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The effect of time spent outdoors during summer on daily blood glucose and steps in women with type 2 diabetes

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Abstract This study investigated changes in glycemic control following a small increase in time spent outdoors. Women participants with type 2 diabetes (N = 46) wore an iBUTTON temperature monitor and a pedometer for 1 week and recorded their morning fasting blood glucose (FBG) daily. They went about their normal activities for 2 days (baseline) and were asked to add 30 min of time outdoors during Days 3–7 (intervention). Linear mixed effects models were used to test whether morning FBG values were different on days following intervention versus baseline days, and whether steps and/or heat exposure changed. Results were stratified by indicators of good versus poor glycemic control prior to initiation of the study. On average, blood glucose was reduced by 6.1 mg/dL (95% CI −11.5, −0.6) on mornings after intervention days after adjusting for age, BMI, and ambient weather conditions. Participants in the poor glycemic control group (n = 16) experienced a 15.8 mg/dL decrease (95% CI −27.1, −4.5) in morning FBG on days following the intervention compared to a 1.6 mg/dL decrease (95%CI −7.7, 4.5) for participants in the good glycemic control group (n = 30). Including daily steps or heat exposure did not attenuate the association between intervention and morning FBG. The present study suggests spending an additional 30 min outdoors may improve glycemic control; however, further examination with a larger sample over a longer duration and determination of mediators of this relationship is warranted.

Keywords T2DM · Diabetes · Fasting glucose · Time spent outdoors · Ambient temperature · Physical activity

Introduction

Glycemic control for persons diagnosed with type 2 diabetes is challenging. Building on Thaler and Sustein's idea of nudge theory (Thaler and Sunstein 2008) where small changes may create a choice architecture that makes the healthy choice easier or the default choice has shown public health promise when applied to obesity research (Arno and Thomas 2016). Since obesity and diabetes are highly correlated (Golay and Ybarra 2005), some approaches found successful in persons with obesity may be effective in persons with diabetes. A nudge-based risk communication intervention providing personalized life expectancy information was shown to be feasible and acceptable for individuals with poor glycemic control (Rouyard et al. 2018). However, the nudge approach related to time spent outdoors for improved glycemic control has largely been unexplored. Small, potentially unnoticeable changes to one's life may

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offer some improvement in glycemic control in persons with type 2 diabetes.

Physical activity in particular has been positively associated with glycemic control (American Diabetes Association 2003). However, many adults with type 2 diabetes find adhering to the recommendations for physical activity challenging (Zhao et al. 2008). The American College of Sports Medicine and the American Diabetes Association define specific evidence-based physical activity recommendations for persons with type 2 diabetes. They recommend "150 min/week of moderate to rigorous aerobic exercise spread over at least 3 days during the week" (Colberg et al. 2010). They further clarify that individuals with poor blood glucose control (with blood glucose exceeding 300 mg/dL) use caution and only proceed if they feel well and hydrated (Colberg et al. 2010). Interventions such as establishing walking clubs promote outdoor activities to sustain these recommendations (Hamasaki 2016; Negri et al. 2010); however, environmental conditions like weather and summer heat are potential barriers to maintaining outdoor physical activity (Sanderson et al. 2002; Gothe and Kendall 2016; Wagner et al. 2016). Despite the barrier to physical activity, some evidence shows associations between moderate and vigorous physical activity with time spent outdoors in children and adults (Gray et al. 2015; Beyer et al. 2018).

Physiological effects of heat exposure have also been associated with glycemic control. A review by Yardley et al. (2013) suggests lower skin blood flow and reduced sweating of individuals with type 2 diabetes leads to greater susceptibility to heat-related illnesses. Glucose tolerance tests in healthy young men suggest exposure to high ambient temperatures may *increase* fasting glucose levels and insulin post exposure (Dumke et al. 2015). However, in another study under highly controlled conditions, acute hyperthermia from head-out hot water immersion *did not alter* glucose or insulin responses 24 h post-treatment in participants with type 2 diabetes and obesity and healthy adults (Rivas et al. 2016). Other evidence in human studies, such as overall lower A1c during spring and summer versus autumn and winter months, suggests heat exposure may lead to *better* glycemic control via increased blood flow and insulin absorption, as reviewed in Kenny et al. (2016).

