Combining Global Positioning System (GPS) with Saliva Collection among Sexual Minority Adults: A Feasibility Study

Tzuan Chen (✉ tchen38@uh.edu)

University of Houston <https://orcid.org/0000-0003-4312-7258>

Nathan Grant Smith

University of Houston

Seann Regan

New York University

Ezemenari M. Obasi

University of Houston

Kathryn Freeman Anderson

University of Houston

Lorraine R. Reitzel

University of Houston

Research

Keywords: Global Positioning System (GPS), saliva, sexual minority, feasibility

Posted Date: March 10th, 2020

DOI: <https://doi.org/10.21203/rs.3.rs-16593/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Version of Record: A version of this preprint was published at PLOS ONE on May 6th, 2021. See the published version at <https://doi.org/10.1371/journal.pone.0250333>.

Abstract

Background: This is the first study, of which we are aware, to evaluate the feasibility of simultaneous use of Global Positioning System (GPS) and saliva collection for biomarker assessment among sexual minority (lesbian, gay, bisexual, queer, and other non-heterosexual identities) individuals. The principal motivation for pairing GPS and saliva collection was to investigate how characteristics of the built and social environments along with participants' daily activity paths affect stress. This can contribute to a better understanding of health and health behaviors in the sexual minority community.

Methods: A convenience sample of enrolled participants (N=124) from Houston, Texas was asked to complete questionnaires, carry with them a GPS unit daily, and collect and store 6 samples of saliva at specific times across the span of a day prior to a second visit around one week later.

Results: Of 124 participants, only 16 participants (12.90%) provided no useable GPS data, whereas 98 (79.03%) provided at least 4 days of data. More than three-fourths (n = 98, 79.03%) also provided complete saliva samples.

Conclusions: Our results show that the simultaneous use of GPS and saliva collection to assess sexual minority individuals' activity paths and stress level is feasible.

Introduction

Spatial epidemiology is a fast-growing field, a modern adaptation of the established methodology of geographic analysis, which dates to the 18th century (1). Traditionally, epidemiologic research focuses on person and time, with little attention to the implications of place and space due to project design, data limitations, etc. (2). However, the built (e.g., proximity and density of alcohol and tobacco retail outlets in a neighborhood) and social (e.g., crime rates, racial composition of a neighborhood) environments are critical factors affecting health behaviors and health outcomes (3, 4). Many studies have shown the importance of activity space and residential context on the incidence of health risk behaviors among vulnerable or disparities populations in the United States (5–12), including among sexual minorities (those identifying as lesbian, gay, bisexual, queer, or other non-heterosexual identities) (13, 14).

Over recent decades, the application of technology has enriched the complexity, sophistication, and utility of spatial epidemiology (15–17). The development of geographic information systems (GIS) has provided a powerful capability for researchers to rapidly examine spatial patterns and processes. GIS data and spatial methods have been used in many epidemiologic applications such as disease mapping, rate smoothing, and spatial modeling (18). With the rapid increase in computing power, several related technologies have extended GIS capacities. The availability of affordable personal Global Positioning Systems (GPS), a relatively recent innovation (19), has made their use increasingly popular—a development that has been discussed in many recent health research studies (9, 20). GPS tracking generates considerable geographic data, which allows for near continuous monitoring of mobility (i.e., activity paths). GPS technology not only allows researchers to investigate the impact of spatial contexts

when wedded with GIS data, but also to consider the timing and the duration of exposure within spatial contexts (21, 22). GPS technology has been widely used among diverse populations (7, 9, 14, 23–25) and assessing contextual determinants and correlates of different health behaviors such as health-related product purchasing behaviors, physical activity, dietary intake, and smoking behaviors (10, 12, 23, 26).

Commonly, research participants in naturalistic studies of neuroendocrine markers of stress are required to report their mood at several points throughout the day (27). Collection of these mood data, such as with Ecological Momentary Assessment on a smartphone or equivalent device, is intended to better capture natural fluctuations across the day relative to single-time questionnaire administration and thereby reduce recall errors and other biases and inaccuracies. However, an alternative approach to gathering objective data on mood and stress can be achieved through the collection of biological data. Many studies have examined how salivary analytes (e.g., cortisol), for example, are associated with mood (28, 29). Specifically, salivary cortisol is a nonintrusive marker of stress and an accurate indicator of serum cortisol (30). A number of studies have demonstrated that there is increased secretion of salivary stress biomarkers under different stress conditions, such as during army boot camp (31, 32) and challenging mental tasks (33). For example, Obasi and colleagues (2017) reported that cortisol levels increased in response to a controlled laboratory inducement of acute stress in a sample of rural African American adults (33). However, relatively few studies have examined biomarkers of stress measured by cortisol and other salivary biomarkers among sexual minority groups (34–38).

