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Effectiveness of A Smartphone Directed Physical Activity Program on Cardiometabolic Disease Risk in Desk-Based Office Employees – A Pragmatic, Two-Arm, Parallel, Cluster Randomised Trial

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SUMMARY

Background. Excessive uninterrupted sitting is found to be associated with increased cardiometabolic disease risk in desk-based employees. Point-of-choice prompts using a smartphone application (SmPh-app) may be a feasible method of promoting physical activity and negating cardiometabolic disease risk. The study aims to investigate the effectiveness of SmPh-app directed walk reminders on cardiometabolic disease risk (Fasting Blood Glucose (FBG), aerobic capacity (VO2 max) and Heart Rate Variability (HRV) in desk-based office employees.

Methods. In this pragmatic, two-arm, parallel, cluster randomised trial, desk-based employees (n=53) of five administrative offices (clusters) of a university were randomised to two groups: SMART group in which employees were provided with SmPh-app based (six) walk reminders during working hours and CONTROL group in which employees continued their usual work. As FBG, VO2 max and HRV data were skewed, nonparametric statistical analyses were used for intention-to-treat analysis.

Results. Of 53 desk-based employees initially included in the trial, 47 completed the four weeks trial. Employees in SMART group showed a statistically significant difference in FBG ($p < 0.001$), VO_2 max ($p < 0.05$) and nearly all domains (time, frequency and non-linear) of HRV (pre- *vs*. post-intervention) compared to CONTROL group. SMART group employees were found to reduce FBG by 8 mmol/dL (interquartile range (IQR): -12.25 to -3.75 mmol/dL), improve VO2 max by 2.23 ml/kg/min (IQR: 0.12 to 4.34 ml/kg/min) and improve HRV in all the domains compared to CONTROL group.

Conclusions. SmPh-app based walk reminders improved FBG, functional capacity and HRV in desk-based office employees.

KEY WORDS

Smartphone; break reminders; walk; blood glucose; aerobic capacity; heart rate.

BACKGROUND

Due to automation and excessive use of computers for most occupational tasks, a modern man spends around two-thirds of waking hours in a seated position. "Sedentary behaviour" in office characterised by an energy expenditure ≤ 1.5 Metabolic Equivalents (METs) in sitting or a reclining posture has become inevitable and socially acceptable for a contemporary man (1).

Desk-based employees spend 60–75% of their routine work time in the sitting position and sometimes they

tend to accumulate several bouts of uninterrupted sitting (for more than 30 minutes) in a day (2). Several studies have shown that chronic cardio-metabolic diseases such as diabetes, dyslipidaemia, ischemic coronary disorders, obesity, and hypertension are associated with sedentary behaviour (3). New evidence claims that accumulated bouts of uninterrupted sitting are associated with an increased cardiometabolic disease risk owing to altered glucose and lipid metabolism, reduced heart rate variability, and reduced functional capacity (4). Moreover, prolonged sitting is negatively associated with time and frequency domain measures of Heart Rate Variability (HRV); however, there is a dearth of studies that substantiate the impact of breaking sitting on HRV (5).

Having said that, interrupting prolonged sitting behaviour with light to moderate physical activity or even standing may reduce cardiometabolic disease risk (4). Point-of-choice prompting software installed on electronic devices (*e.g.* work computer, smartphone (SmPh), *etc.*), standing or height-adjustable desks, treadmill and bike work stations, and walking meetings are some interventions employed to break prolonged sitting (6). Moreover, computer or web-based prompts and smartphone (SmPh) based applications (apps) have been the focus of most research studies in the past decade, as a means of interrupting occupational sitting and thus negating its adverse health effects (6). Light physical activities such as walking during break times have been found to improve fasting and postprandial glucose and insulin levels in a customised office setting (7). Further, breaking prolonged sitting behaviour and indulging in light-moderate activities during office hours have been reported to improve energy expenditure and aerobic capacity have been associated with light to moderate activities rather than standing alone during office hours (8).

Nowadays SmPhs are ubiquitous in use and may be used to influence human behaviour based on the principles of the social cognitive approach and ecological model (9). Smph-based applications (app) embedded with accelerometers, magnetometers and gyroscopes could be used to monitor and influence human physical activity patterns. There have been studies on Smph-guided break reminders that have shown a positive effect on lowering the sedentary time and postprandial glucose levels in people with chronic diseases (10). However, the influence of SmPh-based break reminders of physical activity on office employees and their aerobic capacity and heart rate variability remains largely unknown. We thus investigated the effects of a SmPh-app to provide break reminders to "take a walk" on cardiometabolic disease risk, especially Fasting Blood Glucose (FBG), functional capacity (VO_2 max) and Heart Rate Variability (HRV) in desk-based office employees.

