Impact of a Smartphone-Delivered Sedentary Behavior Intervention on Glucose Metabolism in Prediabetic Adults

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ABSTRACT

This study investigates whether an 8-week lifestyle-based, smartphone-delivered intervention targeting reduction in sedentary behavior (i.e., sitting) significantly reduces objectively measured time spent sitting and improves fasting glucose and insulin. The incidence of type II diabetes has continued to increase in the United States and increases in sedentary behavior along with reductions in physical activity throughout the day have contributed to the increase of disease. The prevalence of smartphone usage in the United States has also continued to increase and 77% of all adults own a smartphone. Considering more than half of those adults use their smartphone for health purposes, a smartphone-delivered intervention will be very effective and efficient. There were 31 participants in the study and they started with a 3-week run-in period where a basic self-monitoring component was installed on their smartphone. After this run-in period, participants were randomly assigned to one of the eight experimental conditions. All participants received a basic self-monitoring with feedback component where they self-reported sleep, sedentary, and more active behaviors. Sitting time was measured with the activPAL3c, which is a device that they wore 24/7. Study visits occurred at week 0 (immediately after the 3-week run-in period), week 4, and week 8. Fasting glucose and insulin were measured at each of these visits. Participants logged approximately 60% of their sleep, sedentary, and exercise behaviors, which took 3– 4 min/day to complete. The impact of the intervention was not significant, such that decreases in sedentary time in those assigned to the sedentary component did not significantly differ from those not assigned to the sedentary component at 8 weeks (beta (SE) = -1.19 (.32), $p>0.05$); however, the effect size was moderate (Cohen's d = 0.29). There was no significant impact on fasting glucose or insulin.

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INTRODUCTION/SIGNIFICANCE

The prevalence of type II diabetes is continuing to increase in our society. The NHANES III (1989-1994) and NHANES (1999-2004) studies showed an overall increase in type II diabetes from 5.8% to 7.0%. This increase was more pronounced in men who showed an increase from 5.8% to 7.1% compared to women who increased from 6.0% to 6.5%.[1] Many studies have found a significant correlation between sedentary behavior (i.e. sitting) and type II diabetes and metabolic syndrome. Sedentary behavior is a term that encompasses activities where total energy expenditure is low; including prolonged sitting during a commute, the workday or leisure activities (watching TV, playing video games, being on the computer, etc.).[2] Metabolic syndrome is when a person has three of the following five risk factors for heart disease and other health problems; large waistline, high triglycerides, low HDL, high blood pressure, or high fasting blood sugar. When sedentary behavior is quantified, the average American spends 7.67 hours per day sitting. This number is lowest in youths ages 6-11 who spend 6.07 hours sitting and highest in adults ages 70-85 where time spent sitting is 9.28 hours per day.[4]

Although physical activity is very important in reducing the likelihood of developing an adverse health condition, it is also important to reduce the total amount of time spent sitting each day. New research agendas are looking into ways to reduce or break-up prolonged sitting time in an effort to increase light intensity and moderate to vigorous intensity physical activities throughout the entire day. One study showed that participants who did not engage in any moderate or vigorous physical activity during leisure time had almost twice the odds of having metabolic syndrome as those who reportedly engaged in at least 150 minutes per week of such activity.[3] In a study performed by Dr. Hu and his colleagues, they showed that sedentary behaviors, independent of exercise levels, were associated with significantly elevated risks of obesity and type 2 diabetes. When comparing multiple types of sedentary behavior (watching TV, driving, and other sitting at home), TV watching was most strongly associated with increased risk of type II diabetes. For every extra 2 hours/day spent watching TV, there was a 14% increased risk of type II diabetes. In addition, there was a 12% risk reduction of type II diabetes associated with 2 hours/day spent standing or walking around at home. It was also estimated that 43% of new type II diabetes could be attributed to the joint effects of either more than 10 hours/week of TV watching or less than 30 min/day of walking.[5]

Cell phone usage is a huge part of our current society with 90% of adults owning a cell phone and 77% using a smartphone. Many users of physical activity apps report that they are easy to use, increase their motivation, and they feel comfortable using them in public. They also reported that they enjoyed being able to see their progress over time and have a record that shows their long-term health outcomes.[6] In an overview of ten studies using a mobile app to target physical activity, eight of them reported an increase in physical activity during the course of using the app. Although there is a limited amount of research on the effectiveness of mobile apps for health interventions, the existing literature shows great potential for the effectiveness of using apps to positively influence behaviors and health outcomes. This research is also important considering the average smartphone owner has 41 apps installed and 52% of smartphone owners use their phones for health purposes.[6]

Our goal for the study was to address two main research questions. The first is whether or not an 8-week lifestyle-based, smartphone-delivered intervention targeting reductions in sedentary behavior (i.e., sitting) significantly reduces objectively measured time spent sitting. We hypothesize that the participants who received the smartphone-delivered intervention will have a significant reduction in sedentary behavior compared to the control group. The second question is whether or not the intervention significantly improves fasting glucose and insulin. Similarly, we hypothesize that those who receive the intervention will have a significant improvement in their fasting glucose and insulin compared to the control group.

