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Feasibility of the diabetes and technology for increased activity (DaTA) study: A pilot intervention in high-risk rural adults.

Abstract

Background: Rural Canadians are at increased risk of metabolic syndrome. Physical inactivity is a primary target for preventing and reversing metabolic syndrome. Adherence to lifestyle interventions may be enhanced using cell phones and self-monitoring technologies. This study investigated the feasibility of a physical activity and self-monitoring intervention targeting high-risk adults in rural Ontario.

Methods: Rural adults (n = 25, M=57.0 ± 8.7 years) with ≥2 criteria for metabolic syndrome participated in an 8-week stage-matched physical activity and self-monitoring intervention. Participants monitored blood glucose, blood pressure, weight, and physical activity using self-monitoring devices and Blackberry™ Smart phones. VO_{2max}, stage of change, waist circumference, weight, blood lipids, and HbA1c were measured at weeks 1, 4, and 8.

Results: Adherence to self-monitoring was >94%. Participants' experiences and perceptions of the technology were positive. Mean stage of change increased 1 stage, physical activity increased 26%, and predicted VO_{2max} increased 17% ($p<0.05$). Significant changes in weight, waist circumference, diastolic blood pressure, LDL cholesterol, and total cholesterol were found.

Conclusions: This stage-matched technology intervention for increased physical activity was feasible and effective.

Keywords: Metabolic syndrome, physical activity, cardiovascular health, technology, rural health

Background

Rural Canadians are at high risk of developing metabolic syndrome (1), a clustering of risk factors that often results in type 2 diabetes and cardiovascular disease or complications (2) (3). In addition to reduced access to health care resources such as clinics and diabetes educators, rural communities have difficulty recruiting primary health care providers such as family physicians and nurse practitioners (4). Lifestyle factors such as sedentary living and poor nutritional habits often contribute to the development of metabolic syndrome. This can be exacerbated by environmental factors in rural communities. For example, opportunities for physical activity are limited in many rural areas due to lack of private and public infrastructure such as gyms, recreational facilities, sidewalks, and appropriate lighting on rural roads (5) (6). Poor weather conditions during the winter and long distances between places also make it challenging for rural Canadians to live an active lifestyle because unlike their urban counterparts, it may be too far or too dangerous to engage in active transportation (6). These factors make it particularly hard for aging rural Canadians to be physically active and thus, achieve the health benefits associated with an increased fitness level.

Physical inactivity has been identified as a primary risk reduction target for rural adults at risk for type 2 diabetes and cardiovascular disease (7) (8) (9). While large-scale studies such as the Diabetes Prevention Study (7) and the Finnish Diabetes Prevention study (9) have established that physical activity and healthy lifestyle behaviors prevent the development of type 2 diabetes in high-risk individuals, few studies have looked at the effectiveness of using self-monitoring and mobile technologies as a means of delivering a lifestyle intervention.

Emerging evidence shows that physical activity interventions using novel technologies such as cell phone text messaging, reminders, and applications are promising tools for enhancing adherence to behaviour change interventions (10). Improvement of specific risk factors such as HbA1c (11) (12) and blood pressure (13) using home self-monitoring devices and cell phones have also been demonstrated in diabetic and hypertensive populations, respectively.

This is the first study to use cell phone technology combined with self-monitored and a stage-matched physical activity intervention with metabolic syndrome patients in a rural community. The purpose of this pilot project is to test the feasibility and effectiveness of the intervention and decide whether a larger randomized trial is warranted.

We hypothesized that adherence rates for self-monitoring protocols would be 34% or greater based on results from a prior technology-based behaviour change intervention in a high risk populations (12). It was expected that participants would find the technology helpful, easy-to-use, and that perceived burden of using the technology would be low. Improvements in participants' stage of change, physical activity levels, and cardiorespiratory fitness were another hypothesized outcome of the study. Finally, significant changes in some cardiovascular risk factors including systolic and diastolic blood pressure, waist circumference, weight, and blood lipid levels, as well as HbA1c and fasting blood glucose were anticipated.

