

Impact of Wearable Technology on Physical Activity, Fitness, and Health Outcomes in College Students with Disabilities

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Abstract Physical activity (PA) in the United States progressively continues to decline despite research highlighting the importance of an active lifestyle. Particularly, recommended levels of PA are associated with reduced risk for a large number of negative, yet preventable health conditions in apparently healthy populations. Unfortunately, individuals who report having one or more disabilities perform far less PA than their apparently healthy counterparts. While technological advancements such as wearable devices to monitor PA have become popular, few studies have evaluated the effectiveness of wearable technology-based interventions on increasing PA levels and improving health outcomes in college students and individuals with disabilities. Thus, the purposes of this investigation were (1) to evaluate if providing a Fitbit PA tracking device to college students with disabilities would increase PA and improve health outcomes such as cardiovascular (CV) fitness and body composition, and (2) to investigate whether the addition of health education sessions would provide additional benefits. A total of 24 participants (27 ± 7 years) were given a Fitbit and had their PA monitored over twelve weeks. Group randomization was conducted where one group received only the Fitbit (FO) and a second group where participants also received health education sessions (E+F). Pre and post physiological assessments were also conducted. No significant group*time interactions were observed. Significant increases in mean treadmill duration and VO_{2peak} occurred from pre to post. Mean daily steps in the E+F group were significantly higher than the FO group (8134 ± 441 vs. 7581 ± 577 , respectively). Twelve weeks of Fitbit usage was effective in increasing CV fitness in individuals who identified as having one or more disabilities. Considering the lack of a significant improvement in health outcomes by the addition of educational programming the use of a Fitbit alone may be sufficient to improve CV fitness in this population.

Keywords: physical activity, disabilities, activity tracking, college-age students, health disparities

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1. Introduction

The second edition of the Physical Activity Guidelines for Americans (PAGA) recently released by the United States Department of Health and Human Services has provided specific recommendations for physical activity (PA). In particular, adults have been recommended to participate in at least 150 minutes/week of moderate intensity PA or 75 minutes of vigorous PA [1]. However, according to Healthy People 2020, 32.6% of adults aged 18 or older have reported not engaging in any PA. In addition, of those adults who do participate in PA, only 18.2% meet the current guidelines [2]. College-aged

individuals seem to be even less active, with 50.0% of those aged 18-30 not meeting current PA guidelines [3]. This is concerning because many life-long health behaviors are developed during the college years [4,5,6]. Thus, behavioral interventions aimed at increasing exposure and adherence to PA, meeting or exceeding daily recommended levels, within this demographic is crucial.

A large, but less addressed population in the PA literature is individuals with disabilities. Approximately 12.6% of individuals living in the United States have some form of physical disability [7]. The Center for Disease Control and Prevention (2016) noted that the obesity rate for adults with disabilities was 58.0% greater than adults without disabilities. According to Healthy People 2020, 56.0% of adults with disabilities reported

engaging in no leisure time PA compared to 36.0% of adults without a disability, and consequently, reported greater rates of health problems than adults without disabilities [2]. When comparing adults with disabilities to those without, those with a disability were noted to be three times more likely to have a disease such as heart disease, stroke, and some forms of cancer. While more information is needed regarding specific disabilities, sufficient evidence exists to recommend that adults with disabilities participate in regular activity and the guidelines are consistent with those for apparently healthy adults [1]. Secondary conditions are often a result of lack of physical activity. These conditions may contribute to physical and psychological dysfunction exceeding the effects of the disability itself, and influence barriers to community participation, employment, and general quality of life for individuals with disabilities [8,9]. Preventative health and the overall wellness needs of people with disabilities are often ignored due to barriers such as low socio-economic status, lack of adapted equipment and facilities, lack of transportation, and a focus on the primary aspects of the disability. As a result of these obstacles, it significantly increases the likelihood for becoming overweight or obese, as well as having negative health outcomes and secondary conditions related to obesity and their disabilities [10]. Thus, affordable and convenient methods to empower this population to participate in PA are necessary.