In summary, there is minimal and conflicting evidence regarding relationships between thermal exposures and glucose control, and supporting evidence that time spent outdoors generally increases physical activity and that increases in physical activity lead to better glycemic control. Therefore, this study set out to examine the relationship between time spent outdoors, heat exposure, physical activity, and glycemic control in individuals with type 2 diabetes during the summer months. The objective of the study is to evaluate whether a small amount of additional time spent outdoors, 30 min per day, improved glycemic control in women with type 2 diabetes. We hypothesize that increasing time spent outdoors may lead to increased steps and minimal increases in heat exposure thereby leading to an overall reduction in morning fasting glucose levels the next day. Feasibility of recruitment and procedures and measurement techniques were also evaluated and variance of outcome measures was estimated.

Methods

Study design and overview

In the summer of 2017, residents were recruited in urban Birmingham AL (N = 90) and rural areas in Wilcox County, AL (N = 90) to participate in a study to monitor their personal heat exposure and steps as an estimate of physical activity for seven days. The climate in both study areas is humid subtropical, with normal summer maximums of 90 °F (91 °F) in Birmingham (West Central AL). A subset of participants (N = 46) reported being diagnosed with type 2 diabetes and also reported measuring their fasting blood glucose (FBG) each morning. These participants were given the opportunity to participate in a sub-study, which is the subject of the present analysis. Briefly, participants wore an iBUTTON temperature monitor on their shoe and a pedometer on their waist (described in more detail below). They went about their normal daily activity (baseline) for the first 2 days of participation and were then asked to add 30 min of additional outdoor time on the third through seventh day (intervention) of participation. They completed a demographic questionnaire and a questionnaire on type 2 diabetes and glycemic control strategies through a 1-h training presentation by researchers at the initial enrollment session held at local community gathering spaces (community center and county extension office). Participants kept a daily log of their time spent outdoors, morning FBG, and pedometer steps. Participants also completed an exit questionnaire on the last day of participation. They received three follow-up phone calls during the week of participation to troubleshoot any challenges with compliance to wearing the monitors and filling out the daily logs. This study was registered with clinicaltrials.gov (NCT 03614780) and approved by Virginia Tech Institutional Review Board (15-761).

Participant recruitment, screening, and eligibility criteria

Community partners (Friends of West End, Birmingham AL and West Central Alabama Community Health Improvement League, Camden AL) recruited participants using convenience and snowball sampling approaches. Potential participants were screened and recruited during the spring and summer of 2017 (Supplementary material 1). Enrollment and participation occurred between July 10th, 2017 and July 19th, 2017. Eligibility criteria included being a woman, age 19–66, and availability and consent to participate in the week-long study. The study was limited to women to reduce variability for primary variables of interest and improve the ability to recruit and follow-up with participants based on previous studies conducted by the community-academic partnership. In addition, women with type 2 diabetes have higher risks than men for blindness, depression, and heart disease—the most common complications of diabetes (Kautzky-Willer et al. 2016). Screening for participation in the glucose control sub-study occurred at enrollment for the main study. All 180 participants were asked: (1) if they had been previously diagnosed with type 2 diabetes by a medical professional and if yes, (2) if they checked their blood glucose daily. Targeted recruitment was 30 participants per location. If they answered yes to both screening questions they were given the opportunity to participate in the sub-study that required recording their morning FBG values in the daily log and filling out an additional questionnaire on their experience living with type 2 diabetes. Neither participants nor study personnel were blinded to the intervention. Main study sample size was based on an initial study to determine differences in heat exposure between urban and rural settings (Bernhard et al. 2015). Sub-study sample size was determined by the number of eligible and consenting participants.