Attitudes toward sexual minorities have changed remarkably in the United States during the past three decades, and some of society's key institutions have recognized sexual minorities as an important health disparities group to study independently of heterosexual persons (39, 40). For example, sexual minorities experience higher risks for many negative physical and mental health outcomes (e.g., chronic disease, human immunodeficiency virus (HIV) infection, and anxiety disorders (41–45)), and non-health promoting behaviors (e.g., smoking, heavy drinking, and illicit drug use (44)) relative to heterosexuals. Growing evidence suggests sexual minorities, as members of a disadvantaged social group, are exposed to more stress than members of majority groups (46–49). The health disparities experienced among sexual minorities can be explained by minority stress theory (50). Specifically, Meyer's minority stress model posits that sexual minorities are exposed to myriad and detrimental stressors, which in turn contribute to the higher prevalence of health-risk behaviors and associated disorders and diseases (51–54).

Tracking activity paths using GPS is a novel approach that provides researchers with an objective assessment of physical location where people interact with the built and social environmental contexts without the need for participant recall. Likewise, assessing stress through saliva has several advantages over self-report. For example, it is less intrusive than collecting blood or urine samples, relatively easy for participants to self-collect, and can be used to measure important biomarkers. There are currently no other published studies combining the use of GPS and salivary cortisol in sexual minority adults. Integrating GPS technology with salivary cortisol collection is an innovative strategy for depicting stress level in real time and in environment contexts among groups vulnerable for health disparities. Despite

increasing acknowledgements of the importance of the built and social environments for health, the feasibility of pairing the use of a GPS device and saliva collections in a sexual minority community remains poorly understood.

The purposes of this study were: (1) to assess the feasibility of recruiting participants for the purpose of obtaining location and wear-time data using a GPS monitor for sexual minority adults in real life settings; and (2) to explore the feasibility of collecting saliva samples throughout a single day from sexual minority adults living in Houston, Texas.

Materials And Methods

Eligibility and Recruitment

Project FRESH AIR (Focused Research to Enhance Social Health Among Individuals in the Rainbow) was designed to better understand how psychosocial stressors affect self-reported health and health behaviors among lesbian, gay, bisexual, and queer (LGBQ) adults. This project was unique in its combination of several data sources including questionnaires, anthropometric measurement, carbon monoxide assessment, GPS tracking, and salivary cortisol assaying among sexual minority individuals. Eligibility criteria included aged 18 years or older, self-reported sexual minority, provision of valid contact information, and self-reported willingness to comply with the study protocol. Those who were pregnant, lactating, possibly pregnant, or taking prescription medication that could not be stopped during the day in which the saliva samples were collected were excluded from participation due to potential effects on assay results.

Recruitment was achieved by means of the distribution of study flyers at accommodating businesses and healthcare centers within neighborhoods with a high proportion of sexual minority adults (e.g., Montrose). We also advertised on a university campus, within LGBQ-targeted magazines (e.g., Outsmart), online (e.g., Scruff), and on internal (university) television screens. The goal was to recruit 124 participants based on initial power estimates and funding for study procedures. Participants were primarily recruited through information from friends or other participants ($n = 53$, 42.74%), followed by lesbian, gay, bisexual, and transgender (LGBT)-focused centers ($n = 30$, 24.19%), Other/Not provided ($n = 26$, 20.97%), and print and electronic advertisement ($n = 15$, 12.10%). Study procedures were approved by the IRB at the University of Houston and written informed consent was obtained from all participants. Recruitment, enrollment, and data collection spanned February to October 2015.

GPS Protocol and Data Processing Procedures

Participants were required to make two visits to the University of Houston. During visit 1, they were screened, consented, and enrolled. They were assigned a GPS monitoring device to carry between study visits. During visit 2, approximately one week later, participants returned the GPS unit. The GPS device was used to monitor participants' location to gain a better understanding of the potential influence of environmental context on participants' health and health behaviors. The GPS provided data on where

participants spent most of their time, allowing future analysis to examine exposure to environmental factors in those places (e.g., tobacco outlet density and proximity, fast food density and proximity, as well as broader food environment, alcohol/bar exposure, etc.). As this protocol was designed to measure feasibility, there was no minimum number of days required for GPS collection; rather, days of collection were dependent on the participants' availability to return for the 2nd visit. Participants were compensated with Target gift cards with a value of \$30 at visit 1 for the completion of study procedures including questionnaires and a value of \$20 at visit 2 for returning the GPS device. Researchers used the i-gotU GT-120 travel and sports GPS logger device (MobileAction, Taipei, Taiwan), which has been used in previous studies (55–57). Participants were asked to carry the small GPS device during all times except when bathing, swimming, and sleeping. They were provided with a lanyard to wear it around their neck. Participants were also asked to charge the device nightly and were provided with a charging cord. In addition to verbal explanation, participants were provided with a “take home” card reiterating these instructions.