Methods

Study Design

We conducted a two-month pilot study to evaluate the feasibility and effectiveness of using Blackberry^{TM} Smart phones and self-monitoring technologies paired with a stage-matched STEP^{TM} test exercise prescription in rural patients with metabolic syndrome. Participants came to the research center for clinic visits at baseline (V1), 1 month (V2), and 2 months (V3). At each clinic visit blood samples were collected for measurement of blood lipids and HbA1c. A complete physical examination that included measurements of weight, height, and waist circumference was completed. The STEP^{TM} Test Exercise Prescription was completed at each visit. This involved completing a Stages of Change for Physical Activity Questionnaire and performing the STEP^{TM} test to assess predicted VO_{2max}, followed by goal setting and a stage-matched exercise prescription. The DaTA Study Technology Experience Survey as completed at V3.

At baseline participants were given several self-monitoring devices: a Blackberry^{TM} Smart phone, a Bluetooth-enabled glucometer, an automated home blood pressure monitor, and a pedometer. Training was provided on all devices at this visit. Self-monitored glucose measurements were to be submitted twice daily: once before breakfast and again before going to bed. Pedometer data was entered manually at the end of each day. Home blood pressure readings were to be collected 3 times/week on Sunday, Tuesday, and Thursday. Blood glucose measurements from the glucometer and blood pressure measurements from the home blood pressure monitor were wirelessly transferred to the patient's Blackberry^{TM} device in real time and then to a secure, encrypted database supplied by HealthAnywhere^{TM} and managed by Sykes Canada.

Sample

A self-selected sample of six male and 19 female adults aged 28-75 ($M = 57.0 \pm 8.7$) living in a rural area of Southwestern Ontario volunteered to be part of the study. The sample size for this pilot study was set at 25 due to the number of available Blackberry™ Smart phones and accompanying two-month data plans. Participants were recruited through advertisements in the local newspaper, health care providers at the local health clinic, and word of mouth.

Participants were screened initially on the telephone after contacting the study coordinator, followed by a screening at the clinic during their baseline visit. Eligible participants were required to present with two or more criteria for metabolic syndrome: diastolic blood pressure >90mmHg and/or systolic blood pressure >135mHg, waist circumference >88cm for men and >103cm for women, triglycerides >1.7mol/L, HDL cholesterol <1.23 in men and <1.35 in women, and elevated blood sugar (fasting >6.0 or HbA1c >7.0%) (2). Exclusion criteria included uncontrolled or severe hypertension (systolic ≥ 180mmHg or diastolic ≥ 110mmHg), type 1 diabetes, a history of cardiovascular disease or angina, symptomatic congestive heart failure, unstable pulmonary disease, or second to third degree heart block. Patients on medications known to affect heart rate, medications that might cause a co-intervention effect or who had started or changed dose of a lipid-lowering agent within the last 3 months were not included in the study. Individuals with pacemakers, unstable metabolic disease (e.g. thyroid disease), or orthopaedic or rheumatologic problems that could impair exercise ability were also excluded. Lastly, patients with a history of problems with drugs or alcohol, and those with emotional, cognitive, or psychiatric problems were ineligible for study participation.

Instrumentation

STEP^{TM} Test Exercise Prescription

The Step Test for Exercise Prescription (STEP^{TM}) was developed by Petrella et al. (16) to create a simple exercise prescription protocol that could easily be performed in a doctor's office. The STEP^{TM} test uses the Transtheoretical Model of behavior change and a simple predictive VO_{2max} test to provide individualized exercise recommendations.

The Stage of Change for Physical Activity Questionnaire was used to determine each participant's readiness for physical activity. This tool was adapted by Marcus et al. (14) from the stages of change tool developed by Prochaska and Diclemente (15) to help assess people's readiness to quit smoking. This staging instrument consists of five mutually exclusive items and has demonstrated acceptable test-retest reliability ($\kappa = 0.78$, [14]).