Wearable technology has enabled individuals a greater ability to account for PA and is marketed as a motivating resource. Wearable devices and their accompanying smart phone applications have been increasing in popularity and affordability [11]. Many wearable PA tracking devices such as the Fitbit offer options for goal setting, rewards, and even social support through mobile interfaces that enable the user to connect to and interact with their peers [12]. Further, these devices offer individuals the opportunity to self-monitor PA habits and trends [13]. Research in the general population has shown that Fitbit use may be an effective technique for supporting health promotion efforts [14]. This wearable technology offers an attractive platform for instituting PA interventions targeting college students because it is appealing to this population [15]. Fitbits are one of the most recognized and widely used exercise devices, and have been acknowledged with “wearable technology” rating high in the 2016 and 2017 American College of Sports Medicine (ACSM) Fitness Trends [16,17]. Interacting with peers and sharing PA goals provides a source of accountability. As a result of this social interaction, this may, in part, explain why these devices have demonstrated promise as a potential pathway for increasing physical activity behavior [18]. While wearable trackers have shown positive outcomes in increasing average steps, research is limited on their impact on health outcomes [19].

Literature suggests that college students are a grossly under-evaluated population when it comes to physical activity interventions [20,21,22,23]. Very few studies have examined PA in this population segment, which is concerning considering individuals with disabilities may be far less active than their able-bodied counterparts, and thus present with substantially greater risks for disease [24]. Technology-based interventions to promote PA in college students have shown potential to positively impact

PA outcomes in several studies [23,25,26] and have been demonstrated to be appropriate for use in individuals with disabilities [27]. However, to our knowledge few studies have evaluated the effectiveness of wearable technology-based interventions on PA and their impact on fitness and health outcomes in college students and individuals with disabilities. [19]. Therefore, the purposes of this investigation were (1) to evaluate if providing a Fitbit to college students with disabilities would improve PA and health outcomes, and (2) to investigate whether the addition of a comprehensive health education session would further enhance the impact of these devices.

2. Materials and Methods

All study procedures were approved by the University’s Institutional Review Board [1665-2081]. The inclusion criteria for the participants in this study were as follows: any full or part-time student over the age of 18 who identified as having a disability. Participants were recruited via email distributed by the Director of Disability Services to all registered students who were currently receiving services. No particular requirements were made in this email. Students only had to identify as having one or more disabilities which qualified them for assistance through Disability Services. They were not required to disclose their disability to the researchers. An informed written consent and PAR-Q forms were completed prior to participation. If a participant answered “yes” to any of the six questions on the PAR-Q, additional physician’s consent was required for participation. A total of 24 participants (27 ± 7 years of age) completed comprehensive physiological assessments prior to participating in the intervention. Anthropometric data including age, height, weight, and body composition were collected pre and post intervention. Body composition was assessed via bioelectrical impedance analysis (Tanita Inc., Arlington Heights, IL). Cardiovascular fitness was assessed using the modified Balke Treadmill Protocol [28]. This test was performed as a peak test that maintained a consistent pace while grade increased incrementally until volitional fatigue. Twenty-three participants completed post testing; however, of these two individuals did not wear their device consistently to extract PA data and were subsequently removed from the study. A total of 21 participants (27 ± 8 years) were then included in the results.

Following pre-testing, all participants were given a Fitbit Charge HR (Fitbit Inc., San Francisco, CA) and asked to wear the device 24 hours a day for 12 weeks. This device has been demonstrated to be valid and reliable for collecting a variety of health behavior data, such as heart rate, steps, distance traveled, floors climbed, calories burned, active minutes, hours asleep, and times awakened [29].