All GPS devices were associated with a unique ID number that was different from the participant ID number. Due to battery drain considerations, the tracking interval of the GPS devices used in this study was set at 15 minutes. At visit 2, project staff downloaded the GPS data on a single password-protected computer in a locked research lab. The GPS devices used in this study were by design “passive,” meaning the location data of participants could not be seen in real time. The research team uploaded GPS data to encrypted project computers, and used GIS software (ESRI ArcGIS 10.6) for post-processing.

Complete GPS data was defined as having 4 or more days of data, as this study did not require a full 7 days of GPS data. Having 4 or more days of GPS data provides some variability whereby consistency of activity paths may be determined, and, in many cases, both weekdays and weekend data could be captured.

Saliva Cortisol Collection Procedures

Between visits 1 and visit 2, participants were asked to collect 6 samples of saliva over the course of a single day at specified times: (1) when waking up and before getting out of bed; (2) 30 minutes after waking up before brushing teeth; (3) 90 minutes after waking up; (4) at approximately 2:00 p.m. or an hour after lunch; (5) at approximately 5:00 p.m. or before dinner; and (6) before going to bed. Saliva samples were collected to study the fluctuation of stress-related hormones/enzymes throughout the day. Participants were provided with 6 vials for saliva collection at visit 1, and collection procedures were reviewed. Participants collected the sample by spitting into a plastic vial that was labeled with their participant ID number, a process that should have required no more than 5 minutes for each saliva sample. Participants were instructed not to eat, drink, or smoke cigarettes 30 minutes before collecting a sample. Participants were also asked to not take prescription medications on the day of sample collection (until after the last sample was collected). Participants were instructed to store their saliva samples in their freezer until visit 2. Participants received a small Styrofoam cooler and an ice pack that would facilitate storage and transport of the samples to the University of Houston under temperature-

controlled conditions. In addition to verbal explanation, participants were provided with a "take home" card reiterating these instructions.

Participants received a "Collection Diary" in which they were asked several questions about each saliva collection, including time taken, duration of procedure, mood, if anything unusual had occurred that day, etc. Participants returned the Collection Diary, the cooler, the ice pack, and the saliva samples at visit 2. At that time, research personnel asked a few questions about the saliva collection process (e.g., were they able to freeze the sample immediately? were there any problems with collection?), and noted answers that might compromise the integrity of the samples. Participants were compensated \$5 in Target gift cards for each saliva sample returned at visit 2. All saliva samples were immediately stored in an ultracold laboratory freezer (-80° C). Research personnel entered Collection Diary data into a spreadsheet by hand and determinations were made about integrity of samples based on information provided by the participant and visual inspection of the vials.

Socio-Demographic Characteristics

Information concerning participants' sociodemographic characteristics was collected, including age, gender (cisgender male, cisgender female, or transgender), sexual orientation (monosexual vs. bisexual), race (non-Latino white vs. other race/ethnicity), and education ($\leq$ high school education vs. trade school/college degree).

Statistical Analysis

The descriptive statistics regarding the participants' characteristics and recruitment information were generated. Study participants were classified into 4 groups based on their data completion: GPS alone (≥ 4 days), saliva data alone (collected all 6 saliva samples), both GPS and saliva data (i.e., ≥ 4 days of GPS data and collected all 6 saliva samples), and neither GPS nor saliva data. Analysis of variance and Fisher's exact test were used to examine the differences by these groups in participants' age and other sociodemographic characteristics, respectively. In addition, descriptive statistics and missing pattern of saliva collection were provided. GPS data, including the number of days of data per participant, were presented. All statistical analyses were conducted using SAS 9.4 (58).

Results

Participants

Of the 124 participants, 70.97% (n = 88) participants had complete GPS and saliva data; 8.06% (n = 10) participants had complete GPS data but not saliva data; 8.06% (n = 10) participants had complete saliva data but not GPS data; and 12.9% (n = 16) participants did not have either GPS or saliva data.

Of the 124 participants, 119 (95.97%) participants provided valid demographics. Of the 119 participants with valid responses, the average age was 36.41 (± 14.85) years and 50.42% were cisgender male; 52.94% were monosexual; 38.66% reported being African American; 36.97% reported being non-Latino

white; 63.87% reported a high school education or less education (Table 1). No significant differences were found in participants' characteristics across the four groups.

Table 1 Characteristics of Participants by Different Types of Data Completion.