METHODS

Study design and ethical approval

This was a pragmantic, two-arm, parallel, cluster randomised controlled trial conducted at administrative offices of Manipal Academy of Higher Education (MAHE) in India from February 2019 to June 2019. Kasturba Medical College and Hospitals (KMC & KH) Institutional Ethics Committee (676/2018) approved the study which was then registered with the clinical trial registry of India (CTRI/2019/01/017117). The research was conducted ethically according to international standards and as described by Padulo *et al.* (11).

Study setting and participants

Only seven of 23 administrative offices of respective constituent institutions of MAHE were contacted and necessary permissions were sought from them for participant recruitment. Desk-based employees, aged 25-60 years, of either gender, with a sitting time > 6 hours per day and a self-reported physical activity < 150 minutes/week), who agreed to undergo fasting glucose testing (both pre- and post-intervention period) and be available for four weeks of study/intervention routine were recruited. Employees who were pre-diagnosed with cardiometabolic disorders including uncontrolled hypertension, diabetes and heart diseases, and neuromusculoskeletal disorders that would affect their participation in the study were excluded. Desk-based employees were eligible in the intervention cluster only if they had smartphones (Android version above 4.0). The desk-based employees who were pregnant, planning to go on leave or serving a notice period following resignation were also excluded from the study. As we did not get the necessary permission from two administrative offices out of seven approached, only five clusters (n=76) were included and randomised to either arm (intervention or control). Employees in the clusters signed written informed consent before their participation in the study. All the study participants were advised to follow a standard dietary intake of 2300 Kcal/day from a dietary chart given during the period of familiarisation.

Sample size and power

To establish a between-arm difference of at least a 3 mmol/dl (12) difference of fasting glucose (effect size of 0.5) with an intra-cluster correlation coefficient (ρ) of 0.5 and clusters having a small sample size of 14 ± 5, we required 42 desk-based employees with 21 in each arm at a 95% significance level and a power of 50%. The formula used was:

Effective sample size = $^{mk}/_{1 + \rho (m - 1)}$ where:

- m is the population size in each group;
- k is the number of clusters;
- ρ is the inter cluster coefficient.

SmPh-app based walk reminders

"Take a walk" (TW) (Happy Lives, Pune 2018) is a simple Android based app that runs on a Java platform and is freely available on the Google Play store. The TW app reminds the employees to walk at regular intervals during the day where the timings and dates can be set according to their individual needs. Necessary permissions through e-mail were sought from the developer for administering the TW app to desk-based employees.

Randomization and blinding

Random allocation of clusters to intervention (SMART) and usual work (CONTROL) groups (**figure 1**) was done (by TCZ) to minimise the contamination of the interventions among the participants. An experienced exercise physiologist, who was blinded to the randomisation and intervention assignment, measured the outcome variables of interest at the baseline and follow-up period. The measurements were entered in a coded sheet; data entry was done in a password-protected computer.

Baseline screening for eligibility

Participants belonging to the clusters of each group were instructed to abstain from caffeinated beverages and vigorous exercise for 24 hours and should have had eight hours of adequate sleep before the day of the baseline measurement. The participants underwent FBG test by the finger-stick method and maximal aerobic capacity (VO_2 max) was quantified through a submaximal exercise test. The sedentary healthy desk-based office employees from the clusters were included if they had an FBG < 100 mg/dL and a reduced aerobic capacity with VO2 max < 26.5 ml/kg/min.