The fitness test component of the STEP^{TM} test is a timed self-paced stepping test, requiring the participant to step up and down two steps, each 20cm in height. Age, sex, post-test heart rate, and time are then used to calculate predicted VO_{2max}. Predicted VO_{2max} from the STEP^{TM} test was found to have a high correlation with direct gas measurement using a metabolic cart. Using regression analysis, Petrella et al. (16) found a correlation of 0.93 for women and 0.91 for men when comparing VO_{2max} by direct gas measurement during a Balke ramp treadmill test to predicted VO_{2max} on the STEP^{TM} test. Acceptable test-retest reliability of this test has been demonstrated ($r=0.93$) (16). Based on predicted VO_{2max} the STEP^{TM} test categorizes participants based on normative data for sex and age into one of the following fitness categories: Below Average, Average, Good, and High. From this information the assessor (physician or researcher) determines the appropriate exercise recommendations (staging) for each participant according to ACSM guidelines including a target exercise heart rate between 70-85% of their age-predicted maximal heart rate.

Self-monitoring devices

Participants used several self-monitoring devices during the study. Automatic reminders were pre-programmed into each Blackberry™ Smart phone so that participants received an alert every time a reading was scheduled to be taken. The self-monitoring protocol included blood glucose measurements twice each day: once while fasted before breakfast (AM) and once before bed (PM). Blood glucose measurements were taken using a Bluetooth-enabled One Touch glucometer and corresponding test strips (Lifescan One Touch Ultra2 and Polymap wireless adaptor PWR-08-03). Blood pressure measurements were taken three times/week using a Bluetooth-enabled home blood pressure monitor (A & D Medical #UA-767PBT). Patients were instructed to sit down in a quiet place where they could rest their left arm at chest level, put the blood pressure cuff on, and sit quietly for 3-5 minutes before taking each reading. Daily physical activity was measured using a pedometer (Omeron # HJ-150) and daily step counts were entered manually into the Blackberry™ Smart phone each evening. Mean steps/day during week 1, week 4, and week 8 were calculated to reduce the effects of day-to-day variation in physical activity and provide a more reliable estimate of average steps/day. Weight was entered manually into the Smart phone every week.

DaTA Study Technology Experience Survey

A survey was created to assess participants' experience and attitude toward the technologies involved in the intervention. This experimental survey consists of 27 questions and assesses previous technology experience, comfort level, ease of use, perception, and burden of using the technology. Questions 1-8 are close-ended questions (yes or no) about previous and current experience with technology. Questions 9-12 assess prior experience with the devices used in the study and are rated on a four-point likert scale ranging from 1 = almost never to 4 = almost always. Items 13 to 26 examine participant comfort, burden, ease of use, and overall perception of the technology used for the study. Items are ranked on a four-point likert scale ranging from 1 = strongly disagree to 4 = strongly agree. Sample items include "I am comfortable using a heart rate monitor to complete the study" and "The self-monitoring events were easily scheduled into my daily activities". Question 27 "How much time did the DaTA study technologies require each day?" was scored as follows: 1 = <20 min, 2 = 20-40min, 3 = 40-60min, and 4 = >60min. Psychometric properties were not evaluated.

Data Management

All self-monitoring data was encrypted and automatically transferred from patient Blackberry™ Smart phones to a HealthAnywhere™ database specifically created for the study using Secure Socket Layer protocols and signed certificates. Data was transferred exclusively over secured links and messages did not contain any personal identification information. Messages transmitted between the HealthAnywhere™ server and participants' Blackberrys™ follow the guidelines for Health Level Seven (HL7) domain Common Message Element Types (CMETs). "Level Seven" refers to the applications level of the International Standards Organization (ISO) model of communications for Open Systems Interconnection. This is the level that interfaces directly to and performs application services (17). HealthAnywhere^{TM} uses the HL7 domain to transform input from the Blackberry^{TM} Smart phones into electronic patient health records on the secure HealthAnywhere^{TM} database. The company complies with the Health Insurance Portability and Accountability Act which protects personal health information. Patients provided consent to transmit their Secure Socket Layer (SSL) encrypted data to HealthAnywhere^{TM} firewall-protected server. Server access is restricted to authorized personnel at the hosting center. Only authorized logins are permitted using Secure Shell (SSH) encrypted tunnel with a valid username and password. Clinic data were collected on a paper-based case report form for each patient and securely stored in binders at the Gateway Rural Health Research Institute in Seaforth, Ontario, Canada.