Data sources/measurement

Participants were asked to self-report on a log their daily morning FBG for a period of 7 days. To address the primary question of whether the intervention of additional time outdoors was successful at reducing morning FBG, the daily morning FBG on Days 4–7 (days following intervention days) were compared to morning FBG on Days 1–3 (days following baseline days). Note Day 3 is included as a baseline day for morning FBG as it was assumed that morning fasting glucose reflected activities on the day prior; however, Day 3 is considered an intervention day for the personal heat exposure and step data.

Participants also reported at the end of each day compliance with the 30 additional minutes of time outdoors. Outdoor time was defined as anything outdoors of an enclosed structure. Suggested examples for participants were sitting on a covered porch or gazebo/pavilion, gardening, dining outdoors, or walking. Participants were encouraged to choose the location and activity for additional time outdoors for convenience and to follow safe outdoor practices to avoid dehydration, sunburn, or excessive exertion during afternoon peak temperature hours. A secondary outcome temperature (°F) was measured by an iBUTTON (Maxim Integrated Products, Inc. iBUTTON Model DS1922L), which is roughly the size of a watch battery, worn clipped to the top of the shoe with reported accuracy of 0.5 °C. iBUTTON temperature data was averaged hourly and then over a 24-h period between 6 am and 5:59 am for a single daily value of maximum hourly temperature and average daily temperature experienced for each person-day. Temperatures over 50 °C (i.e. 122 °F) were removed ($n=1$ person-hour). Weather station data was downloaded from the NNDC Climate Data Online (National Oceanic Atmospheric Administration) and included precipitation (yes/no), daily maximum temperature average, and daily minimum temperature average.

Steps taken, as measured by the Yamax Digi-Walker electronic pedometer (SW-200), were considered an estimate of physical activity and a secondary outcome. Participants wore the pedometer and recorded the steps each evening on their daily log without hitting reset, recording the cumulative number of steps per week. The daily logs and pedometer data were examined for accidental resets and other malfunctions of the pedometers. Some pedometers malfunctioned (likely battery loss of power) and some participants had difficulty opening the pedometer cover to access number of steps and accidentally reset the step count, despite training on the use of pedometers. Accidental resets were acknowledged on the daily log by participants, at the turn-in session exit survey, and notes recorded during check-in phone calls on Days 2, 4, and 6.

Body composition measurements (height, weight, body fat %, total body water %, muscle mass, and basal metabolic rate) were collected at the enrollment session and turn-in session using a stadiometer, Befour Inc. Model #PS660 scale, and the Tanita BC-553 portable body composition scale. Body Mass Index (BMI) was calculated from measured height and weight (Wells and Fewtrell 2006).

Participants also completed a questionnaire adapted from The Diabetes Self-Management Questionnaire from Schmitt et al. (2013) about their ability to manage their type 2 diabetes, including: medications, behavioral changes like diet and exercise, their perception of their ability to manage their type 2 diabetes, other medical concerns, whether their glucose was in the desired range at the last medical appointment, age of diagnosis, and frequency and timing of checking blood glucose. Specifically, whether their glucose was in the range that the doctor recommended at their last appointment was considered for these purposes a proxy for glycemic control; possible responses were 'yes' or 'no' and considered as 'good' or 'poor' glycemic control, respectively. The data were also stratified by whether participants' 3-day average baseline morning FBG as reported on the daily log was ≤ 130 (mg/dL) or > 130 (mg/dL) another proxy for 'good' or 'poor' glycemic control based on the American Diabetes Association Standards of Care (American Diabetes Association 2016).