	Total (n = 119)	Complete GPS Alone (n = 9)	Complete Saliva Alone (n = 10)	Complete GPS and Saliva (n = 86)	Neither GPS nor Saliva (n = 14)	p-value^a
	M (SD)/% [n]	M (SD)/% [n]	M (SD)/% [n]	M (SD)/% [n]	M (SD)/% [n]	
Age	36.41 (14.85)	39.56 (9.29)	33.1 (10.49)	35.57 (15.81)	41.93 (13.6)	0.3787
Gender						0.1965
Cisgender Male	50.42 [60]	8.33 [5]	3.33 [2]	73.33 [44]	15 [9]	
Cisgender Female	31.09 [37]	5.41 [2]	8.11 [3]	75.68 [28]	10.81 [4]	
Transgender	18.49 [22]	9.09 [2]	22.73 [5]	63.64 [14]	4.55 [1]	
Sexual Orientation						0.5997
Monosexual	52.94 [63]	7.94 [5]	9.52 [6]	74.6 [47]	7.94 [5]	
Bisexual	47.06 [56]	7.14 [4]	7.14 [4]	69.64 [39]	16.07 [9]	
Race/Ethnicity						0.7055
Asian	3.36 [4]	0 [0]	25 [1]	75 [3]	0 [0]	
Black	38.66 [46]	10.87 [5]	4.35 [2]	67.39 [31]	17.39 [8]	
Latino	15.97 [19]	10.53 [2]	5.26 [1]	78.95 [15]	5.26 [1]	
Non-Latino White	36.97 [44]	4.55 [2]	11.36 [5]	72.73 [32]	11.36 [5]	
Other/Multiracial	5.04 [6]	0 [0]	16.67 [1]	83.33 [5]	0 [0]	
Education						0.6362

^aAnalysis of variance and Fisher's Exact test were used to compare between 4 groups in age and all the other characteristics, respectively.

	Total (n = 119)	Complete GPS Alone (n = 9)	Complete Saliva Alone (n = 10)	Complete GPS and Saliva (n = 86)	Neither GPS nor Saliva (n = 14)	p-value ^a
≤ High School Diploma	63.87 [76]	6.58 [5]	7.89 [6]	71.05 [54]	14.47 [11]	
Trade School/College Degree	36.13 [43]	9.3 [4]	9.3 [4]	74.42 [32]	6.98 [3]	
^a Analysis of variance and Fisher's Exact test were used to compare between 4 groups in age and all the other characteristics, respectively.						

GPS Data

Of 124 participants, 16 participants (12.9%) of the sample did not provide any useable GPS data. There were 108 (87.10%) participants providing at least one day of GPS data and 98 (79.03%) with at least 4 days of data. GPS wear day values varied among the 108 participants with GPS data (M = 7.33; SD = 2.51; Range: 1–16). Fewer than half (n = 50, 40.32%) wore the GPS device one week or less. Participants wearing a GPS device for 8 days had the highest frequency (n = 41, 33.06%). Of those with GPS data, there were 17 participants (13.71%) who had GPS data for a period of 9 or more days. Except 2 participants who wore the GPS at least 15 days, participants who wore the GPS 7 days had the highest average daily valid GPS points (i.e., latitude and longitude values) of 453.74 (SD = 1893.28), followed by those who wore the GPS 8 days who had mean of 140.05 (SD = 450.39) valid GPS points per day (Table 2).

Table 2 GPS Wear Time and Average Daily Valid GPS Points

Number of GPS Wear Days	Frequency	%	Mean of Valid GPS Points/Day	SD of Valid GPS Points/Day
Missing	16	12.9	NA	NA
1	2	1.61	4	2.83
2	3	2.42	31.67	12.27
3	5	4.03	40.33	62.7
4	2	1.61	13.38	10.43
5	7	5.65	62.14	53.03
6	7	5.65	40.6	35.47
7	24	19.35	453.74	1893.28
8	41	33.06	140.05	450.39
9	6	4.84	115.94	81.84
10	2	1.61	99.65	102.04
11	5	4.03	38.53	17.19
14	2	1.61	91.64	26.67
15	1	0.81	230.47	NA
16	1	0.81	919.25	NA
Total	124	100	186.14	935.89
Note. SD = Standard Deviation. NA = Non-Applicable.				

Saliva Data

More than three-fourths of the participants (n = 98, 79.03%) presented a complete saliva sample collection. There were 4 (3.23%), 2 (1.61%) and 1 (0.81%) participants who provided only the first one, the first two, or three saliva samples, respectively. There were 19 participants (15.32%) who did not provide any saliva samples.

Discussion

To the best of our knowledge, no study has investigated the feasibility of combined use of GPS information and saliva collection among a sexual minority population. The incidence of health disparities among sexual minorities has gained increasing scholarly and theoretical attention (39, 40). Sexual

minorities tend to be exposed to higher degree of stress from social stigma and discrimination than heterosexuals, resulting in a greater potential for adverse health behaviors and health outcomes (50–54). Results of the current pilot study indicate that research protocols that pair GPS data collection with participant-collected salivary cortisol data are feasible among this population subgroup. Sexual minority individuals provided rich contextual data on their activity paths by wearing a GPS device. The GPS device provided automatic collection of data that could be easily synchronized with secondary GIS data on the built environment, and biological markers of stress could be assessed using saliva samples collection with little-to-no burden on participants observed from behavior.