Participants were randomized by flipping a two-sided coin into a group which also received additional health education (E+F) or a group only asked to wear the Fitbit (FO). The E+F group was asked to attend five bi-weekly educational settings lasting one hour over the course of the study. Subjects of the educational settings included the following: review of Fitbit features and troubleshooting, goal setting, starting and maintaining an exercise program, motivational topics, nutritional counseling, social support

sessions, and strategies to maintain positive behavioral change. The FO did not meet during the intervention period but were encouraged to reach out to researchers if they experienced any issues with their device. Post-testing took place following 12 weeks of the intervention and included the same battery of assessments completed prior to the intervention. Fitabase software (San Diego, CA), a third-party database, was used to collect and extract daily PA data from the Fitbit devices. These devices utilize triaxial accelerometry which is tabulated on a daily basis. Compilation of overall PA scores included total active minutes (TAM), very active minutes (VAM), fairly active minutes (FAM), lightly active minutes (LAM) sedentary minutes (SM), and mean daily step counts. Determination of MVPA occurred by way of summing daily FAM and VAM. Acceptable validity and test-retest reliability of the Fitbit device for the quantification of MVPA in both laboratory and free-living conditions have been demonstrated in the general population [29,30] and is a method that has been published elsewhere [31,32,33].

The Physical Activity Scale for Individuals with Physical Disabilities (PASIPD) was also administered to assess PA prior to and following completion of the intervention. The PASIPD contains 12 items and five factors: (a) home repair and lawn and garden work, (b) housework, (c) vigorous sport and recreation, (d) light/moderate sport and recreation, and (e) occupation. Respondents were asked to indicate the weekly frequency and duration of their engagement in each activity. Scores were computed by multiplying the average hours per day of an activity by a metabolic equivalent of task (MET) value, which represents the intensity of physical activities. The scores are summed across all items, and the maximum possible score is 199.5 MET hours per day (MET-hr/d). Test-retest reliability for the PASIPD over a 1-week interval was reported to be 0.77 [34]. Internal consistency coefficients for the five PASIPD factors range from 0.37 to 0.59 [35].

3. Statistical Analyses

A series of 2x2 (group x time) repeated measures analysis of variance (RMANOVA) were utilized to evaluate group differences and time-related changes among dependent variables. Several independent *t*-tests were used to evaluate differences in average daily steps and total weekly MVPA, TAM, VAM, FAM, LAM, and SM by group. A priori boxplot data inspection techniques revealed no outlying data or anomalous numerical occurrences. Dependent variables were normally distributed as assessed by Shapiro-Wilk's test ($p > 0.05$). There was homogeneity of variances for average daily steps ($p = 0.561$), MVPA ($p = 0.443$), TAM ($p = .565$), VAM ($p = .301$), FAM ($p = .215$), LAM ($p = .810$) and SM ($p = .333$) by group as assessed by Levene's test for equality of variances. All statistical procedures were performed in SPSS Version 22 (IBM®) and alpha was set at .05 for all analyses.

4. Results

Groups were not significantly different at baseline in regards to age, height, or weight (all $p > 0.05$) (Table 1).

No significant ($p > 0.05$) group by time interactions were found for treadmill duration, VO_{2peak} , PASIPD, weight, or body fat percent (all $p > 0.05$) (Table 2).

Table 1. Initial Participant Demographics

	E+F (n=10)	FO (n=11)	Combined (n=21)
Age (years)	27 ± 8	27 ± 8	27 ± 8
Height (cm)	165 ± 9	165 ± 11	165 ± 10
Weight (kg)	75 ± 21	68 ± 17	72 ± 19
Body fat (%)	32 ± 14	28 ± 8	30 ± 11
Female (n)	8	7	15
Male (n)	2	4	6

Note: E+F = educational programming and Fitbit usage; FO = Fitbit only.

There was an increase in PASIPD scores in both groups with main effects results trending towards significance ($p = 0.055$). No statistically significant main effect of group was observed for treadmill duration, VO_{2peak} , PASIPD, weight, or body fat percent (all $p > 0.05$). There was a significant increase in mean treadmill duration ($F_{1,19} = 9.78$, $p = 0.006$) and VO_{2peak} ($F_{1,19} = 10.431$, $p = 0.004$) from pre to post when groups were combined. Mean daily steps in the E+F group ($F_{1,19} = 2.638$, $p = 0.015$) were significantly higher than the FO group (8134 ± 441 vs. 7581 ± 577 , respectively). These results are presented in Table 3 as mean ± SD and graphically in Figure 1.