Data analysis

From the daily logs, there were potentially 322 person-days available for step reporting with 304 (94.4%) reported in daily logs (18 person-days (5.6%) were left blank on daily logs). Missing data were handled according to the decision tree in Supplementary material 3. As described above, participants were instructed not to hit reset on their pedometers; therefore steps on day prior were subtracted from steps on day of to identify steps per day for Days 2–7. If that yielded a negative number (30 person-days (9.3%) out of 322 total), daily logs and notes from check-in phone calls were checked for accidental reset by participant and values were changed accordingly (See Supplementary material 3). Additional data evaluation was conducted to form a more restrictive dataset. For this dataset, two participants' data (14 person-days (4.3%) of 322) were removed for repeated pedometer malfunction and reported steps over 20,000 were also removed (4 person-days (1.2%) out of the 322) (See Supplementary material 3).

Linear mixed effects models (LME) were fitted to test whether steps recorded increased during intervention days, temperature increased on intervention days, and whether morning FBG values decreased on day following an intervention day, accounting for repeated measures for individual participants. Additional tests were performed to check for mediation of the intervention effect on morning FBG via steps taken or temperatures experienced following the mediation approach of MacKinnon et al. (2007). The fitlme function in Matlab R2017b was used to run regression models. All analyses were intent to treat. For the main models, the dependent variable was morning FBG as reported by participants on daily logs, and a random intercept was fitted. The main model includes 1-day lagged precipitation, maximum temperature, minimum temperature, and intervention, as well as BMI. In secondary analyses, we stratified the dataset by (1) the survey question proxy for 'good glycemic control' and 'poor glycemic control' and (2) 3-day baseline morning FBG average ≤ 130 for 'good glycemic control' or > 130 for 'poor glycemic control.' A paired *t* test checked for differences in body composition variables. Significance level (α) set at 0.05 for all statistical tests. The TREND checklist for this study is available in Supplementary material 2.

Results

During the summer of 2017, of the 180 participants in the overall study, 46 female participants with type 2 diabetes participated in this study from urban Birmingham, in Jefferson County, Alabama, and rural West Central Alabama, primarily Wilcox County (n = 11 and 35, respectively). There were no deviations to the study protocol after enrollment and all participants completed the study. Self-reported mean age (range) for participants was 54.8 (27, 66). Self-reported ancestry and ethnicity was African or Black and non-Hispanic for 100% of participants, and most participants reported having a high school diploma or higher (100%, 80%) with fewer reporting a bachelor's degree or higher (0%, 14.3%), in Birmingham and West Central Alabama, respectively. The demographics of the study participants were comparable to census data retrieved for Jefferson and Wilcox County, AL (African-American or Black: 43.4%, 71.2%, respectively; high school diploma or higher 89.4%, 79.1%, or bachelor's degree or higher 31.9%, 12%, respectively) (United States Census Bureau 2019). Participants had a mean (range) BMI of 37.9 (24, 65) and on average lost 0.65 ± 2.7 (− 8.8, 3.8) pounds from the enrollment session to the turn-in session; however, this was not a significant difference ($p = 0.1$). Since body fat (%) and BMI are highly correlated in this sample (0.74, $p < 0.0001$), BMI was included in the model for greater comparability to known literature. Additional mean (range) of measures collected are summarized in Table 1.

The primary model (Table 2) showed that glucose decreased by an average of 6.1 mg/dL on days after

Table 1 Mean (SD) and ranges of relevant measures of fasting blood glucose, personal temperature, and steps at baseline and intervention

	Baseline		Intervention	
	Mean ± SD	Range	Mean ± SD	Range
Fasting blood glucose[a]	143.5 ± 52.1	(78, 351)	138.3 ± 45.8	(69, 313)
Personal daily mean temperature (°F)[b,c]	79.1 ± 2.8	(73.3, 86.5)	78.9 ± 3.2	(69.3, 90.0)
Personal daily maximum temperature (°F)[b,c]	88.5 ± 5.0	(79.4, 117.1)	88.5 ± 6.4	(75.7, 119.0)
Steps (inclusive criteria)[d]	2612.6 ± 3401.2	(86, 15,217)	4789.2 ± 7685.5	(42, 68,487)
Steps (restrictive criteria)[d]	3642.5 ± 3351.8	(86,15,217)	3698.4 ± 3177.1	(42, 16,012)

