A feasibility study to examine whether time spent outdoors during the summer affects acute daily fasting blood glucose and steps

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INTRODUCTION

Physical activity has been positively associated with glycemic control in persons with type 2 diabetes (T2D); however potential exposure to heat may be a barrier to physical activity outdoors in the summer months. This study investigated whether it would be feasible to detect changes in glycemic control in women with Type 2 Diabetes (T2D) related to a small change (additional 30 minutes) in time spent outdoors during the summer months.

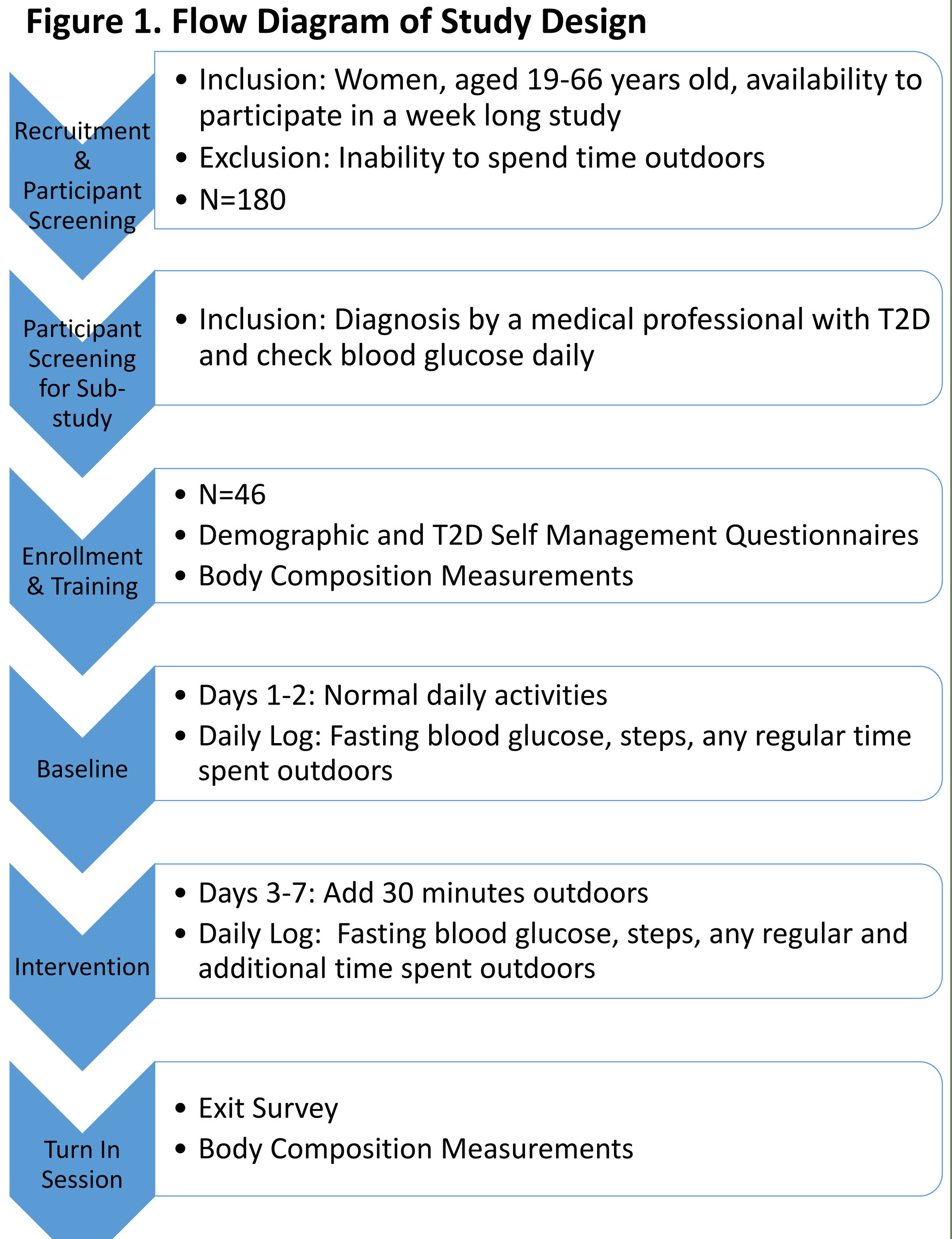
Aims:

We hypothesize increasing time spent outdoors may lead to increased steps, and only minimal increases in heat exposure thereby leading to an overall reduction in fasting glucose levels the next day.

1. Assess whether fasting blood glucose values decreased on days following an intervention day.
2. Assess whether steps and personal heat exposure (daily mean and daily max) increase on intervention days and whether they have a mediating effect on fasting blood glucose.
3. Assess whether self-reported management of T2D modifies the relationship between intervention and fasting blood glucose.

METHODS

Figure 1. Flow Diagram of Study Design



Data Sources and Statistical Analysis

- Linear Mixed Effects Models were performed in MATLAB R2017b.

$$Glucose \sim 1 + Intervention_{Day\ Prior} + Age + BMI + Precipitation_{Day\ Prior} + WS\ T_{Max\ Day\ Prior} + WS\ TM_{in\ Day\ Prior} + (1|id)$$

- Weather Station (WS) temperatures (max and min) and precipitation was downloaded from NCDC Climate Data Online (NOAA)
- Compliance Criteria:
  1. Checked "yes" on Daily log for additional 30 minutes outdoors on intervention days
  2. Wrote a time in for outdoor time
  3. Wrote in an activity in the description that could be reasonably or is most commonly performed outdoors
- Secondary analysis stratified by survey response question below in good versus poor management of condition:
  "At your last appointment, was your blood sugar in the desired range that your doctor has recommended?"