The use of a GPS device has been widely accepted in the general population; (typically these are embedded in smartphones) however, very few studies employing a GPS device have been done in the sexual minority community. We found that a majority of the sexual minority individuals in this study were willing to wear a GPS device, which is consistent with previous research (14, 59, 60). While our study showed 79.03% of participants had at least 4 days GPS data, it is challenging to compare our results with those of other studies due to the longer GPS sampling epoch set up in this study. For example, Duncan and colleagues (2016) showed the feasibility and acceptability of using GPS methods among a sample of young men who have sex with men (YMSM) in New York City. They reported having at least one hour of GPS data (GPS device was set to record information in 30-second intervals) for one day, and 84% of their sample had at least one hour on 7 or more days for those YMSM ($n = 75$, 92% 22 or 23 years old) with any GPS data. However, an important conclusion from both studies is that this form of data collection is acceptable to research participants from this community.

In the current study, there was wide variability in the amount of GPS data that were collected per participant. One obvious contributor was the research design that did not require wear for a specified duration of days. However, other factors may also be relevant here, including satellite signal loss, atmospheric conditions, and interference from terrestrial objects (multipath error) contributing to missing coordinates (61). Additionally, it is possible that the device was not worn regularly or daily due to competing interests and activities, including that some participants may have regarded the device as noticeable or cumbersome in some situations (e.g., while exercising, in their place of employment). Finally, it is worth mentioning that all participants who were screened eligible for participation in this study chose to participate and were not deterred by study procedures, including the impact of GPS data collection on their privacy. However, generally speaking, individuals in vulnerable populations, including sexual minority persons, may possess a heightened sense of intrusion into their privacy from the tracking of their locations (62, 63). Therefore, future studies with different samples may see greater variability in the acceptability of these procedures.

This study also successfully employed saliva collection among a diverse group of adult sexual minorities. Compared to other types of biological samples, saliva is relatively easy to gather. Of 124 participants, more than three-quarters of participants successfully collected 6 entire saliva samples. Other studies among subgroups of the sexual minority community have yielded similarly promising results. For example, in a recent saliva and hair collection feasibility study exploring HIV infection and chronic stress

among a sample of 10 transwomen in Puerto Rico, participants were all willing to provide one-time saliva sample with the assistance of the research team (36, 37, 38, 64). Saliva sample self- or researcher-collection has also been used among young sexual minority men (63, 66), and no problems or concerns were documented in obtaining multiple saliva samples over a longer period of time (e.g., 4 saliva samples each day over the course of 5 consecutive days in a study by Cook et al.).

This feasibility study has limitations. First, the sample was relatively small and from a single city. The relatively small sample and unique participant characteristics contributed to the possibility that findings reported here should be interpreted conservatively. That is, we cannot generalize these findings from a sexual minority sample in Houston, Texas to other sexual minority adult populations residing in other areas. Second, it was not possible to disaggregate the participants' GPS data by the number of hours participants wore the GPS. Third, no qualitative data regarding the acceptability and perception of GPS and saliva collection were collected from the participants after the assessment period. Such data could have allowed us to assess the burden on sexual minority participants of wearing a GPS or collecting saliva samples. Fourth, the non-compliance of wearing a GPS device throughout the day could skew the findings in terms of constructing the activity space. Despite these limitations, this study provides important preliminary evidence supporting the combined use of GPS devices and self-collection of saliva samples among individuals in a sexual minority population.

The study's strengths include the unique sample, diverse in its enrollment of race/ethnicity individuals, and of cisgender men and women and transgender individuals, and the distinctive methodology of the combined use of a GPS device and saliva collection. The simultaneous use of GPS monitors and saliva collection to assess sexual minority individuals' location and stress biomarkers will allow scientists to investigate the complex effects of the built and social environments and stress. Our findings may reflect characteristics of the sample, which—in addition to being relatively small—reflects a limited range of population and geographic representation. Further research should investigate the extent to which similar findings might be obtained for sexual minorities in other geographical areas.

Conclusion

This study demonstrated the feasibility of simultaneous use of a GPS device and collection of saliva samples. GPS methods may be used to measure mobility and environmental exposure, while collected saliva samples may be used for examining stress reactivity from diurnal patterns of salivary cortisol. Given the health disparities faced by sexual minority populations, this feasibility study shed light on the potential use of GPS and saliva to enhance the understanding of the mechanisms underlying the complex interaction between environment contexts and stress in the sexual minority community. Future research with larger sexual minority populations diverse in terms of age, ethnicity, gender identity, and socioeconomic status, or research integrating ecological momentary assessment/GPS using smartphones is warranted.