MATERIALS AND METHODS

Study Population and Design

Eligibility requirements for the study included: participants must be between ages 35 and 60, have glucose greater than 100, BMI greater than 25, physically inactive, report a mild or more severe sleep complaint, currently using an Android smartphone, and be able to sufficiently understand English. In addition the participants had to be able to complete all assessments, willing to learn basic technology usage skills, and wear monitoring devices. Potential participants were excluded from the study if they were diagnosed with a seizure disorder, physically active, had an unmanaged sleep disorder other than insomnia (e.g., obstructive sleep apnea), planned to travel during the study, or were pregnant. There were a total of 31 participants in the study. Of those 31, 21 were from the Phoenix VA and the other 10 were recruited from ASU. Of the VA participants, four subjects were lost to follow-up after randomization (17/21, 81 % retention). Reasons for lost to follow-up were due to unrelated health concerns (n=1) and loss of contact (n=3). There were no differences in demographic characteristics between withdrawn and lost to follow-up participants from participants who completed the study.

The goal of the overall trial was to determine the initial efficacy of a smartphone “app” entitled “BeWell24” and its impact on behavioral and cardiometabolic outcomes. Specifically, BeWell24 was designed into components that target three distinct behaviors, sleep, sedentary behavior, and physical activity (see Figure 1). The sleep component (Panel B) promotes good sleep hygiene by teaching the participants to re-associate the bed and bedroom with cues for sleep and promotes a consistent sleep-wake pattern. The sedentary component (Panel C) helps patients to identify prolonged periods of sitting and replace these behaviors with either more physical activity or sleep. The physical activity component (Panel D) gives the participants goals to increase the frequency and duration of their physical activity and ultimately exceed national guidelines for physical activity. A self-monitoring component was used to track each of the behaviors (Panel A).

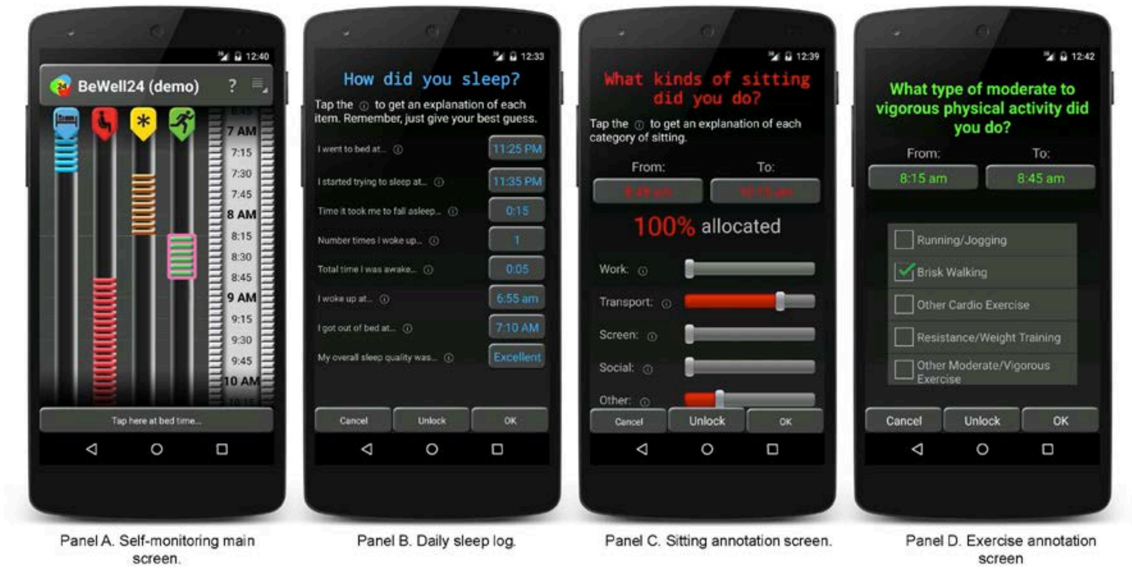

Figure 1: Screenshots of BeWell24 self-monitoring component. a Self-monitoring main screen. b Daily sleep log. c Sitting annotation screen. d Exercise annotation screen

To test the individual effects of each behavioral component (sleep, sedentary behavior, physical activity), we utilized the multiphase optimization strategy (MOST) design, conducting a 2x2x2 full-factorial experiment. The groups were split up according to Table 1 and each participant was randomly assigned to one of the groups on the first day of the study. The MOST design is best suited for this project since it allows the larger trial to establish preliminary efficacy for the three intervention components and to estimate effect sizes for interaction components.