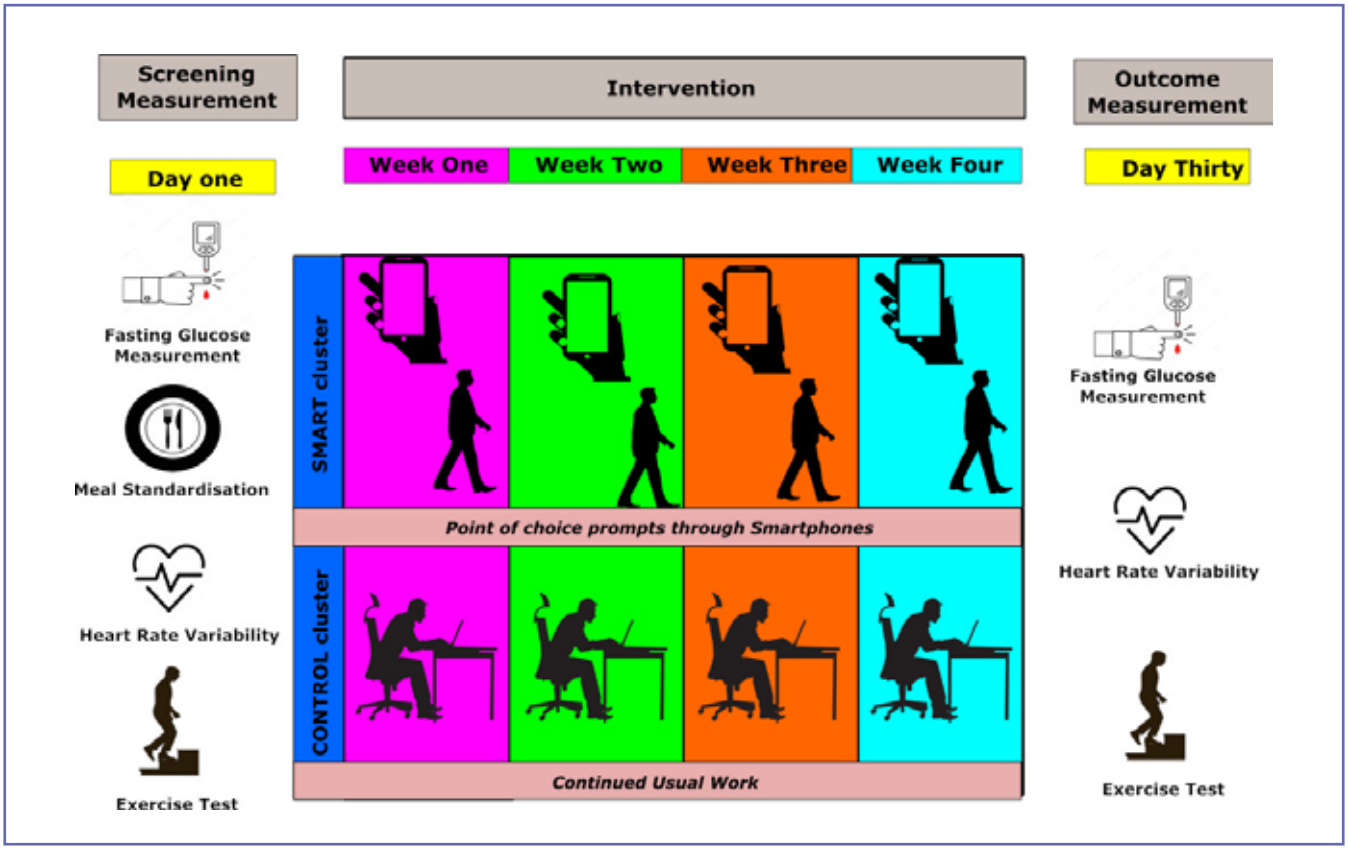

Figure 1. Infographic showing the randomisation process and the trial procedure.

Procedure

After the baseline measurements of FBG, VO2 max and HRV, the clusters were randomised, respectively, for four weeks of intervention. The employees of the SMART group were then requested to download and install the TW app in their SmPh. Explanation of the procedure and familiarization of log entry were given to the participants on the initial day of the intervention. The break reminders were set for two minutes of walk every one hour during work time (9:00 AM, 10:00 AM, 11:00 AM, 12:00 AM, 3:00 PM, and 4:00 PM). Participants manually logged into the TW app at the end of every 2 minutes of "walk break". The self-paced walk was administered for two minutes during the break reminders, and the compliance to the break reminders was logged both in the TW app and activity manual log, to cross validate the break timings with the application. Every week adherence to the walk breaks was collected from the employees SmPhs. At least 70% of walk attendance in four weeks was deemed necessary for inclusion in the final analysis. The employees recruited in the CONTROL group continued their routine occupational and leisure activities for the next four weeks of the trial period. Both the clusters were assessed for VO2 max, HRV and FBS at the end of four weeks by the blinded assessor. The whole procedure is presented as an infographic (**figure 1**).

Outcome data

FBG

Finger-stick Glucose Testing (FGT) was used for testing the FBG in the employees at 7:15 AM after 8 hrs of fasting. The Accu-Chek Active™ blood glucometer and test strips (Roche Diagnostics, Mannheim, Germany) were used for the FBG measurements. The glucometer was calibrated daily using the control solution as per the manufacturer's standards. The coefficient of variation for FBS through finger stick measurement was found to be 1.9-6.4% (13). The FGT has been proven to be an accurate measure compared to laboratory blood glucose monitoring by enzyme-linked immunoassay method for diagnostic purposes (sensitivity of 81% and specificity of 65%) (14).

VO_2 max

VO_2 max was estimated by a submaximal exercise test - the Queens College Step (QCS) test. The QCS was performed using a box with a height of 41.3 cm. A cadence of 24 steps/minute and 22 steps/minute, for males and females respectively, was performed with a metronome for three minutes. After cessation of the test, the radial pulse rate was measured from 5 to 20 s during the recovery period. The pulse count was multiplied by four (beats per minute) to obtain the Recovery Heart Rate (RHR), which was then employed in predicting the VO_2 max (111.3 – (0.42 × RHR)) (15). An Indian study found that the estimated VO_2 max by the QCS test is reliable and valid ($r=0.95$; $p < 0.001$) as compared to directly measured VO_2 max by the Douglas bag method (15).

