus for all participants. Exclusion criteria for potential participants performing well above the CDC's PA recommendations are usually not included in PA interventions, allowing for improvements in PA to be seen (Muller-Riemenshneider, Reinhold, Nocon, & Willich, 2008).

A potential reason our data did not correlate or meet statistical significance is the error in recording and reporting PA data. The Nike+ FuelBand varies in its measurement of activity, some participants reported their highest values after long car rides with limited PA and complained of low values after biking, running, or doing yoga. Wearable PA sensors used in other studies have also varied in accuracy dependent upon where the sensor is worn and what activity is being performed (Chen & Bassett, 2005; Murphy, 2009) There could also be human error involved in entering FuelPoints and daily PA levels into the smart phone application. This human error can be biased by social desirability, a lack of understanding, or even simple over/under estimation of actual PA performed. Another reason could be the loss of interest once the novelty of the wearable sensor and the intervention wore off. This loss of interest was seen in another study using a wearable PA sensor, their participants commented during the follow-up interview that once the novelty of the technology wore off there was nothing they liked. One participant commented that when they "began to think that it wasn't accurate, it lost its appeal" (Fausset et al., 2013, p. 1686).

It is recommended for future studies using accelerometers that the participants are familiar with the device and the software to be used before the intervention begins. To remove some human error it is also recommended that the accelerometer data be collected directly from the device. In addition, we encourage those who are designing new wearable activity sensors to design sensors with programs that will allow for the accurate detection of and the proper credit for the type of activity to be performed (Consolvo, Everitt, Smith, & Landay, 2006). This would hopefully allow the monitor to more accurately sense and record actual activity level and prevent erroneous PA attributions to sedentary activities.

CONCLUSION

Currently 31% of the world's population are not meeting the minimum physical activity requirements (World Health Organization [WHO], 2015). The pandemic of physical inactivity is adding to the increasing rate of chronic diseases and disabilities. With the increasing levels of physical inactivity, more exercise interventions are being done with wearable activity sensors to try and increase PA and decrease chronic disease. The current middle aged population (the baby boomers), comprises more than 20% of the US population and they spend more than half of their days sedentary, yet they are a forgotten demographic and are rarely the target demographic of these exercise interventions. When involved in a community based intervention, middle aged adults (39-64) self-reported an increase in levels of both moderate and vigorous physical activity but these increases were not seen by the objective PA sensors. In future community studies, care should be taken when using objective measures of PA to ensure that participants know how to use them, that they are working properly throughout the study, and that they are not the only measures of PA used in the study

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Table 1

*Treatment Group with FuelBand Data Demographic Profile (*N = 100)

Group	*n*	Percent
Gender		
Male	35	35
Female	65	65
Age		
39-52	29	31.7
53-57	35	36.6
58-64	36	31.7
Education Level (*n* = 81)		
Some College	15	18.5
Bachelor's Degree	33	40.7
Graduate Degree	33	40.7
After outliers have been removed (*N=98)*		
Gender		
Male	34	34.7
Female	64	65.3
Age		
39-52	28	28.6
53-57	35	35.7
58-64	35	35.7

Table 2
Change in Moderate and Vigorous Physical Activity across the 6 month intervention using the Pre, Mid, and Post Survey Data.

	Moderate PA All Subjects		Moderate PA Novices		Vigorous PA All Subjects		Vigorous PA Novices	
	1a	1b	2a	2b	3a	3b	4a	4b
Intercept	0.844 (p=.990)	-1.148 (p=.993)	-181.244 (p<.001)	-23.785 (p=.797)	-21.207 (p=.650)	-2.464 (p=.978)	-138.272 (p<.001)	-84.850 (p=.143)
Time	296.127 (p<.001)	289.836 (p=.006)	332.364 (p<.001)	114.304 (p=.355)	160.634 (p=.002)	121.961 (p=.217)	210.065 (p<.001)	124.349 (p=.106)
$Time^2$	-71.723 (p=.002)	-69.863 (p=.087)	-74.009 (p<.001)	-20.166 (p.519)	-38.664 (p=.003)	-24.956 (p=.296)	-46.724 (p<.001)	-24.044 (p=.215)
Treatment Group		2.438 (p=.987)		-213.115 (p=.052)		-28.327 (p=.782)		-69.982 (p=.291)
Treatment Group x Time		-6.136 (p=.975)		295.313 (p=.043)		55.540 (p=.631)		112.608 (p=.202)
Treatment Group x $Time^2$		0.311 (p=.995)		-72.942 (p=.048)		-19.368 (p=.490)		-29.757 (p=.182)
-2Log Liklihood	5609.59	5609.52	2061.38	2056.62	5182.43	5177.61	2687.37	2680.97
Parameters	9	12	9	12	9	12	9	12
X^2(df)	X^2(3)=.074 (p=.995)		X^2(3)=4.756 (p=.191)*		X^2(3)=4.815 (p=0.186)		X^2(3)=6.398 (p=.094)	

Note: Values given are the estimates of fixed effects. The "a" column analyses are run with data from the entire sample. The "b" column analyses are run with data from the treatment group.