Statistical analysis

Basic descriptive analysis was performed. A one-way repeated measures ANOVA was conducted to compare clinical outcomes at V1, V2, and V3, and for corresponding self-monitoring data at weeks 1, 4, and 8. Post-hoc analysis using a paired T-test was performed to assess differences between time points when the ANOVA showed statistically significant differences. A chi square non-parametric test was used to assess changes in stage of change. Statistical significance was set at $p < 0.05$ and all analyses were performed using the Statistical Package for the Social Sciences (SPSS v.19.0, IBM, Armonk, NY). Adherence to self-monitoring protocols was calculated as the percentage of scheduled measurements that were taken. Self-monitoring data that was entered between the hours of midnight and 5am was considered as data from the previous calendar day. Missing data were handled using the last outcome carried forward approach (18).

Ethics Approval

The study was approved by the Health Sciences Research Ethics Board of the University of Western Ontario and by the Clinical Research Impact Committee at Parkwood Hospital, London, Ontario.

Results

Twenty-five adults (mean age 57.0 ± 9.0) were recruited for the study. One individual withdrew after one week due to an unrelated medical problem. All remaining participants completed the study (n=24). Participant baseline characteristics are presented in Table 1. At baseline, participants fulfilled ≥2 of the criteria for metabolic syndrome (2).

Adherence to the self-monitoring protocols was high. Participants completed >94% of their scheduled readings for steps/day, blood pressure, weight, and blood glucose (Table 3). They also rated their experience of using the self-monitoring devices and Blackberry^{TM} Smart phones very highly. Patients had various levels of experience using monitoring devices prior to the study. Home blood pressure monitors were the most commonly used device, with 25.0% reporting frequently using a blood pressure monitor at home and 45.8% reporting they had not used this device before. Twenty-five percent of participants reported frequent use of a home blood glucose monitor while 66.6% reported never using this device. Prior to the intervention pedometers were used regularly by 4.2% of the participants with 70.8% of the group reporting never using this device. Most participants (83.3%) reported that they had not used a Blackberry™ Smart phone or similar device prior to their involvement in the research study but 12.5% had used a device like this frequently.

Comfort level using the devices was high. Most participants strongly agreed or agreed that they were comfortable using the Blackberry™ Smart phone (91.6%), blood glucose monitor (95.8%), blood pressure monitor (91.7%), pedometer (95.8%), and heart rate monitor (95.8%) to complete the study. Some discomfort using the blood pressure monitor and the Blackberry™ Smart phone was reported by 8.3% of the participants. Participants found the Blackberry™ Smart phone screen easy to read (20.8% agree; 70.8% strongly agree) and study instructions easy to understand (33.3% agree; 58.3% strongly agree). Overall, it was reported that self-monitoring gave participants a sense of security (41.7% agree; 58.3% strongly agree) and helped them adopt new habits to improve their wellbeing (16.7% agree; 83.3% strongly agree). Perceived burden was low, as 100% of participants disagreed or strongly disagreed that managing the technology took too much time or interfered with other activities. In terms of daily time commitment 91.7% of participants reported that self-monitoring took < 20 min to perform the self-monitoring each day, while the remaining 8.3% used 20-40 min/day. Results from the Technology Experience Survey are presented in Table 3.

Stage of Change, Physical Activity, and Predicted VO2max

At baseline ten participants had already been exercising for at least three months (maintenance stage), while eight were in the preparation stage, three were contemplating increasing their physical activity, and three were in the action stage. On average, participants increased their stage of change by almost 1 stage by the end of the study ($p<0.05$). At V3 one participant was in the preparation stage, three were in the action stage, and 20 were in maintenance (Table 4).

Mean steps per day increased significantly from an average of 5560.48 ± 1929.79 steps/day during the first week of the study to 7011.06 ± 2683.52 steps/day during week eight ($p<0.05$). All patients were able to complete the STEP™ test. Predicted VO_{2max} increased significantly from 29.54 ± 5.48 $mL/kg/min^{-1}$ at baseline to 34.67 ± 6.87 $mL/kg/min^{-1}$ at 2 months, ($p<0.05$).