Abbreviations

GPS: Global Positioning System

GIS: Geographic Information Systems

LGBQ: lesbian, gay, bisexual, and queer

LGBT: lesbian, gay, bisexual, and transgender

YMSM: Young Men who have Sex with Men

Declarations

Ethics Approval and Consent to Participate

Study procedures were approved by the IRB at the University of Houston and written informed consent was obtained from all participants.

Consent for Publication

Not applicable.

Availability of Data and Materials

The datasets generated and analyzed during the current study are not publicly available due to the potential disclosure of participants' information but are available from the corresponding author on reasonable request.

Funding and Disclosures

This project, jointly led by LR Reitzel and NG Smith, was supported by their institutional funding from the University of Houston. Project components were further supported by NIDA through R01 DA034739 (to EM Obasi). Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the project supporters.

Conflict of Interest Disclosures

The authors have no conflicts of interest.

Authors' Contributions

T.C. conducted the analyses and wrote the initial draft. S.D.R. analyzed the GIS data. L.R.R., N.S.G., and E.M.O. designed study. T.C., N.G.S., S.D.R., E.M.O., K.F.A., and L.R.R. critically reviewed drafts of the manuscript and provided final review of the manuscript to be published. All the coauthors made substantial contributions to this manuscript. All authors read and approved the final manuscript.

Acknowledgements

The authors wish to thank Lauren Lee and Surya Chinamuthevi for their assistance on this manuscript. The first-author obtained permission from Ms. Lee and Mr. Chinamuthevi to name them in the acknowledgements.

References

1. Walter SD 2000. Disease mapping: a historical perspective. In: Spatial Epidemiology: Methods and Applications (Elliott P, Wakefield J, Best N, Briggs DJ, eds). Oxford:Oxford University Press, 223–252.
2. Rezaeian, M., Dunn, G., St Leger, S., & Appleby, L. (2007). Geographical epidemiology, spatial analysis and geographical information systems: a multidisciplinary glossary. *Journal of Epidemiology & Community Health*, 61(2), 98-102.
3. Short, S. E., & Mollborn, S. (2015). Social determinants and health behaviors: conceptual frames and empirical advances. *Current opinion in psychology*, 5, 78-84.
4. Glanz, K., Rimer, B. K., & Viswanath, K. (Eds.). (2015). *Health behavior: Theory, research, and practice*. John Wiley & Sons.
5. Frank, R., Cerdá, M., & Rendón, M. (2007). Barrios and Burbs: Residential Context and Health-Risk Behaviors among Angeleno Adolescents. *Journal of Health and Social Behavior*, 48(3), 283–300. doi: 10.1177/002214650704800306
6. Reitzel, L. R., Regan, S. D., Nguyen, N., Cromley, E. K., Strong, L.L., Wetter, D. W., & McNeill, L.H. (2014). Density and proximity of fast food restaurants and body mass index among African Americans. *American Journal of Public Health*, 104, 110-116.
7. Reitzel, L. R., Kendzor, D. E., Nguyen, N., Regan, S. D., Okuyemi, K. S., Castro, Y., ... Businelle, M. S. (2014). Shelter proximity and affect among homeless smokers making a quit attempt. *American Journal of Health Behavior*, 38, 161-169.
8. Reitzel, L. R., Cromley, E. K., Li, Y., Cao, Y., Dela Mater, R., Mazas, C. A., ... Wetter, D. W. (2011). The effect of tobacco outlet density and proximity on smoking cessation. *American Journal of Public Health*, 101, 315-320.
9. Watkins, K. L.*, Regan, S. D., Nguyen, N., Businelle, M. S., Kendzor, D. E., Lam, C., ... Reitzel, L. R.^ (2014). Advancing cessation research by integrating EMA and geospatial methodologies: Associations between tobacco retail outlets and real-time smoking urges during a quit attempt. *Nicotine & Tobacco Research*, 16 supplement 2, S93-101.
10. Reitzel, L. R., Okamoto, H.*, Hernandez, D. C., Regan, S. D., McNeill, L. H., & Obasi, E. M. (2016). The built food environment and dietary intake among African-American adults. *American Journal of Health Behavior*, 40, 3-11.
11. Zenk, S. N., Schulz, A. J., Matthews, S. A., Odoms-Young, A., Wilbur, J., Wegrzyn, L., ... & Stokes, C. (2011). Activity space environment and dietary and physical activity behaviors: a pilot study. *Health & place*, 17(5), 1150-1161.