Table 3

All Participants' Demographics Profile (N = 139)

Group	*n*	Percent
Gender		
Male	47	33.8
Female	92	66.2
Age Tertiles		
39-51	46	31.5
52-58	53	36.3
59-64	46	31.5
Control Group (*N* = 39)		
Gender		
Male	12	30.8
Female	27	69.2

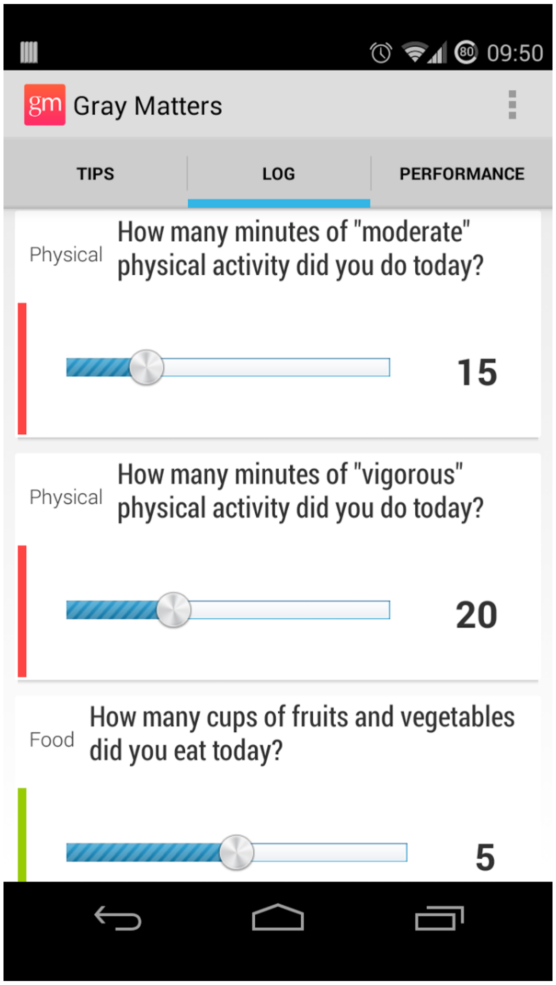
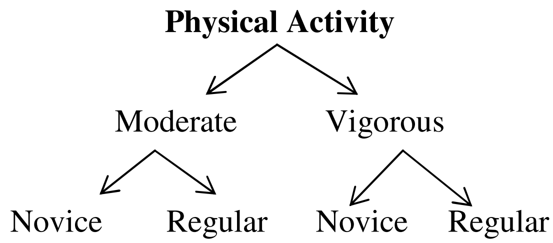


Figure 2. Smart Phone Application for Daily Entering of Moderate and Vigorous Physical Activity.



Physical activity levels were defined using the CDC's weekly recommendations (CDC, 2014).

Novice: Participants achieving *less than* the recommended 150 minutes of moderate or less than 75 minutes of vigorous physical activity per week.

Regular: Participants achieving the recommended 150 minutes of moderate or 75 minutes of vigorous physical activity per week.

Figure 3. Flow Chart of the Divisions of Physical Activity used in this study.