[a] Reported from daily logs; baseline days 1–3; consider intervention days prior as days 4–7

[b] 24-h averages based on 6 am to 5:59 am hourly data

[c] Baseline days 1–2, intervention days 3–7

[d] The two different methods for calculating average steps are described in the "Methods" section and Supplementary material 3

Table 2 Results of primary linear mixed effects model describing the relationship between the intervention and fasting blood glucose when adjusting for age, Body Mass Index (BMI), and ambient weather conditions [precipitation (WS Precipitation), weather station maximum (WST Max) and minimum temperatures (WST Min)]

	β	*p* value	L 95%CI	U 95% CI
Intercept	195.5	0.1	−64.3	455.3
Age	0.8	0.3	−0.8	2.3
BMI	−0.5	0.5	−2.1	1.0
Intervention $_{\text{day prior}}$	**−6.1**	**0.03**	**−11.5**	**−0.6**
WST Min $_{\text{day prior}}$	−1.2	0.3	−3.7	1.2
WST Max $_{\text{day prior}}$	0.1	0.9	−1.5	1.8
WS precipitation $_{\text{day prior}}$	4.7	0.1	−1.6	11.1

The numbers in bold correspond to a significance level of $\alpha \leq 0.05$

intervention days ($p = 0.03$, 95%CI −11.5, −0.6) when adjusting for age, BMI, and weather station variables. Neither age nor BMI were significantly associated with glucose. Temperature (daily mean and daily max hourly) and steps (inclusive criteria and restrictive criteria) were not significantly increased on intervention days (Table 3, Supplementary material 4). Tests for mediation (Supplementary material 5 and Supplementary material 6) did not suggest steps as measured by pedometers (steps inclusive criteria, steps restrictive criteria) or personal temperature (day prior daily mean 6am time range, day prior daily max hourly 6 am time range) mediated the effect of the intervention on FBG.

Participants were stratified by their response to the survey question regarding whether their blood sugar was in the range the doctor recommended at their last appointment (no n = 16, yes n = 30, poor and good glycemic control respectively). Stratified analysis showed that participants who reported that at a recent appointment their glucose was out of the doctor recommended range (poor glycemic control group) experienced on average a 15.8 mg/dL drop in morning FBG on day following the intervention (*p* value = 0.006, 95%CI −27.1, −4.5) (Table 4, Model 1). Participants in the good glycemic control group did not see significant change in their morning FBG (β-1.6, *p* value 0.6, 95%CI −7.7, 4.5) (Table 4, Model 2). Neither steps nor personal temperature experienced significantly affected this relationship in either subgroup (Supplementary material 7). When stratifying by ≤ 130 'good' glycemic control (n = 25) or > 130 'poor glycemic control' (n = 21), participants in the 'good' glycemic group did not see a significant change in their morning FBG (β 3.7, *p* value 0.6, 95%CI −1.7, 3.1) (Table 4, Model 4). However, participants in the 'poor' glycemic group did see a significant decrease of 14.4 mg/dL in morning FBG on day following the intervention (*p* value 0.003, 95%CI −24.1, −4.7) (Table 4, Model 4).

According to the Exit Survey, participants reported that they were able to complete the additional 30 min outdoors on all or most days (93.5%, n = 43), and they found the intervention easy to remember to do (93.5%, n = 43). Participants reported the time spent outdoors as enjoyable (87.0%, n = 40) or neutral (4.3%, n = 2), with only a few seeing it as an obligation (8.7%, n = 4). There were no adverse events or measured unintended effects to report.