HRV

HRV was measured as per earlier guidelines outlined by the Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology (16) The employees were provided with a Polar H7 chest strap (Polar Electro Oy, Kempele, Finland) and instructed to secure it snuggly around the chest at the level of fifth intercostal space. Resting heart rate was recorded in a lying position for 10 minutes through a Bluetooth paired Smph-app (Elite HRV, NC, USA) with a sampling frequency of 1100 Hz. The participants were instructed to relax and bre athe at a natural rate. The R-R files were exported from Elite HRV SmPh application by email to a personal computer for analysis using Kubios HRV 3.3.1 (Kubios, Finland). Each file was corrected for artefacts as per manufacturer guidelines of Kubios HRV (cubic spline interpolation method). The validity of the Polar sensors has been reported to be higher (ICC > 0.99) compared to an electrocardiogram in measuring HRV (16).

The time domain HRV indices calculated were the Root Mean Squared Successive Differences (RMSSD) of Inter-Beat Intervals (IBIs) and the standard deviation of IBIs (SDNN). The frequency domain HRV indices calculated were very low frequency power (VLF, 0.003-0.04 Hz), low frequency power (LF, 0.04-0.15 Hz), high frequency power (HF, 0.15-0.4 Hz), and the ratio between LF and HF components (LF/HF). The nonlinear domains (SD1, SD2, SD1/SD2 index) were measured using a cubic spline interpolation method.

Adherence

Walking adherence was calculated by counting the number of sessions performed as mentioned in the activity diary (log) (17) with self-reported break time and duration of the walks. A threshold of 70% adherence was deemed necessary for inclusion in the data analysis; *i.e.*, a minimum of 100/144 break reminders should have been utilized for walking during the 4-week intervention by the SMART group employees.

Statistical Analysis

The continuous variables of FBG, VO_2 max, and time and frequency domain measures of HRV before and after intervention were not normally distributed as noted in the Shap-

iro-Wilk tests and histograms. Data are expressed as median and interquartile range. Since follow-up of six employees were lost during the four weeks intervention, the data of these participants were also included in the intention-to-treat analysis. We used baseline observation carried forward (BOCF) for including the missing data in analysis.

The Mann-Whitney U test (between-group baseline comparisons), Wilcoxon Signed-Rank test (within-group comparisons) and the Kruskal Wallis test (between-group comparisons) were used as appropriate. *Post-hoc* comparisons were done using the Wilcoxon Signed-Rank test and Holm-Bonferroni method with the adjusted p value for multiple comparisons. Adjusted p value= Target p value/ (Rank number of the pairs that are significant (n) + 1). To be statistically significant, the post-hoc pairwise comparisons of FBG, VO_2 max and time, frequency and non-linear domains of HRV should have a p value less than 0.025. The effect sizes were calculated by Cramer V imputations of Chi-square statistics, $V=\sqrt{\frac{\bar{x}}{n(\alpha_f)}}$

where:

- is the Chi-square value;
- n is the sample;
- df is the degrees of freedom.

The effect sizes of < 0.3, > 0.3 to < 0.5 and > 0.5 are considered as low, medium and high respectively (18). All the statistical analyses were done using the Statistical Package for Social Sciences Software (SPSS IBM® v. 23, IBM, USA). The study results are reported based on the recommendations of Padulo *et al.* (19).

RESULTS

Flow of participants through the study

Out of fifty-three desk-based workers from five clusters included initially into the study, 47 participants (SMART group, n=28 (18 females) with ≥ 70% walk attendance; CONTROL group, n=19 (11 females)) completed the four weeks of the study (**figure 2**). On average, the total walk time during the scheduled breaks was 10.2 ± 1.8 min for the SMART group employees as calculated from their self-reported activity log. The baseline characteristics were not significantly different between groups (**table I**).

FBG

A statistically significant difference in FBG was found between the SMART group compared to the CONTROL group (X^2=24.10; p <0.001) (**table II**).

The SMART group demonstrated a reduction in FBG with an effect size of 0.674 (moderate) compared to the CONTROL group post-intervention. Within-group comparisons revealed that the SMART group showed a significant reduction in FBG by 8 mmol/dL (IQR -12.25 to -3.75 mmol/dL); Z=-4.37; p < 0.001, compared to the CONTROL group (Z=-0.41; p=0.682) (**table III**).

VO_2 max

VO_2 max scores were significantly different between the SMART and CONTROL groups (X^2=13.22; p < 0.05). The SMART group employees were found to improve VO2 max by 2.23 ml/kg/min (IQR 0.12 TO 4.34 ml/kg/min) post-intervention than the CONTROL group (**table II**) which may not be clinically significant (effect size=0.499, p > 0.025). Within-group comparisons revealed that the SMART group demonstrated a significant difference in VO_2 max (Z=-3.95; p=0.000) compared to the CONTROL group (Z=-0.41; p=0.685) (**table III**).

HRV

Between SMART and control groups, all the variables of time, frequency and non-linear domains showed a significant difference except SDNN (X^2=2.24; p=0.135) (**table II**). A statistically significant difference in time, frequency and nonlinear domains were found within the SMART group compared to CONTROL (**table III**). On *post-hoc* pair-wise comparisons using the Holm–Bonferroni correction revealed statistically significant improvement in all the variables of time, frequency and nonlinear domains for the SMART (p < 0.025). On the contrary, though some HRV variables turned statistically significant in the CONTROL group they did not seem to clinically improve at the end of study. There were no adverse events during the study.