I will specifically be looking at the effect of the sedentary component of the app and its effect on sitting time and fasting glucose and insulin. Because of the a priori randomized full-factorial design, the effect of sleep and physical activity behavior were controlled for in all analyses.

Experimental condition number	Intervention components		
	Physical activity component	Sedentary behavior component	Sleep component
1	No	No	No
2	No	No	Yes
3	No	Yes	No
4	No	Yes	Yes
5	Yes	No	No
6	Yes	No	Yes
7	Yes	Yes	No
8	Yes	Yes	Yes

All participants were encouraged to use the self-monitoring component throughout the intervention

Table 1: Multiphase optimization strategy design for BeWell24

Data Collection

After obtaining eligibility and consent, participants entered a 3-week run-in period where a basic self-monitoring component was installed on their smartphone. This run in period was used to quantify and control for any initial effects from self-monitoring behavior and/or wearing an accelerometer and identify non-compliant participants prior to randomization. After this run-in period, participants were randomly assigned to one of the eight experimental conditions. All participants received a basic self-monitoring with feedback component where they self-reported sleep, sedentary, and more active behaviors. The behavioral replacement for sedentary behavior component is a self-regulatory, scheduling-based strategy, inspired by Dr. Buman et al's work on the beneficial effects of replacing sedentary time with sleep or physical activity (light, moderate, or vigorous). Participants replaced periods of prolonged sitting with these other behaviors (e.g., going for a walk, additional sleep). A $25 incentive was offered for each of the 4 study visits (baseline, weeks 1, 4, and 8).

The primary outcome that I looked at is sitting time. This was measured with the activPAL3c. This device provides the most valid measure of posture (sitting vs. standing) for free-living settings and uses a transducer that is the most suitable for detecting lower intensity movements. The device is completely waterproofed, which allowed the patient to keep it on 24 hours/day for 7 or more consecutive days. The primary outputs of the activPAL are time spent siting, time spent upright, and time spent "stepping." We used the time spent sitting variable as our primary outcome of sitting. We also examined sit-stand transitions, or sedentary "breaks," which were also captured by the activPAL.

Fasting glucose and insulin were obtained from the participant on the first day of the study and during weeks 4 and 8. These biomarkers were measured at PVAHCS clinical laboratory following a >9h fast for the veteran participants and at the ABC building for all other participants.

RESULTS

On average, participants self-monitored about 60% of the 24-hr day and this monitoring took 3–4 min per day to complete. Peak usage occurred during week 2 of the intervention for both the sleep and sedentary components, but on average steadied at around 30-min/ week for these two components. Usage of the exercise component remained lower than the sleep and sedentary components throughout the intervention period. There were 18 participants who received the sedentary component of the intervention and 13 participants who did not. All results control for the MOST design (assignment to sleep and physical activity components). The sedentary intervention arm had 972.45 ± 62.54 min per 16 hour day of sedentary time at baseline, 919.23 ± 55.42 min per 16 hour day at 4 weeks, and 924.12 ± 61.93 min per 16 hour day at 8 weeks. The non sedentary intervention arm had 964.23 ± 59.63 min per 16 hour day of sedentary time at baseline, 971.87 ± 68.92 min per 16 hour day at 4 weeks, and 952.49 ± 63.42 min per 16 hour day at 8 weeks (see Figure 2). The impact of the intervention was not significant, such that decreases in sedentary time in those assigned to the sedentary component did not significantly differ from those not assigned to the sedentary component at 8 weeks (beta (SE) = -1.19 (.32), $p>0.05$); however, the effect size was moderate (Cohen's d = 0.29). There was no significant impact on fasting glucose (see Figure 3) and insulin (not shown).