Conclusions

Limitations

Small sample size may have limited the power to detect significant differences in temperature and steps between baseline days versus intervention days. The heightened probability of non-replicable findings in low powered studies is also acknowledged. The short time frame may have limited the ability to detect differences in glucose levels, and potential variation due to different products used to measure FBG were not evaluated. Pedometer malfunction and accidental resets limited the number of pedometer days available for analysis. In addition, this study relied on self-reported glucose and pedometer information on daily logs. A longer-term study would be needed to determine whether additional daily time spent outdoors improves glycemic control outcomes

Table 3 Results of linear mixed effects models describing the relationship between the intervention and personal temperature (daily max hourly) or steps adjusting for weather variables [precipitation (WS Precipitation), weather station maximum (WST Max) and minimum temperatures (WST Min)]

	Model 1				Model 2			
	Personal temperature (daily max hourly)				Steps			
	β	*p* value	L 95%CI	U 95% CI	β	*p* value	L 95%CI	U 95% CI
Intercept	120.7	3.40E−06	70.5	171	9845.8	0.4	−15,910	35,602
Intervention	−0.5	0.4	−1.7	0.7	−69.9	0.8	−695.8	556.1
WS precipitation	0.5	0.4	−0.8	1.9	121.3	0.7	−547.6	790.1
WST Max	0.3	0.09	−0.04	0.6	97.2	0.2	−63.4	257.7
WST Min	−0.8	0.002	−1.3	−0.3	−210.0	0.1	−469.3	49.4

Table 4 Results of linear mixed effects models stratified by disease glycemic control according to survey results and standardized cutoffs (poor vs. good) with describing the relationship between the intervention and fasting blood glucose when adjusting for age, Body Mass Index (BMI), and weather variables [precipitation (WS Precipitation), weather station maximum (WST Max) and minimum temperatures (WST Min)]

	Poor glycemic control[a]				Good glycemic control[a]			
	β	*p* value	L95%CI	U95%CI	β	*p* value	L95%CI	U95%CI
Intercept	135	0.6	–403.7	673.6	140.1	0.3	–141.9	422
Age	3	0.08	–0.4	6.4	0.4	0.6	–1	1.7
BMI	2.4	0.3	–2	6.7	0.1	0.8	–1.3	1.6
Intervention $_{\text{day prior}}$	**–15.8**	**0.006**	**–27.1**	**–4.5**	–1.6	0.6	–7.7	4.5
WS precipitation $_{\text{day prior}}$	4.7	0.4	–7.4	16.8	3.2	0.4	–4.1	10.6
WST Max$_{\text{day prior}}$	0.4	0.8	–2.5	3.2	–0.1	0.9	–2.1	1.9
WST Min$_{\text{day prior}}$	–3.4	0.2	–8.6	1.7	–0.4	0.7	–3.2	2.3
	Poor glycemic control[b]				Good glycemic control[b]			
	β	*p* value	L95%CI	U95%CI	β	*p* value	L95%CI	U95%CI
Intercept	175.6	0.4	–247.5	598.8	127.3	0.3	–107.0	361.6
Age	2.3	0.1	–0.4	5.1	–0.03	0.9	–0.7	0.7
BMI	–1.2	0.3	–3.6	1.1	0.1	0.8	–0.7	0.9
Intervention $_{\text{day prior}}$	**–14.4**	**0.003**	**–24.1**	**–4.7**	3.7	0.6	–1.7	3.1
WS Precipitation $_{\text{day prior}}$	12.4	0.03	1.1	23.7	–4.7	0.1	–10.9	1.6
WST Max$_{\text{day prior}}$	0.9	0.5	–1.8	3.6	–0.7	0.4	–2.5	1.0
WST Min$_{\text{day prior}}$	–2.3	0.3	–6.3	1.7	0.7	0.6	–1.8	3.1

The numbers in bold correspond to a significance level of $\alpha \leq 0.05$

[a] Survey results n = 16 poor, n = 30 good

[b] Morning fasting blood glucose daily log cutoff > or ≤ 130 (poor n = 21 vs. good n = 25 glycemic control, respectively)

beyond 5 days. The results may not be generalizable beyond the study population.