Cardiovascular Risk Factors

Statistically significant improvements were seen in several cardiovascular risk factors. Waist circumference at V2 (108.65 ± 11.64 cm) and V3 (107.68 ± 11.64 cm) was significantly different from baseline (111.54 ± 9.00 cm). The same pattern was found for weight which dropped from 92.61 ± 13.68 kg at baseline to 91.72 ± 13.81 kg at V2 and 91.37 ± 13.81 kg at V3. Diastolic blood pressure at V2 (79.29 ± 9.64 mmHg) and V3 (79.29 ± 13.03 mmHg) was significantly lower than baseline (84.42 ± 8.45 mmHg). LDL cholesterol changed from 3.42 ± 1.26 mmol/L at V1 to 3.13 ± 1.10 mmol/L at V3 and total cholesterol decreased from 5.48 ± 1.27 mmol/L at V1 to 5.19 ± 1.11 mmol/L at V3. No change was seen in fasting blood glucose, HbA1c levels, triglycerides, or HDL cholesterol (Table 5). Significance level was set at $\rho<0.05$ for all statistical analyses.

Discussion

This pilot study showed that using self-monitoring devices and Blackberry™ Smart phones is a feasible and effective way to promote adherence to a stage-matched physical activity intervention in a population of high risk rural adults. In addition to high adherence and positive perceptions of the intervention, participants also increased their physical activity, improved their aerobic fitness levels, and experienced improvements in several markers of cardiovascular health.

Technology Experience

Adherence to self-monitoring protocols was higher than previous studies using cell phones and self-monitoring to change health behaviours. In a 2-month intervention to improve physical activity using continuous accelerometer data collection with internet and cell phone monitoring Hurling et al. (10) found that participants accessed the study technology an average of 2.9 times/week. With no set monitoring protocol but 85% of the participants accessed the technology at least once/week during the first month and 75% did during the last 5 weeks of the study (10). Although the current study involved a structured and intensive self-monitoring protocol, usage of the study technologies was greater than in this less intensive study suggesting that a more intensive intervention with a clearly defined protocol may be more engaging. In another study Faridi et al. (12) conducted a three-month self-monitoring intervention for patients with type 2 diabetes using glucometers, pedometers, and cell phones. Adherence was 33% on average, with three participants completing 100% of all scheduled readings and five participants completing none of them. The participants in our study had metabolic syndrome, whereas these studies targeted adults with type 2 diabetes so it is possible that there are fundamental differences in motivation or stage of change between these two groups that contributed to our strong adherence rates.

Our study findings show that middle-aged adults in rural Ontario are open to learning how to use new technology. This finding is particularly important, as using novel technology in older populations is sometimes avoided due to assumptions that they are not interested in learning how to use it or will have too much difficulty using technological devices (19). Our results suggest that using self-monitoring and innovative communication technologies is feasible with middle-aged adults and is a well-received strategy in this age group.

Stage of Change

Stage of change for physical activity represents an individual's psychological readiness to change their physical activity behaviour (15). Mean baseline stage of change was high for the participants in our study, likely reflecting the fact that volunteers are generally highly motivated. Previous physical activity interventions have showed good short-term results regarding stage of change progression in sedentary adults. Calfas et al. (20) showed that a Transtheoretical Model approach to increasing physical activity can be effective in facilitating increased physical activity readiness. In their 6-week randomized trial, 52% of participants in the intervention group became regularly physically active by the end of the trial compared to 12% of the control group (20). A review by Hutchinson et al. (21) also reported positive changes in stage of change in 18/24 short-term (< 6 months) physical activity interventions based on the Transtheoretical Model. These findings are similar to those of the current study.

To date few studies have applied a Transtheoretical Model-based exercise intervention to a metabolic syndrome population. The SNAC study (22) used the STEP™ test exercise prescription used in the current study. Their sample of high-risk adults with pre-diabetes and/or pre-hypertension was similar to a metabolic syndrome population however they did not report data for stage of change so it is unknown what effect the intervention had on the variable (22).