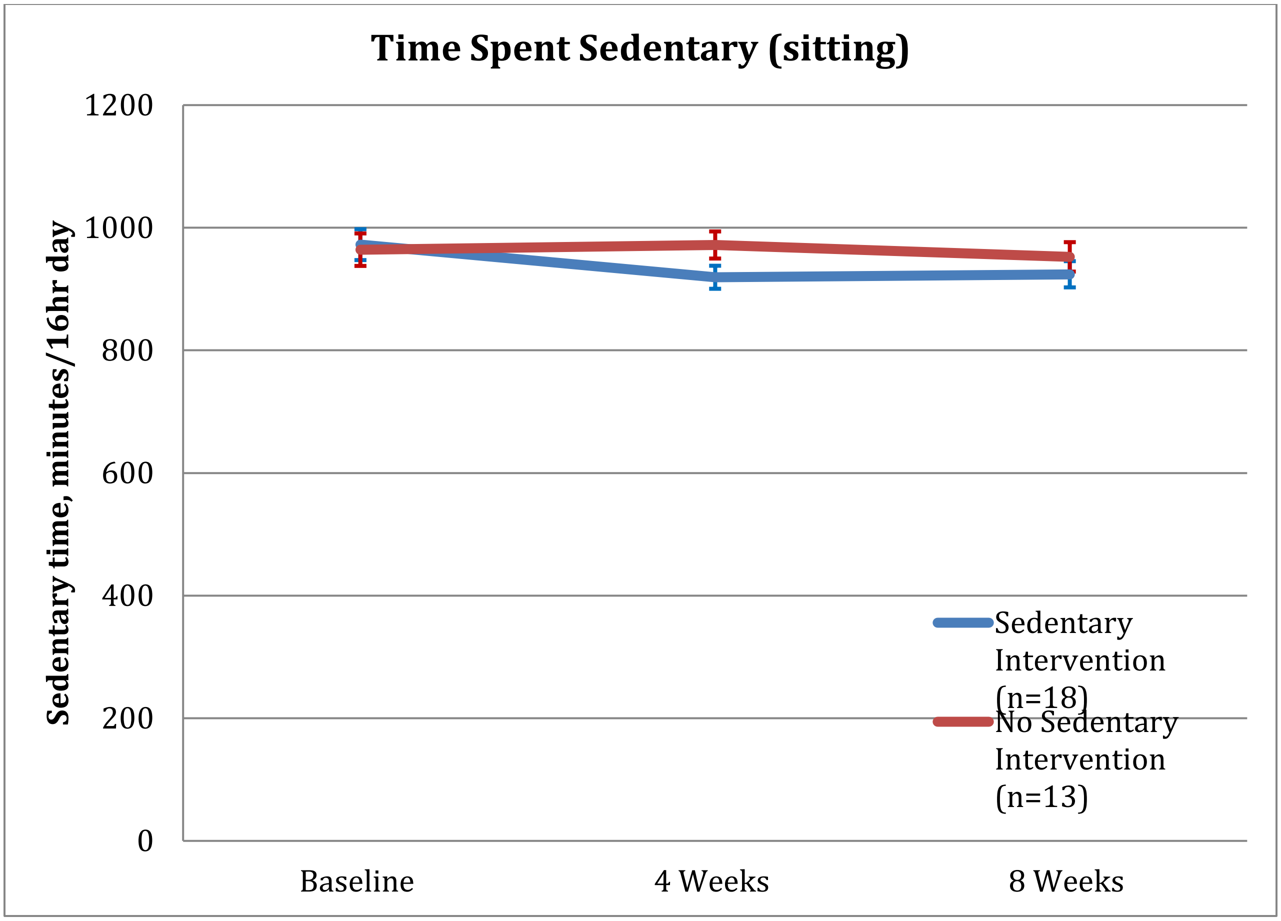

Figure 2: Comparison of time spent sitting between the groups that either did or did not receive the sedentary intervention component of the app