Strengths

This paper presents measurements of personal temperature exposure and morning FBG in free-living participants. The results support the inverse relationship between morning FBG and an additional 30 min of time spent outdoors on the previous day. The reduction in morning FBG was even lower for participants who reported poor glycemic control. This may be related to lower levels of physical activity or other variables that were not measured in this study, such as stress level. However, increases in measures of the hypothesized mediators, physical activity and personal temperature exposure, were not detected on the intervention days in this study.

These results show promise for a nudge approach to improving glycemic control in individuals with type 2 diabetes through additional time outdoors. Future larger studies that are powered to detect significant changes in physical activity and personal heat exposure, in addition to other potentially related variables such as diet and stress, are warranted (Bai et al. 2016). The present study demonstrates feasibility, as participants were able to complete the study protocol, with no losses to follow-up or drop-outs, and reported that the intervention was acceptable.

Future studies can build on this protocol while incorporating preferred measures of glycemic control like A1c (American Diabetes Association 2016). While Self-Monitoring of Glucose Control (SMGC) measures immediate blood glucose level, glycosylated hemoglobin (A1c) is an indicator of metabolic control over the last 2–3 months and risk of microvascular complications in individuals with diabetes (Klein et al. 1988). A1c measures the percentage of red blood cells to which glucose is attached. The American Diabetes Association recommends that individuals with diabetes maintain A1c value of less than 7% and that A1c be measured at least twice per year (American Diabetes Association 2007). Maintaining A1c levels at or below 7% in patients with diabetes is associated with decreased medical expenses and lower rates of health complications (Minshall et al. 2005; Chen et al. 2008; de Lissovoy et al. 2000; Shetty et al. 2005; Valentine et al. 2006). Overall, risk of complications is reduced by 21–40% for each percentage point decrease in A1c (de Lissovoy et al. 2000; Manley 2003). Like SMGC, A1c can be measured at home via a test kit with a small blood sample obtained via finger prick.

Future studies could also measure glucose continuously, as this would allow for a more time sensitive characterization of the relationship between blood glucose, temperature and time spent outdoors. To examine potential mediators, Vitamin D levels may be a useful measure to include in future studies, as Vitamin D supplementation has been shown to reduce glycemic variability in persons with T1DM and insulin resistance in persons with T2DM (Felício et al. 2018; Li et al. 2018). In addition, future studies should perform follow-up phone calls to assess whether the intervention of additional time spent outdoors or wearing the pedometer is continuing after the study period. Finally, additional appropriate methods to assess dietary intake without reliance upon self-report and using accelerometers to capture non-step forms of physical activity should be considered in future studies.

This pilot study contributes evidence regarding the relationships among time spent outdoors, physical activity, and glucose control responding to a call for assessing the relationship between pedometer-determined physical activity and health outcomes like glycemic control as suggested by Tudor Locke and Myers (Tudor-Locke and Myers 2001). This study is particularly relevant as it is well-documented that racial disparities exist in the prevalence of type 2 diabetes that extend beyond socioeconomic variables to physiological differences with African Americans having a lower insulin sensitivity and higher fasting insulin concentrations compared to white participants in previous investigations (Hyatt et al. 2009). Thus, it is important to examine ways to improve glucose control particularly in African Americans.

In conclusion, this study suggests that morning FBG can decrease acutely on the day following intervention of 30 min additional time spent outdoors in African American women participants with type 2 diabetes, even when physical activity, as measured by steps, is not significantly increased. This minimally disruptive intervention was acceptable to participants.

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Compliance with ethical standards

Conflict of interest Molly B. Richardson, Courtney Chmielewski, Connor Y. H. Wu, Mary B. Evans, Leslie A. McClure, Kathryn W. Hosig and Julia M. Gohlke declare that they have no conflict of interest.

Human and animal rights and Informed consent All procedures followed were in accordance with ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000. Informed consent was obtained from all participants prior to inclusion in the study.

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