Table 2. Means ± SD for Each Dependent Variable by Time and Group

	E+F (n=10)		FO (n=11)		Combined (n=21)	
	Pre	Post	Pre	Post	Pre	Post
Treadmill Time (min)	10±4	13±5	12±4	13±4	11±4	13±4*
VO_{2peak} (ml/kg ⁻¹ /min ⁻¹)	31± 8	35±9	32±7	35±6	32±7	35±7*
PASIPD	15±14	17±14	18±8	22±10	17±11	19±12
Weight (kg)	75±21	76±21	68±17	68±17	71±19	72±19
Body fat (%)	32±13	33±13	27±8	27±8	29±11	30±11

Note: PASIPD = Physical Activity Scale for Individuals with Physical Disabilities; * indicates a significant difference between pre and post. $p < 0.05$.

Table 3. Means ± SD for Average Steps per Day by Group

Week	E+F (n = 10)	FO (n = 11)
1	7776 ± 2588	7364 ± 3938
2	8228 ± 2179	8320 ± 4101
3	8257 ± 2190	6785 ± 3600
4	8799 ± 2910	8665 ± 3723
5	7559 ± 2168	6661 ± 2953
6	7989 ± 2374	7353 ± 2451
7	8607 ± 2553	7580 ± 3881
8	7621 ± 2749	7814 ± 3137
9	8272 ± 1940	7288 ± 3217
10	8621 ± 2377	7399 ± 2221
11	7504 ± 2162	7779 ± 2696
12	8369 ± 2349	7963 ± 2790
Average over the 12 Weeks	8134 ± 441*	7581 ± 577

Note: E+F = educational programming and Fitbit usage; FO = Fitbit only usage *indicates a difference between groups. $p < 0.05$.

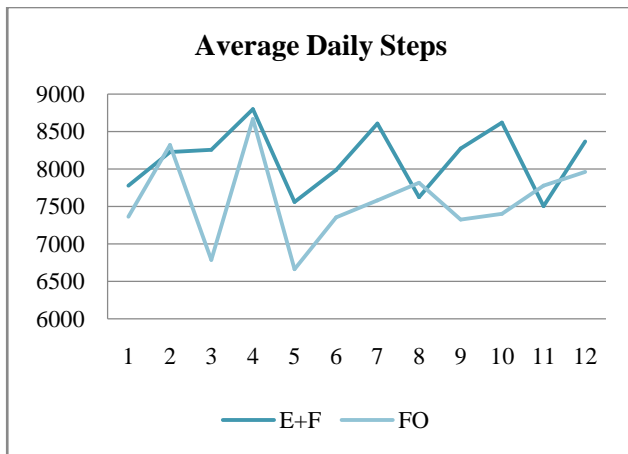


Figure 1. Group Daily Step Averages by Week

There was not a statistically significant difference between groups for MVPA, $t(22) = -1.531$, $p = 0.14$ or FAM, $t(22) = 0.006$, $p = 0.995$. There was a statistically significant difference in activity with the E+F group participating in more TAM, $t(22) = 7.496$, $p < 0.001$ and LAM $t(22) = 8.66$, $p < 0.001$, than the FO group. The FO group participated in significantly greater VAM, $t(22) = -2.321$, $p = 0.03$ and SM $t(22) = -9.220$, $p < 0.001$ than the E+F group. Descriptive data for average weekly physical activity minutes are presented in Table 4 as mean \pm SD.

Table 4. Means \pm SD for Average Weekly Physical Activity Minutes by Group

Physical Activity Variables	E+F (n = 10)	FO (n = 11)
VAM	60 \pm 15	77 \pm 19*
FAM	80 \pm 11	80 \pm 15
LAM	1740 \pm 94*	1415 \pm 90
SM	5345 \pm 229	6331 \pm 292*
TAM	1820 \pm 99*	1572 \pm 110
MVPA	141 \pm 22	157 \pm 30

Note: VAM = Very active minutes; FAM = Fairly active minutes; LAM = Lightly active minutes; SM = sedentary minutes; TAM = Total active minutes (VAM + FAM + LAM); MVPA = Moderate to vigorous physical activity (VAM + FAM), E+F = educational programming and Fitbit usage; FO = Fitbit only usage *indicates a difference between groups. $p < 0.05$. * indicates a significant difference between groups. $p < 0.05$.