Figure 2. Pedometer and Temperature Monitor A) Yamax Digi-Walker electronic pedometer (SW-200) B) iBUTTON DS1922L C) Model to show how to wear monitors (with permission)

Study Population

Participants were women, primarily African American with mean (range) BMI 37.9 (24, 65) and age 54.8 (27, 66). Participants reported compliance on n=286 of 322 person-days (88.9%).

Table 1: Mean (Range) of outcome variable and potential mediating factors

	Mean	Range
Glucose	140.5	(69, 351)
Daily Mean Temperature (hourly) (°F)	78.9	(69, 90)
Daily Maximum Temperature (hourly) (°F)	88.5	(76, 118)
Steps	4305.2	(97, 68487)

RESULTS

Aim 1: On average, fasting blood glucose was reduced by 6.1 mg/dL in mornings after intervention days (95%CI -11.5, -0.6, p-value 0.03) after adjusting for age, BMI, and weather conditions.

Table 2: Primary Model

	β	(95%CI)	p-value
Intercept	195.5	(-64.3, 455.4)	0.1
Age	0.8	(-0.8, 2.3)	0.3
BMI	-0.5	(-2.1, 1)	0.5
$Intervention_{Day\ Prior}$	**-6.1**	**(-11.5, -0.6)**	**0.02**

- Models include adjustment for weather (Weather station data on maximum and minimum temperature and precipitation).
- Additional model **with only compliant** intervention days prior was similar to the model presented in Table 2 (**$Intervention_{day\ prior}$ β -7.3 (95%CI -12.8, -1.7), p-value 0.01**).

Aim 2a: Personal temperature (daily mean, daily max) and steps were not significantly increased on intervention days.

Table 3: Outcome variable: Personal temperature (daily mean and daily max) and steps

	Personal temperature (daily mean hourly)			Steps		
	β	(95%CI)	p-value	β	(95%CI	p-value
Intercept	79.1	(58.5, 101.3)	1.70E-12	9091.0	(-40905, 59087)	0.7
Intervention	-0.2	(-0.7, 0.3)	0.4	826.5	(-447.7, 2100.6)	0.2

- Personal temperature (daily maximum hourly average) was non-significant (Intervention β 0.006 (95%CI -1.2, 1.2), p-value 0.9).
- All models presented also include adjustment for weather.

Aim 2b: Neither steps nor personal temperature exposure as measured by iBUTTON sensor were significantly associated with fasting glucose on the following morning.

- Personal temperature (daily mean hourly average) was non significant when adjusting for age, BMI, and weather station data ($Intervention_{day\ prior}$ β -0.2 (95%CI -0.7, 0.3), p-value 0.4).
- Personal temperature (daily maximum hourly average) was also non-significant ($Intervention_{day\ prior}$ β -0.5 (95%CI -1.8, 0.8), p-value 0.4).
- All models presented include adjustment for age, BMI, and weather conditions.

Aim 3: Participants in the poor management group (n=16) experienced on average a 15.8mg/dL decrease in fasting blood glucose on days following intervention (95%CI -27.1, 4.5, p-value 0.006).

Table 4: Table of analysis stratified by poor and good management of T2D (n=16, 30, respectively) from questionnaire response

	Poor Management			Good Management		
	β	(95%CI)	p-value	β	(95%CI)	p-value
Intercept	135	(-403.7, 673.6)	0.6	140.1	(-141.9, 422)	0.3
Age	3	(-0.4, 6.4)	0.08	0.4	(-1, 1.7)	0.6
BMI	2.4	(-2, 6.7)	0.3	0.1	(-1.3, 1.6)	0.8
$Intervention_{Day\ Prior}$	**-15.8**	**(-27.1, -4.5)**	**0.006**	-1.6	(-7.7, 4.5)	0.6

- Models include adjustment for weather conditions.
- Participants in the good management group (n=30) did not see significant change to their fasting blood glucose ($Intervention_{day\ prior}$ β-1.6 (95%CI -7.7, 4.5), p-value 0.6).
- Neither steps nor personal temperature experienced (daily mean or daily max) significantly affected this relationship in either subgroup.

Summary of Results

- Analysis of this dataset suggests fasting blood glucose decreased on days following the intervention of an additional 30 minutes spent outdoors.
- Neither personal temperature experienced nor steps were significantly increased, which were the hypothesized mediators.
- Potential limitations are low sample size, imprecise measurement of steps and/ or temperature, and reliance on self-report for compliance. Blood glucose is highly influenced by food intake; however, ad libitum food records for this week were beyond the scope of this study.
- The association between intervention and reduced fasting blood glucose was stronger in participants who reported that at a recent appointment their glucose was out of the doctor recommended range, indicating challenges with management of their condition.

CONCLUSIONS

This pilot study contributes evidence regarding time spent outdoors, physical activity, and glucose control and responds to a call for assessing the relationship between time spent outdoors and health outcomes like glucose control. Further research is necessary before any future recommendations related to heat exposure in this vulnerable population should be considered.

Next Steps:

- Assess additional measures of compliance (phone and exit surveys).
- Explore pre/ post- body composition measurements.
- Explore original participant population (n=180) physical activity, time spent outdoors, and environmental-related deterrents to physical activity.
- Determine appropriate method to assess dietary intake in this population (food diary, 24-hour recall, doubly-labeled water, etc.).

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