DISCUSSION

The purpose of this study was to investigate whether SmPhapp (TW) directed physical activity reminders would facilitate walking and improve FBG, VO_2 max, and time and frequency domain measures of HRV in desk-based office employees. This study found significant differences in fasting glucose, functional capacity and heart rate variability after a 4-week smartphone mediated physical activity program for desk-based office employees than the usual workgroup in real-time office settings. The key findings in this study are: a) compared to the control group, statistically significant reductions in FBS, VO2 max and HRV in the SMART group; b) SMART group showed significant reduction in FBG, and improvement in functional capacity and HRV compared to baseline values, with no clinical-

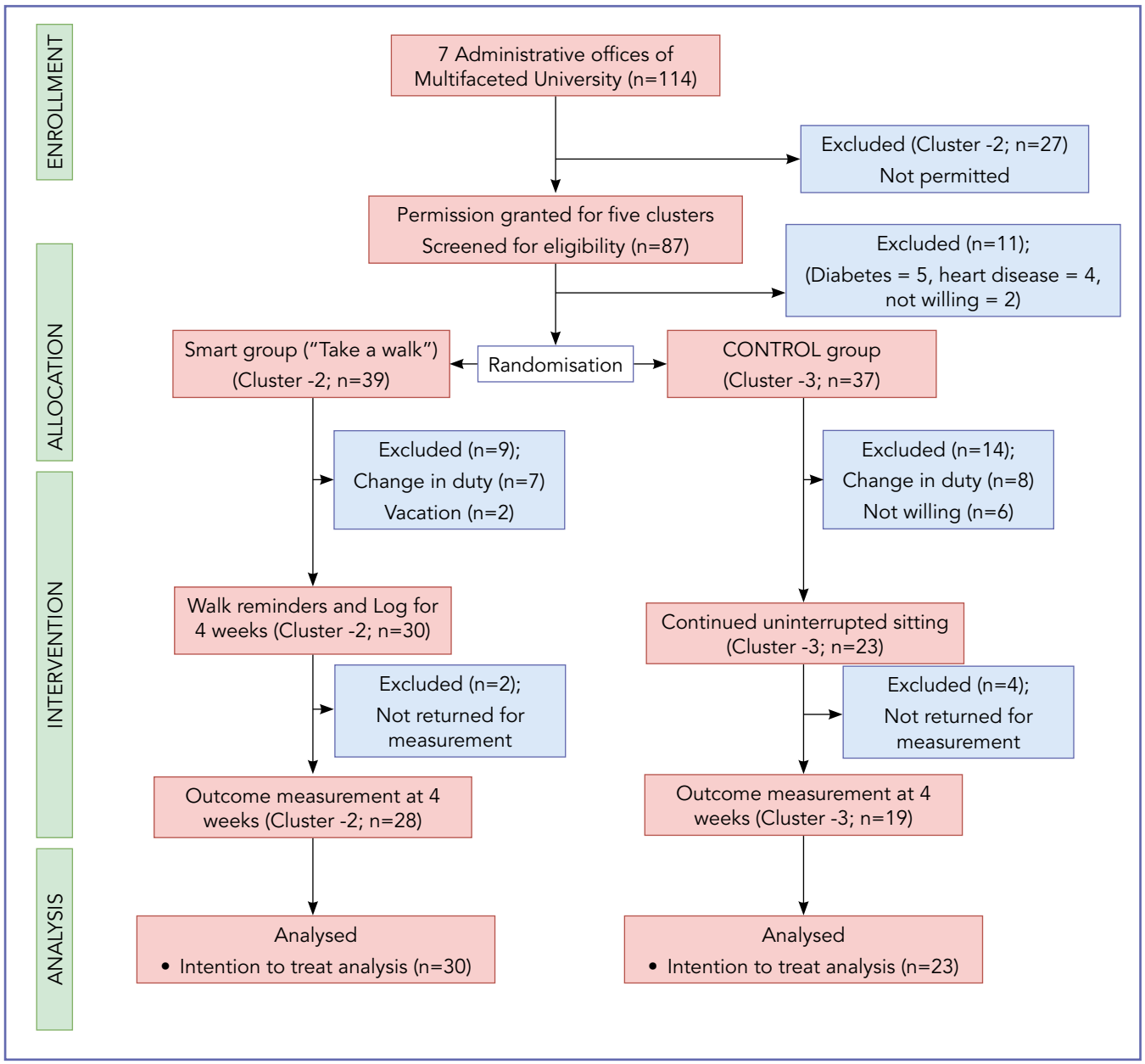

Figure 2. CONSORT flow diagram showing the flow of participants through the study.

ly evident improvement in the control group. These observations suggest that SmPh-app directed physical activity reminders may improve cardiometabolic risk markers such as FBS, VO2 max and heart rate variability. Smartphones based physical activity reminders may positively impact on attitude and perceived behavioural control by the theoretical framework of reasoned action, operant conditioning and planned behaviour (20).