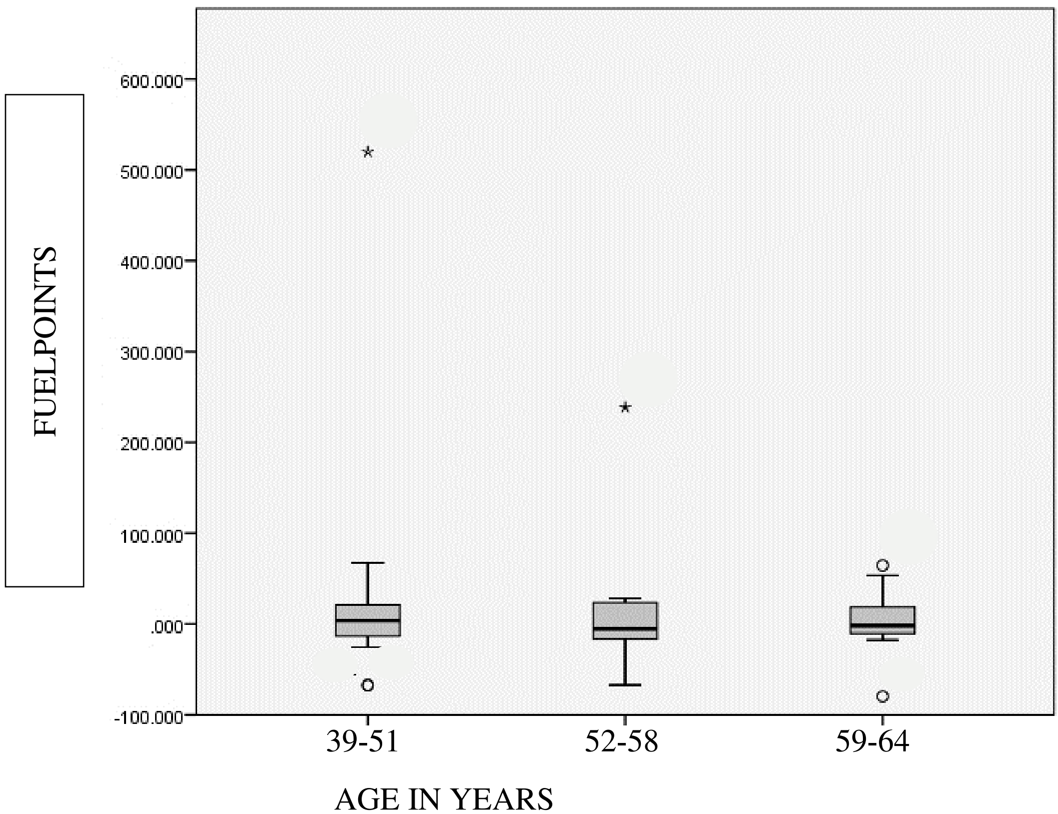


Figure 4. The distribution of FuelPoints per age tertile after removal of the highest two outliers.

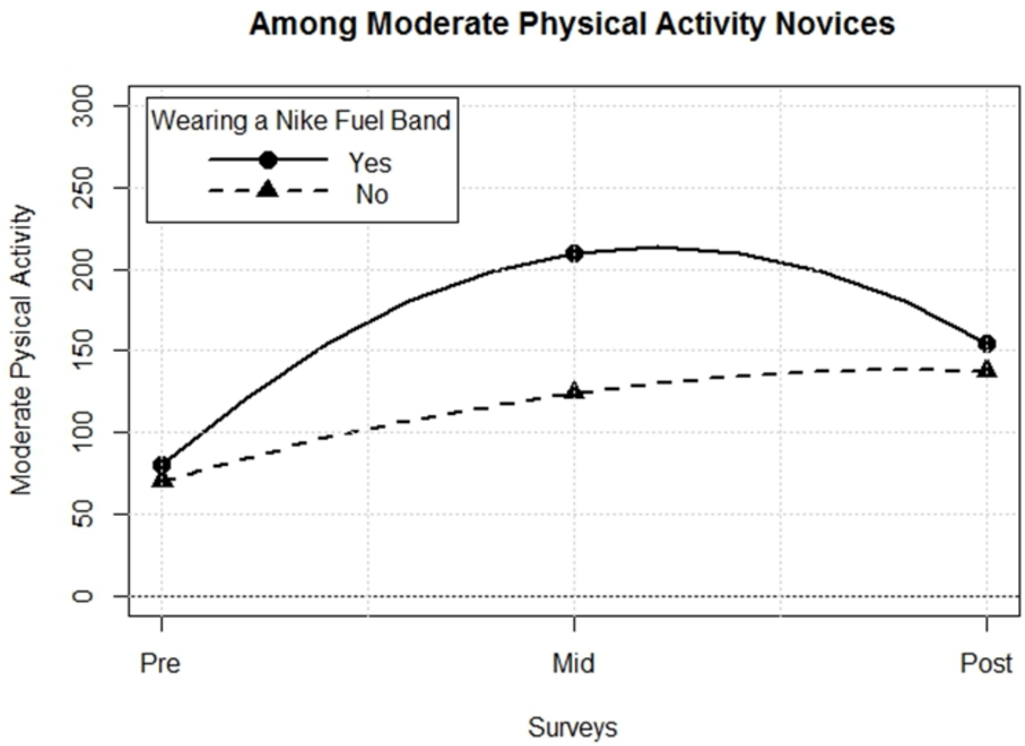


Figure 5. Change in Moderate Physical Activity Levels for Novice Exercisers across the Intervention.