5. Discussion

The results of this study would indicate that utilization of the Fitbit was effective as cardiovascular fitness (VO_{2peak}) was improved in both groups. Step counts, TAM and LAM in the E+F group were significantly greater than those observed in the FO group; however, MVPA did not increase and did not result in a significantly higher increase in cardiovascular fitness than the FO group. Physical activity increased in both groups as assessed through the PASIPD, however, results were not significant. This result is in agreement with some [15,31,36] but in contrast to others who have shown increased activity from the use of a wearable activity tracker [11,37,38,39]. An important distinction is that PA levels prior to and after the intervention in this study were measured through survey format rather than via direct measurement through

accelerometry. It is also important to note that the intervention was not focused on encouraging increasing PA levels as it was of interest to investigate whether the use of a Fitbit alone impacted PA. Therefore, the focus of the educational aspect of this study was intended to increase knowledge and awareness of the importance of just being physically fit and was not focused on engaging individuals toward initiating or increasing moderate or vigorous types of PA.

As a benchmark for attainment of weekly PA, the American College of Sports Medicine (ACSM) recommends that individuals are engaging in a minimum of 150 minutes of MVPA each week [40]. While the results of this investigation did indicate improvement in cardiovascular fitness levels in both groups, the results of this investigation also highlight a significant deficit in PA among this sample as mean daily steps in both groups fell short of the 10,000 steps per day recommendation [41]. Using the summation of VAM and TAM the E+F group on average was near the ACSM's recommendation of 150 minutes of MVPA per week and the FO group exceeded it (141.0 ± 22.0 and 157.0 ± 30.0 minutes, respectively). The often-cited goal of 10,000 steps per day has been shown to be associated with health benefits and is generally accepted without any current authoritative endorsement and research supporting that recommendation is limited. A recent systematic review evaluated the relationship of PA by step counts with various health outcomes in addition to interpreting these findings in the context of the development for the new PA guidelines. Results from that investigation showed an inverse dose response relationship of daily steps with important health outcomes such as all-cause mortality, cardiovascular events, and type 2 diabetes. However, investigators concluded more evidence will be necessary before a specific step count is translated and endorsed for public health guidelines [42]. Despite the lack of a specific step count in the 2018 PAGA, for many individuals measuring daily step counts is a relatively straightforward measure of PA and may be easier than attempting to quantify intensity. The abundance of available devices, such as the Fitbit, make step counts an easy and accessible way to monitor and set PA goals. Recommended amounts of MVPA have been computed to be approximately 8,000 to 11,000 steps/day of which a portion of these steps (3,000/day) should be of moderate intensity [41]. In terms of normative data, it appears that 10,000 steps per day is a reasonable target for adults although health benefits may be achieved in as few as 7,000 steps/day, which is the minimum stated in the 2011 ACSM position stand [40,41]. At the conclusion of the intervention, both groups in this study performed far less (8134.0 ± 441.0 and 7581.0 ± 577.0 steps per day, respectively) than the 10,000 minimum daily recommendation. While the results of this investigation indicate substantial deficits in weekly achievement of PA in this population, other investigators have also demonstrated similar occurrences [11]. This highlights the importance of finding an effective modality to increase PA in this population. Presently, the combination of education and a Fitbit seems to provide some benefit. In addition, the results of this investigation also greater reveal a segment of the population who may be even more at risk for health risks related to physical inactivity.

From a practical standpoint, this investigation has also highlighted an area where higher educational administrators and personnel can play a fundamental role in positively impacting the lives of students with disabilities on their campuses. For example, on campuses where wellness initiatives currently exist, a greater amount of purposeful engagement with students who identify as having one or more disabilities should be emphasized in addition to striving to increase PA among the general population of students. By strategically aiding students with disabilities in the pursuit of obtaining, maintaining, and sustaining overall physical health during the college years can only serve to improve this disparity.