FBG

Our study found a significant reduction of 8 mmol/dL in the FBG levels within the SMART group. Our study results agree with the earlier lab-based studies that have demonstrated a significant reduction in FBG levels after interrupting prolonged-sitting (21). The proposed mechanisms for this significant drop (11% from the baseline) in the FBG may be postural muscles contraction mediated transloca-

Table I. Baseline characteristics of the SMART and CONTROL groups involved in the study.

Baseline Characteristics			SMART group (n = 30) *Median (IQR)*	CONTROL group (n = 23) *Median (IQR)*	Z	p*
Age (years)			46 (45 – 48)	46 (44 – 54)	-2.832	0.825
BMI			22.85 (20.18 – 24.43)	23.15 (19.86 – 24.62)	-1.524	0.526
Fasting Blood Glucose (mmol/dL)			89.00 (78.00 – 93.25)	87.00 (81.00 – 88.00)	-0.054	0.257
Maximal Aerobic Capacity VO_{2max} (ml/kg/min)			45.31 (39.01 – 52.32)	36.00 (36.00 – 41.16)	-4.723	0.062
Heart Rate Variability	**Time Domain**	SDNN (ms)	52.68 (51.36 – 53.36)	49.12 (44.76 – 52.12)	-3.267	0.092
		RMSSD (ms)	52.39 (48.24 – 54.20)	54.23 (52.43 – 55.67)	-2.541	0.924
		NN50 (%)	129.43 (129.07 – 129.67)	129.67 (128.86 – 129.18)	-2.620	0.845
		pNN50 (%)	37.43 (37.32 – 37.60)	37.16 (37.02 – 37.24)	-3.446	0.762
	Frequency Domain	VLF (ms^2/Hz)	103.00 (101 – 105)	103.00 (90 – 103)	-2.883	0.164
		LF (ms^2/Hz)	981.00 (972 – 988.25)	984.28 (983.58 – 985.68)	-2.335	0.187
		HF (ms^2/Hz)	970.00 (958 – 984)	981.55 (965 – 984)	-0.953	0.340
		LF/HF (%)	1.02 (0.98 – 1.04)	1.01 (0.96 – 1.04)	-0.363	0.717
	Non-Linear Indices	SD_1 (ms)	37.20 (36.12 – 38.33)	22.10 (22.00 – 25.10)	-6.990	0.067
		SD_2 (ms)	55.00 (51.83 – 59.68)	33.50 (30.7 – 33.5)	-6.990	0.246
		SD_1/SD_2 (%)	1.48 (1.20 – 1.80)	1.52 (1.23 – 1.52)	-3.343	0.922

BMI – Body Mass Index; HF power – Absolute power of the high-frequency band (0.15 – 0.4 Hz); LF power – Absolute power of the low-frequency band (0.04 – 0.15 Hz); pNN50 – percentage of successive RR intervals that differ by more than 50 ms; RMSSD – Root Mean Square of successive RR interval differences; SDNN interval (ms) – Standard Deviation of NN intervals; *singnifcance as specified by Mann Whitney U test.

tion of GLUT4 transporters expression and insulin receptor sensitivity similar to the moderate-vigorous physical activities as a physical activity intervention (22). Our findings are in concordance with a recent metanalysis that established a moderate effect on post-prandial glucose levels (SEM=0.54; p=0.00001) with frequent breaks in sitting compared continuous/uninterrupted sitting (23).

VO_2 max

We found a statistically significant improvement of maximal aerobic capacity (VO_2 max) by 1.4 ml/kg/min (1.33%) which is not a clinically significant improvement. This may be an important finding of our study stating that simple walk breaks during office hours may not improve functional capacity. The clinically meaningful difference of VO2 max is claimed to be a 6% increase from the baseline based on previous study (24). Though it could be speculated that the moderate-vigorous walk may improve the functional capacity through improved energy expenditure and cardiovascular stress, it is not evident in our study. We hypothesized that simple low-moderate walking may not improve aerobic capacity whereas moderate-vigorous walking may improve VO2 max (Cohen's d=5.28).

HRV

Our study found a significant improvement of almost all the variables across all the domains of HRV. Though poor HRV is recognized an indicator of cardiometabolic disease risk, its relation with prolonged sitting is established recently (5). By breaking sitting, we could reverse altered autonomic function (enhanced sympathetic and reduced parasympathetic reflexes) which may reduce long-term cardiometabolic risk in sedentary desk-based office employees. In our study, we did not find statistical significance only in SDNN component of time domain. This finding warrants further studies to find the insignificant effect of sitting breaks on time domain, SDNN. We hypothesize that the insignificant results on SDNN may be due to inherent short-term variability of successive RR intervals itself (25). Among other time domain variables, SDNN may be volatile due to circadian rhythm when recorded in short term but it could be a gold standard for assessing cardiometabolic disease risk when recorded long-term (25).