Physical Activity & Cardiorespiratory Fitness

Average steps per day increased by an average of 1451 steps, ($p<0.05$). This represents a 26% increase in walking, running, and other cardiovascular activities that can be monitored using a pedometer. These findings are lower than those from other studies. In a systematic review of the literature pedometer use was found to increase physical activity by an average of 2491 steps/day compared to non-pedometer control (23). It is also important to mention that although significant increases in steps/day were achieved by the participants in this study they were well under the 10,000 steps/day recommended (24) (25) which is equivalent to about 8 km (5 miles). A systematic review by Bravata et al. (23) highlight the effectiveness of using pedometers with a physical activity goal of 10,000 step/day to motivate people to significantly increase their daily physical activity despite the reality that few people actually achieve that many steps. A few participants in our study did achieve the goal of 10,000 steps/day but even those who did not reach this goal achieved significant increases in their daily physical activity over the course of the study.

Interestingly, steps/day did not change significantly between baseline and week 4. Since pedometer data was not collected prior to the start of the study, it is possible that steps/day during week 1 is not representative of participants' pre-study physical activity and may in fact be an increase from the week before. In the future, it would be advisable to collect self-monitoring data for a week or two prior to the start of the intervention to establish true baseline values.

Improvements in participants' predicted VO_{2max} (a 17.2% increase) support the study findings that physical activity increased over the course of the study. While this may seem like a dramatic result, short term exercise training studies have shown similar improvements in aerobic fitness in at-risk populations. Toledo et al. (26) demonstrated an improvement in VO_{2max} by 12 ± 1.6% ($\rho < 0.05$) over four months of moderate-intensity exercise in type 2 diabetics. Baynard at al. (27) found a modest 5% increase in aerobic capacity of obese individuals after performing 10 days of treadmill walking at 70-75% of maximal aerobic capacity. Given that both of these training studies used low-moderate exercise intensity and evaluated participants similar to those in our study the 17.2% increase seen in our study is not unreasonable.

Cardiovascular risk factors

Significant changes in some cardiovascular risk factors occurred from V1 to V3, supporting our initial hypothesis that the intervention would result in moderate improvements in cardiovascular risk factors. Waist circumference decreased significantly but remained above the cut-off values for metabolic syndrome. A waist circumference ≥ 102 cm in women or ≥ 88 cm in men is considered high-risk (28). To lose another 6-20 cm around the midsection, participants might need more than two months of increased physical activity. Since there is a dose-response relationship between aerobic exercise volume and decreases in abdominal fat (29) further increases in physical activity volume over a longer time period may be required to get into the healthy range.

Aerobic fitness can help improve one's blood lipid profile, blood glucose control, and lower blood pressure (3,7,9,28). As a pioneer project in this area of study, our results showed modest but significant decreases in diastolic blood pressure, LDL cholesterol, and total cholesterol. Previous self-monitoring interventions involving a physical activity component have shown improvement in some of these risk factors. Park, Kim, and Kim (13) conducted an intervention using cells phones and an educational study website with weekly self-monitoring of weight and blood pressure in a sample of obese hypertensive adults. After three months systolic blood pressure and diastolic blood pressure dropped 9.1 mmHg and 7.2 mmHg, respectively. Weight decreased by 1.6 kg, waist circumference by 2.8 cm, and HDL cholesterol increased by 3.7mg/dl.

Other self-monitoring projects have showed improvements in HbA1c (11, 12). The current study did not see any significant improvements in HbA1c, however glucose regulation may occur with exercise before a meaningful difference in serum glucose levels becomes apparent. A recent study showed that seven days of 60 min of aerobic exercise training/day at ~70% of VO_{2max} produces significant improvements in insulin action with no change in fasting glucose levels in obese type 2 diabetics (30). This suggests that although we did not see significant changes in blood glucose levels during our intervention, it is possible that improvements in insulin action at the cellular level occurred but were not measured.

The current study intervention was much more comprehensive than any previously published studies using self-monitoring technologies however it was shorter in duration and had a small number of subjects. Given these limitations, the improvements in cardiovascular risk factors in just 8 weeks indicate that a larger, long-term study is worth pursuing.