12. Zenk, S. N., Odoms-Young, A. M., Dallas, C., Hardy, E., Watkins, A., Hoskins-Wroten, J., & Holland, L. (2011). "You have to hunt for the fruits, the vegetables": environmental barriers and adaptive strategies to acquire food in a low-income African American neighborhood. *Health education & behavior*, 38(3), 282-292.
13. Neville, Stephen, and Jeffery Adams. (2016). "Views about HIV/STI and Health Promotion among Gay and Bisexual Chinese and South Asian Men Living in Auckland, New Zealand." *International Journal of Qualitative Studies on Health and Well-Being*, vol. 11, no. 1, 2016, p. 30764., doi:10.3402/qhw.v11.30764.
14. Duncan, D. T., Kapadia, F., Regan, S. D., Goedel, W. C., Levy, M. D., Barton, S. C., ... & Halkitis, P. N. (2016). Feasibility and acceptability of global positioning system (GPS) methods to study the spatial contexts of substance use and sexual risk behaviors among young men who have sex with men in New York City: A p18 cohort sub-study. *PloS one*, 11(2), e0147520.
15. Doll, S. R. (1980). The epidemiology of cancer. *Cancer*, 45(10), 2475-2485.
16. Keys, A. (1980). *Seven countries. A multivariate analysis of death and coronary heart disease*. Harvard University Press.
17. Elliott, P., & Wartenberg, D. (2004). Spatial epidemiology: current approaches and future challenges. *Environmental health perspectives*, 112(9), 998-1006.
18. Musa, G. J., Chiang, P. H., Sylk, T., Bavley, R., Keating, W., Lakew, B., ... & Hoven, C. W. (2013). Use of GIS Mapping as a Public Health Tool--From Cholera to Cancer. *Health services insights*, 6, HSI-S10471.
19. A. Rodriguez, A.L. Brown, P.J. Troped Portable global positioning units to complement accelerometry-based physical activity monitors. *Med. Sci. Sports Exerc.*, 37 (2005), pp. S572-S581
20. Kerr, J., Duncan, S., & Schipperjin, J. (2011). Using global positioning systems in health research: a practical approach to data collection and processing. *American journal of preventive medicine*, 41(5), 532-540.
21. Phillips, M. L., Hall, T. A., Esmen, N. A., Lynch, R., & Johnson, D. L. (2001). Use of global positioning system technology to track subject's location during environmental exposure sampling. *Journal of Exposure Science and Environmental Epidemiology*, 11(3), 207.
22. Maddison, R., & Mhurchu, C. N. (2009). Global positioning system: a new opportunity in physical activity measurement. *International Journal of Behavioral Nutrition and Physical Activity*, 6(1), 73.
23. O'Connor, T. M., Cerin, E., Robles, J., Lee, R. E., Kerr, J., Butte, N., ... & Baranowski, T. (2013). Feasibility study to objectively assess activity and location of Hispanic preschoolers: a short communication. *Geospatial health*, 7(2), 375.
24. Prins, R. G., Pierik, F., Etman, A., Sterkenburg, R. P., Kamphuis, C. B. M., & Van Lenthe, F. J. (2014). How many walking and cycling trips made by elderly are beyond commonly used buffer sizes: results from a GPS study. *Health & place*, 27, 127-133.
25. Munir, M. W., Perälä, S., & Mäkelä, K. (2012). Utilization and impacts of GPS tracking in healthcare: a research study for elderly care. *International Journal of Computer Applications*, 45(11), 35-37.