Strengths and limitations of the study

Studies using SmPh-based physical activity measurement and interventions are less common in developing countries

Table II. Comparison of the median change scores between the SMART and CONTROL groups.

Cardiometabolic disease risk variables		SMART Group (n = 30) Change score ($\Delta t_4 - \Delta t_0$) Median (IQR)	CONTROL Group (n = 23) Change score ($\Delta t_4 - \Delta t_0$) Median (IQR)	Between-group median change scores Median (IQR)	Chi-square (X^2)	Kruskal Wallis Significance P < 0.05	Effect Size
Fasting blood glucose (mmol/dl)		-9.00 *(-11.25 – -6.00)*	-1.00 *(-2.52 – 0.86)*	-8 (-12.25 – -3.75)	24.10	0.000**	0.674#
VO_{2max} (ml/kg/min)		1.31 *(0.19 – 3.14)*	0.5*(-0.84 – 0.00)*	2.23 (0.12 – 4.34)	13.22	0.000**	0.499$
Heart Rate Variability measures							
Time Domain	SDNN interval (ms)	1.59 *(-0.30 – 9.56)*	0.00 *(-0.24 – -3.65)*	1.59 (-4.37 – 7.55)	2.73	0.098	0.227
	RMSSD interval (ms)	4.9 *(3.53 – 10.23)*	-0.10 *(-1.69 – 2.27)*	5.03 (2.3 – 7.76)	24.39	0.000**	0.678#
	NN50 (%)	0.96 *(0.38 – 2.14)*	-2.78 *(-5.09 – -1.93)*	3.74 (2.34 – 5.14)	36.63	0.000**	0.831#
	pNN50 (%)	0.96 *(0.38 – 2.14)*	-2.78 *(-5.09 – -1.93)*	3.74 (2.34 – 5.14)	36.63	0.000**	0.831#
Frequency Domain	VLF (ms^2/Hz)	4 *(3.91 – 4.11)*	-1.98 *(-13.00 – 0.00)*	5.98 (-6.82 – 18.78)	20.84	0.000**	0.627#
	LF (ms^2/Hz)	8.13 *(2.06 – 13.25)*	-6.89 *(-21.81 – 0.00)*	15.61 (4.39 – 25.63)	23.00	0.000**	0.659#
	HF (ms^2/Hz)	12.63 *(0.00 – 24.5)*	-5.55 *(-13.00 – 0.00)*	18.18 (6.68 – 29.68)	15.69	0.000**	0.544$
	LF/HF index (%)	-0.04 *(-0.07 – 0.02)*	0.00 *(-0.03 – 0.02)*	-0.04 (-0.49 – 0.41)	14.54	0.000**	0.524$
Non-linear indices	SD1(ms)	3.9 *(3.28 – 4.51)*	13.8 *(10.7 – 13.80)*	-9.9 (-13 – 6.8)	21.81	0.000**	0.641$
	SD2 (ms)	33.6 *(16.96 – 33.6)*	25.9 *(21.82 – 29.26)*	-7.7 (-8.94 – 24.34)	7.94	0.005**	0.387*
	SD1/SD2 (%)	0.67 *(0.28 – 1.04)*	0.13 *(0.05 – 0.21)*	-0.55 (-0.54 – 0.56)	29.10	0.000**	0.741#

**p < 0.001; * - Low effect; $ - medium effect; # - High effect.

HR peak – Peak heart rate attained at the end of the submaximal exercise test; HF – Absolute power of the high-frequency band (0.15 – 0.4 Hz); IQR – Inter Quartile Range; LF– Absolute power of the low-frequency band (0.04 – 0.15 Hz); LF/HF – ratio of LF – HF power; pNN50 – percentage of successive RR intervals that differ by more than 50 ms; RMSSD – Root Mean Square of successive RR interval differences; SDNN interval (ms) – Standard Deviation of NN intervals; SD1 & 2 – Poincare plots perpendicular to line of identity; VO2max – Maximal Aerobic Capacity; Δt_0 – Mean before start of the intervention; Δt_4 – Mean at the end of four weeks.

Table III. Within-group comparisons (pre- *vs.* post-intervention) for cardiometabolic disease risk variables.