Limitations

The primary limitation of this pilot study is the lack of statistical power due to a small sample size. However since the overall purpose of the pilot study was to assess the feasibility and effectiveness of the intervention for a larger randomized controlled trial, sufficient power was not expected. Another limitation to the study is the short duration. It was originally proposed that two months was the minimum amount of time necessary to see changes in physical activity, aerobic fitness, and cardiovascular risk factors. Although we did see significant positive changes in stage of change, physical activity, and predicted VO_{2max}, and some cardiovascular risk factors the intervention may not have been long enough to elicit significant changes in systolic blood pressure, glucose, HbA1c, or triglycerides. Evidence also suggests that short-term exercise interventions have higher adherence rates than long-term interventions so it is possible that the results of the current study are not generalizable to a longer-term intervention.

In terms of instrumentation, the DaTA Study Technology Experience Survey was created for this study and lacks the methodological rigour of a validated questionnaire. However, as a feasibility study, we were interested in capturing the participants' experience with the technologies involved in the study. Currently no validated questionnaire exists that would serve this purpose. Using a pedometer to measure physical activity may have underestimated the amount of physical activity that participants did. Although steps/day increased significantly additional exercise may have contributed to the 17% increase in VO_{2max} that resulted from the two month intervention. In the future capturing total energy expenditure and physical activity should be considered. Having another device such as an accelerometer would be beneficial in measuring non-walking/running type activities in future studies.

As in any physical activity intervention study, self-selection of volunteers may have resulted in a sample at the lower end of the high-risk continuum. This is evidenced by the fact that at baseline several participants were in the maintenance stage of change and none were at the precontemplation stage. Unfortunately it is extremely difficult to recruit people who are not even considering becoming physically active to participate in a physical activity intervention. This reduces the generalizability of the study, as it is unknown if those in the pre-contemplation stage will respond the same way to the intervention as those who are already contemplating or preparing for changes in their physical activity behaviour at the beginning of the study.

Conclusions

Cell phone and self-monitoring devices helped motivated high-risk rural adults track physical activity and health outcome variables during this two month stage-matched physical activity intervention. Overall, participants enjoyed using the technology and found it helpful. The intervention resulted in significant improvements in stage of change, physical activity, predicted VO_{2max}, and several cardiovascular risk factors. A larger randomized controlled trial is warranted to explore the potential impact of this intervention on a larger scale over a longer period of time.

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Table 1. Participants' Baseline Characteristics

Participant Characteristic	Mean ± SD (n=24)
Age (years)	57.03 ± 8.70
Height (cm)	167.13 ± 8.35
Weight (kg)	92.61 ± 13.88
Body Mass Index (kg/m^2)	33.14 ± 4.36
Waist Circumference (cm)	111.54 ± 9.00
Systolic Blood Pressure (mmHg)	140.63 ± 9.74
Diastolic Blood Pressure (mmHg)	84.42 ± 8.45
Triglycerides (mmol/L)	1.80 ± 1.32
HDL Cholesterol (mmol/L)	1.34 ± 0.33
LDL Cholesterol (mmol/L)	3.42 ± 1.26
Total Serum Cholesterol (mmol/L)	5.48 ± 1.27
Serum HbA1c (%)	6.02 ± 0.75
Fasting Blood Glucose (mmol/L)	6.03 ± 2.40

Notes: All values are means ± standard deviation.

Table 2. Participant Adherence to Self-monitoring Protocols

Self-monitoring Variable	Adherence (%)
Pedometer (daily)	97.7
Blood Glucose (am)	95.3
Blood Glucose (pm)	94.6
Weight (weekly)	98.4
Blood Pressure (3x/week)	97.4

Notes: Values represent percentage of required readings submitted. Duplicate or extra data points submitted by participants were not included in the analysis of adherence to the self-monitoring protocol. Participants that completed fewer or more than 8 weeks of the intervention were assessed using the total number of data points expected for the entire duration of their enrolment.