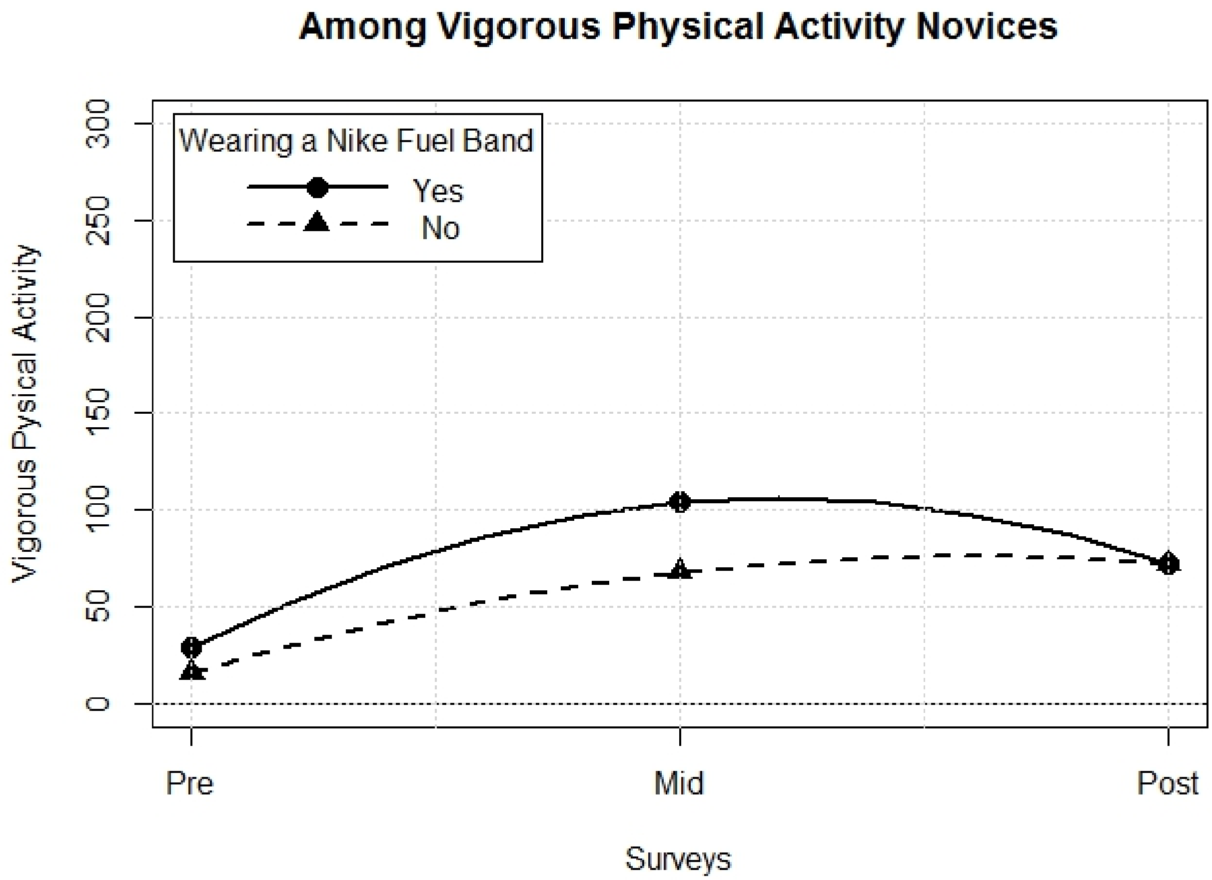


Figure 6. Change in Vigorous Physical Activity Levels for Novice Exercisers across the Intervention.

Table 4.
Data Analyses (t-test, one-way ANOVA) with Ceiling Effect Removed from the FuelBand Sample Data (FuelPoints).

	Moderate Novice	Vigorous Novice	Gender	Age Tertiles
N	69	68	72	71
t-score	-0.859	-0.930	-0.621	
p-value	.393	.356	.537	.547
F-score				0.608

Note. The data analyses were run using the regression slopes for the participants' FuelPoint data.