Cardiometabolic disease risk variables			SMART Group (n = 30)				CONTROL group (n = 23)			
			Pre (t_0) Median (IQR)	Post (t_4) Median (IQR)	Z	p	Pre (t_0) Median (IQR)	Post (t_4) Median (IQR)	Z	p
Fasting blood glucose (mmol/dl)			89 *(78 – 93.25)*	83 (72 – 86)	-4.37	0.000**	87.00 *(81.00 – 88.00)*	87.00 *(80.96 – 92.12)*	-0.41	0.682
VO_{2max} (ml/kg/min)			45.31 *(39.01 – 52.32)*	47.62 (39.57 – 55.86)	-3.95	0.000**	36.00 *(36.00 – 41.16)*	37.54 *(35 – 40.32)*	-0.41	0.685
Heart Rate Variability measures	**Time Domain**	SDNN interval (ms)	52.68 *(51.36 – 53.36)*	54.49 (52.53 -60.23)	-2.87	0.004**	49.12 *(44.76 – 52.12)*	49.38 *(48.12 – 50.62)*	-0.77	0.444
		RMSSD interval (ms)	52.39 *(48.24 – 54.20)*	58.12 (57.37 – 58.56)	-4.62	0.000**	54.23 *(52.43 – 55.67)*	55.14 *(53.24 – 55.67)*	0.04	0.968
		NN50 (beats)	129.43 *(129.07 – 129.67)*	130.35 (129.63 – 132.14)	-4.51	0.000**	129.67 *(128.86 – 129.18)*	126.20 *(123.82 – 127.88)*	3.82	0.000**
		pNN50 (%)	37.43 *(37.32 – 37.60)*	39.03 (38.24 – 39.22)	-4.63	0.000**	37.16 *(37.02 – 37.24)*	35.26 *(34.25 – 37.12)*	3.54	0.000**
	Frequency Domains	VLF (ms^2/Hz)	103 *(101 – 105)*	107 (102 – 112)	-4.70	0.000**	103.00 *(90 – 103)*	90.12 *(84.68 – 103.12)*	2.77	0.006**
		LF (ms^2/Hz)	981 *(972 – 988.25)*	986.5 (978 – 996)	-3.21	0.001**	984.28 *(983.58 – 985.68)*	976.00 *(962 – 984)*	3.22	0.001**
		HF (ms^2/Hz)	970 *(958 – 984)*	986 (973 – 994.5)	-3.29	0.001**	981.55 *(965 – 984)*	975.00 *(962 – 982)*	-2.50	0.013*
		LF/HF (%)	1.02 (0.98 – 1.04)	0.98 (0.94 – 1.01)	-4.55	0.001**	1.01 *(0.96 – 1.04)*	1.01 *(0.98 – 1.04)*	-0.31	0.760
	Non-linear indices	SD1(ms)	37.2 (36.12 – 38.33)	41.10 (38.18 – 44.12)	-4.77	0.000**	22.10 *(22 – 25.10)*	35.8(34.52 – 37.67)	-4.02	0.000**
		SD2 (ms)	55 (51.83 – 59.68)	88.6 (71.96 – 88.60)	-4.84	0.000**	33.50 *(30.7 – 33.5)*	59.4(57.62 – 61.08)	-2.61	0.000**
		SD1/SD2 (%)	1.48 (1.20 – 1.80)	2.15 (1.86 – 2.25)	-5.01	0.000**	1.52 *(1.23 – 1.52)*	1.66 *(1.28 – 2.01)*	-1.08	0.000**

*p < 0.05; **p < 0.005; p as significance from Wilcoxon Sign Rank Test.

HF – Absolute power of the high-frequency band (0.15 – 0.4 Hz); IQR – Inter Quartile Range; LF – Absolute power of the low-frequency band (0.04 – 0.15 Hz); LF/HF – ratio of LF – HF power; pNN50 – percentage of successive RR intervals that differ by more than 50 ms; RMSSD – Root Mean Square of successive RR interval differences; SDNN interval (ms) – Standard Deviation of NN intervals; SD1 & 2 – Poincare plots perpendicular to line of identity; VO2max – Maximal Aerobic Capacity

and our study is the first of its kind in India to demonstrate a significant improvement of HRV through breaking sitting through walk reminders using a freely available SmPh-app (TW) among desk-based employees. Being a pragmatic trial, we just used the TW app to provide break reminders and asked employees to maintain a log of walk attendance; however, we did not monitor the frequency, intensity and/or duration of walking intervention using accelerometers, pedometers etc owing to lack of availability of these devices at our study setting. We emphasize the need for future studies to monitor walking parameters during such interventions. Though a diet chart (recommending 2300 Kcal/day intake) was provided to the employees, their dietary intake and adherence to the recommended diet was not followed during the intervention. If the 6 participants (11.32%) who missed the final measurements would have been retested, it might have added to the strength of the study. However, the retesting was not possible due to change in their work time during the intervention period. Moreover, we estimated the functional capacity through a submaximal test (Queens college step test) whose validity in healthy population is questioned. Future trials should administer maximal exercise test with indirect calorimeter to directly measure VO2 max for precise clinical change.

CONCLUSIONS

In conclusion, our study results augment the fact that SmPh-app based physical activity intervention may reduce cardiometabolic disease risk through behaviour change in short-term in sedentary desk-based employees. Further clinical trials are warranted to use robust SmPh-apps with in-built motion sensors and accelerometers that monitor walking parameters (frequency, intensity, and duration) along with walk reminders.

ETHICS STATEMENT

The study proposal was reviewed and approved by the Kasturba Medical College and Hospitals (KMC & KH) Institutional Ethics Committee [Reference: 676/2018].

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HUMAN RIGHTS

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

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