The results of this investigation have not deviated beyond what the literature has already highlighted on MVPA in college students being somewhat minimal in improvements [15,19]. However, the step count data presented in this investigation are in contrast to that by Rote [39] which found that college students wearing a Fitbit throughout the semester in conjunction with an educational component significantly increased their steps. In addition, the results presented in this paper are also in contrast to others in overweight and obese adult men and women which have shown significant increases in MVPA over the intervention period [11,38]. While it appears that utilizing a Fitbit in addition to a health-related educational component were beneficial in improving weekly step counts, it is important to note that the E+F group receiving additional support was more active than the FO group indicating multi component interventions to promote physical fitness may be more effective [39].

Wearable devices have shown positive outcomes in increasing step counts, however, investigation into the impact on health outcomes and various other physiological variables has been minimal [36]. To our knowledge this is the first study to evaluate the impact of a Fitbit on fitness levels in college students with disabilities. The implementation of a Fitbit as a component of the intervention seems to be a useful tool in increasing cardiovascular fitness in this population. While results from the present study did not find the use of the Fitbit to significantly impact body weight or body composition, the significant increase in cardiovascular fitness is an important finding as it is an important health outcome that has inverse relationships to a variety of chronic health conditions. While not a significant result, the increase in PA in both groups is also a promising outcome of this study. The educational intervention resulted in significantly higher step counts and TAM than the FO group, however, this higher amount of PA did not result in a more significant improvement in cardiovascular fitness. This is likely due to the fact that the FO group had higher amounts of VAM than the E+F group. While attendance rates to these educational sessions was high (80% overall) a limitation to this study is that it was not 100%, which may have impacted our outcomes.

As a population that may be experiencing marginalization by way of negative perceptions or stigma coming from able-bodied community members, the implementation of techniques to reduce barriers to PA or exercise in addition to generating inclusivity and acceptance among their peers is important. The results of this study have not only demonstrated that this population may be at a greater risk

for inactivity-related health conditions, but has also highlighted the feasibility of administering a successful intervention aimed at improving fitness in this sample. However, more questions have arisen that should be addressed in future investigations. For example, our groups reported a broad set of disabilities, but the individual differences between were not evaluated. Future studies should aim to greater understand the potential influence each particular disability classification may play on PA, and how best to individually address the needs of each.

6. Conclusion

Twelve weeks of Fitbit usage and bi-weekly health-related educational programming was feasible and effective in increasing cardiovascular fitness in individuals who identified as having one or more disabilities. Considering the lack of a significant difference in this improvement between groups, a Fitbit alone may be sufficient to improve fitness in this population. However, neither intervention was successful in significantly improving PA levels or other health outcomes. Other strategies or methods may need to be utilized in addition to wearable devices if the goal is to increase PA in this population. Future investigations should look to evaluate the effectiveness of different strategies in addition to the use of wearable technologies for improving physical activity and other health outcomes in these populations. There is currently a large body of evidence surrounding the validity of these wearable trackers but the literature examining their impact on physical activity and the length of that impact is minimal and remains an area of interest for further investigation.

This study contributes to the growing body of literature examining the effectiveness of wearable technology in impacting or improving PA levels in a very under investigated population. Of greater importance, this study also highlights an under-recognized health disparity among college-age individuals, their risk for diseases related to inactivity, and an opportunity for college administrators or wellness coordinators to develop targeted programs aimed at reducing this disparity on college campuses.

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List of Abbreviations

PAGA: Physical Activity Guidelines for Americans

USDHHS: US Department of Health and Human Services

PA: Physical Activity

E+F: Educational programming and Fitbit group

FO: Fitbit Only group

TAM: Total Active Minutes

VAM: Very Active Minutes

FAM: Fairly Active Minutes

LAM: Lightly Active Minutes

SM: Sedentary Minutes

MVPA: Moderate to Vigorous Physical Activity

PASIPD: Physical Activity Scale for Individuals with Physical Disabilities

MET: Metabolic Equivalent

RMANOVA: Repeated Measures Analysis of Variance

ACSM: American College of Sports Medicine

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