Table 3. Responses from the DaTA Study Technology Experience Survey

Item	Responses (%)			
Current technology use	**Yes**			
1. Currently use a Personal computer	87.5			
2. Currently use Internet	79.2			
3. Currently use Cell phone	58.3			
4. Currently use a PDA	16.7			
5. Currently use an Mp3 Player	4.20			
6. Currently use a Game system	0			
7. Currently watch Television	66.7			
8. Currently listen to the Radio	75.0			
Frequency of previous study technology use	**N**	**R**	**S**	**F**
9. How often have you previously used a PDA, Blackberry™ or similar device?	83.3	0	4.2	12.5
10. How often have you previously used a blood pressure cuff at home?	45.8	8.3	20.8	25.0
11. How often have you previously used a blood glucose monitor at home?	66.6	4.2	4.2	25.0
12. How often have you previously used a pedometer (step counter) at home?	70.8	8.3	16.7	4.2
Comfort, Ease-of use, Perceptions, and Burden	**StD**	**D**	**A**	**StA**
13. I am comfortable using a Blackberry™ to complete the study.	4.2	4.2	20.8	70.8
14. I am comfortable using a blood glucose monitor to complete the study.	4.2	0	8.3	87.5
15. I am comfortable using a blood pressure monitor to complete the study.	8.3	0	8.3	83.4
16. I am comfortable using a pedometer to complete the study.	4.2	0	4.2	91.6
17. I am comfortable using a heart rate monitor to complete the study.	4.2	0	12.5	83.3
18. The display screen on the Blackberry™ was easy to read.	0	8.3	20.8	70.8
19. The instructions were easy to understand.	0	8.3	33.3	58.3
20. The devices did not cause me any physical discomfort.	0	0	16.7	83.3
21. The self-monitoring events were easily scheduled into my daily activities.	0	4.2	37.5	58.3
22. When I had technical problems with the devices, the problem was resolved within 24h.	0	0	25.0	75.0
23. Participation in this self-monitoring program gave me a sense of security.	0	0	41.7	58.3
24. Use of the self-monitoring technology helped me adopt new practices that improved my wellbeing.	0	0	16.7	83.3
25. Managing the technology used in the DaTA study took too much time in my day.	75.0	25.0	0	0
26. Managing the technology used in the DaTA study interfered with other activities of daily living.	66.7	33.3	0	0
Time commitment	**<20**	**20-40**	**40-60**	**>60**
27. How much time did using the DaTA study technologies require per day? (min)	91.7	8.3	0	0

Note: All values presented as percentages unless otherwise indicated. Abbreviations: N = Never, R = Rarely, S = Sometimes, F = Frequently, StD = Strongly Disagree, D = Disagree, A= Agree, StA = Strongly Agree.

Table 4. Participants' Stage of Change for Physical Activity

Stage	Frequency		
	V1	V2	V3
Pre-contemplation (1)	0	0	0
Contemplation (2)	3	0	0
Preparation (3)	8	3	1
Action (4)	3	3	3
Maintenance (5)	10	18	20

Table 5. Changes in Major Study Variables at V1, V2, and V3

Study Variable	V1		V2		V3	
	M	SD	M	SD	M	SD
Steps/day	5560.48	1929.79	5709.97	2437.58	7011.06*	2683.52
Predicted VO2max (ml/kg/min^{-1})	29.54	5.48	32.88*	5.99	34.67*	6.87
Waist Circumference (cm)	111.54	9.00	108.65*	11.64	107.68*	11.64
Weight (kg)	92.61	13.88	91.72*	13.68	91.37*	13.81
Fasting Glucose (mmol/L)	6.03	2.40	5.70	1.40	5.52	1.10
HbA1c (%)	6.02	0.75	5.94	1.07	5.88	0.67
Systolic BP (mmHg)	140.63	9.74	137.21	13.36	138.50	18.75
Diastolic BP (mmHg)	84.42	8.45	79.29*	9.64	79.96*	13.03
HDL Cholesterol (mmol/L)	1.80	1.32	1.78	1.17	1.53	0.70
LDL Cholesterol (mmol/L)	1.34	0.33	1.34	0.41	1.35	0.40
Total Cholesterol (mmol/L)	3.42	1.26	3.28	1.10	3.13*	1.10

*Significant difference from V1, $\rho<0.05$

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