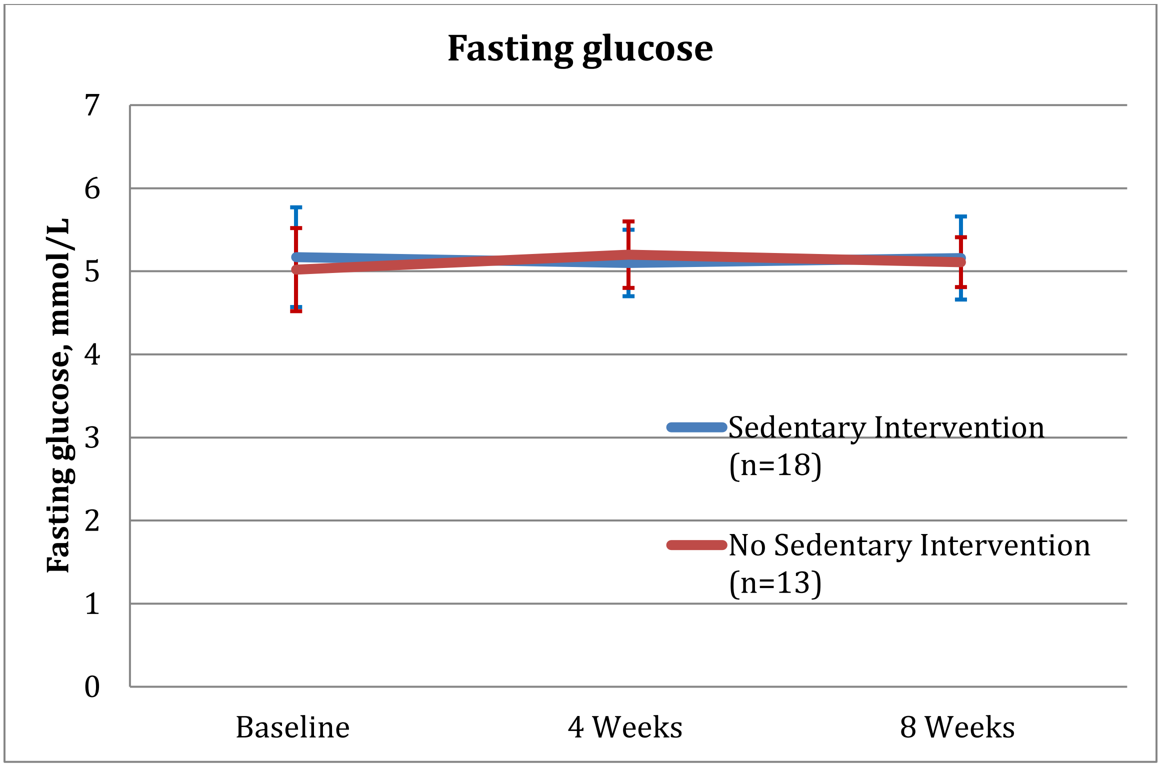

Figure 3: Comparison of changes in fasting glucose between the groups that either did or did not receive the sedentary intervention component of the app

DISCUSSION

The study included a total of 31 participants, and of those participants 18 received the sedentary intervention component of the app and 13 did not. Although there was a slightly higher decrease in sedentary time over the course of the eight weeks in the sedentary intervention group (972.45 ± 62.54 min per 16 hour day vs. 924.12 ± 61.93 min per 16 hour day) compared to the non sedentary intervention group (964.23 ± 59.63 min per 16 hour day vs. 952.49 ± 63.42 min per 16 hour day), this decrease was not statistically significant ($p>0.05$). However, the effect size was moderate (Cohen's $d = 0.29$). There was also no significant change in fasting glucose or insulin over the course of the study.

Although there is limited research on the effectiveness of using smartphone delivered apps to decrease sedentary time and improve cardiometabolic factors, there is research that shows a correlation between reducing sedentary time and decreasing the chance of developing metabolic syndrome. One study looked at sedentary occupation workers to see if workers that decreased their total sedentary time had a lower risk of developing metabolic syndrome. Out of those in the sedentary group, 42.4% developed metabolic syndrome, while only 23.9% in the active group developed metabolic syndrome ($p= 0.009$).[7] Although we did not demonstrate this correlation in our study, we believe that a longer study would be helpful in eliciting a more significant effect on cardiometabolic factors.

This population was not generalizable to the population as a whole since most of the patients were from the Phoenix VA and participants were primarily men (85%) and Caucasian (73%). Other limitations to the study were a relatively small sample size, with only 31 participants and only 27 completing the study. Lastly, it is difficult to see significant changes in fasting glucose and insulin over the course of an eight-week study, which likely contributed to the lack of statistical significance of our results.

FUTURE DIRECTIONS

Appropriate follow up to the study would include a study with a larger sample size and a more diverse population. It would also be useful to follow the subjects over a longer time period to see if the effects are significant if behaviors continue to follow the trend that was established during the eight week time period.

CONCLUSIONS

Although there are studies that show the correlation between sedentary behavior and adverse health outcomes, there are very few studies that test the effectiveness of an intervention on reducing sedentary behavior. Additionally, this is the first study that uses a smart-phone app to deliver the intervention, determine whether the intervention reduces sedentary behavior and whether that leads to a positive change in biomarkers. Although the impact of the intervention was not significant, we are hopeful that future studies will show a more significant impact with the use of smart-phone delivered interventions in reducing sedentary time and positively impacting cardiometabolic biomarkers.

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