26. Sadler, R. C., Clark, A. F., Wilk, P., O'Connor, C., & Gilliland, J. A. (2016). Using GPS and activity tracking to reveal the influence of adolescents' food environment exposure on junk food purchasing. *Canadian Journal of Public Health, 107*(1), eS14-eS20.
27. Saxbe, D. E. (2008). A field (researcher's) guide to cortisol: tracking HPA axis functioning in everyday life. *Health psychology review, 2*(2), 163-190.
28. Stawski, R. S., Cichy, K. E., Piazza, J. R., & Almeida, D. M. (2013). Associations among daily stressors and salivary cortisol: Findings from the National Study of Daily Experiences. *Psychoneuroendocrinology, 38*(11), 2654-2665.
29. Fortunato, C. K., Dribin, A. E., Granger, D. A., & Buss, K. A. (2008). Salivary alpha-amylase and cortisol in toddlers: Differential relations to affective behavior. *Developmental Psychobiology: The Journal of the International Society for Developmental Psychobiology, 50*(8), 807-818.
30. Dickerson, S. S., & Kemeny, M. E. (2004). Acute stressors and cortisol responses: a theoretical integration and synthesis of laboratory research. *Psychological bulletin, 130*(3), 355.
31. Hellhammer, D. H., Wüst, S., & Kudielka, B. M. (2009). Salivary cortisol as a biomarker in stress research. *Psychoneuroendocrinology, 34*(2), 163-171.
32. Koh, D. S. Q., & Koh, G. C. H. (2007). The use of salivary biomarkers in occupational and environmental medicine. *Occupational and environmental medicine, 64*(3), 202-210.
33. Obasi, E. M., Shirtcliff, E. A., Cavanagh, L., Ratliff, K. L., Pittman, D. M., & Brooks, J. J. (2017). Hypothalamic-pituitary-adrenal reactivity to acute stress: an investigation into the roles of perceived stress and family resources. *Prevention Science, 18*(8), 923-931.
34. Austin, S. Bryn, et al. (2016) "Sexual Orientation and Diurnal Cortisol Patterns in a Cohort of U.S. Young Adults." *Psychoneuroendocrinology*, vol. 69, pp. 197–208., doi:10.1016/j.psyneuen.2016.04.012.
35. Madera, S. L. R., Díaz, N. V., Pibernus, A. R., Padilla, M., Guzzi, A. V., Rodríguez, G. R., & Bockting, W. (2017). Exploring the feasibility and acceptability of biomarker collection for HIV infection and chronic stress among transwomen in Puerto Rico. *Revista Puertorriquena de psicología, 28*(2), 268.
36. Juster, R. P., Ouellet, E., Lefebvre-Louis, J.-P., Sindi, S., Johnson, P. J., Smith, N. G., & Lupien, S. (2016). Retrospective coping strategies during sexual orientation identity formation and current biopsychosocial stress. *Anxiety, Stress, & Coping, 29*(2), 119-138.
37. Juster, R. P., Hatzenbuehler, M. L., Mendrek, A., Pfaus, J. G., Smith, N. G., Johnson, P. J., Lefebvre-Louis, J.-P., Raymond, , Marin, M. F., Sindi, S., Lupien, S. J., & Pruessner, J. C. (2015). Sexual orientation modulates endocrine stress reactivity. *Biological Psychiatry, 77*(7), 668-676.
38. Juster, R. P., Smith, N. G., Ouellet, É., Sindi, S., & Lupien, S. J. (2013). Sexual orientation and disclosure in relation to psychiatric symptoms, diurnal cortisol, and allostatic load. *Psychosomatic medicine, 75*(2), 103-116.
39. Sex and Gender Minorities Recognized as Health Disparity Population
<https://www.niaid.nih.gov/grants-contracts/sex-gender-minorities-health-disparity-population>
(Accessed 12/17/2019).

40. Herek, G. M. (2009). Sexual stigma and sexual prejudice in the United States: A conceptual framework. In *Contemporary perspectives on lesbian, gay, and bisexual identities*(pp. 65-111). Springer, New York, NY.
41. Conron KJ, Mimiaga MJ, Landers SJ. A population-based study of sexual orientation identity and gender differences in adult health. *Am J Public Health*. 2010;100(10):1953–1960
42. Cochran, S. D., & Mays, V. M. (2007). Physical health complaints among lesbians, gay men, and bisexual and homosexually experienced heterosexual individuals: results from the California Quality of Life Survey. *American journal of public health*, 97(11), 2048-2055.
43. Bostwick WB, Boyd CJ, Hughes TL, McCabe SE. Dimensions of sexual orientation and the prevalence of mood and anxiety disorders in the United States. *Am J Public Health*. 2010;100(3):468–475
44. Operario, D., Gamarel, K. E., Grin, B. M., Lee, J. H., Kahler, C. W., Marshall, B. D., ... & Zaller, N. D. (2015). Sexual minority health disparities in adult men and women in the United States: National Health and Nutrition Examination Survey, 2001–2010. *American journal of public health*, 105(10), e27-e34.
45. King, M., Semlyen, J., Tai, S. S., Killaspy, H., Osborn, D., Popelyuk, D., & Nazareth, I. (2008). A systematic review of mental disorder, suicide, and deliberate self harm in lesbian, gay and bisexual people. *BMC psychiatry*, 8(1), 70.
46. Bostwick, W. B., Boyd, C. J., Hughes, T. L., & McCabe, S. E. (2010). Dimensions of sexual orientation and the prevalence of mood and anxiety disorders in the United States. *American journal of public health*, 100(3), 468-475.
47. Cochran, S. D., Sullivan, J. G., & Mays, V. M. (2003). Prevalence of mental disorders, psychological distress, and mental health services use among lesbian, gay, and bisexual adults in the United States. *Journal of consulting and clinical psychology*, 71(1), 53.
48. Mays, V. M., & Cochran, S. D. (2001). Mental health correlates of perceived discrimination among lesbian, gay, and bisexual adults in the United States. *American journal of public health*, 91(11), 1869-1876.
49. Gilman SE, Cochran SD, Mays VM, Hughes M, Ostrow D, Kessler RC. Risk of psychiatric disorders among individuals reporting same-sex sexual partners in the National Comorbidity Survey. *Am J Public Health* 2001;91:933–939.
50. Meyer, I. H. (2003). Prejudice, social stress, and mental health in lesbian, gay, and bisexual populations: conceptual issues and research evidence. *Psychological bulletin*, 129(5), 674.
51. Reitzel LR, Smith NG, Obasi EM, Forney M, Leventhal AM. Perceived distress tolerance accounts for the covariance between discrimination experiences and anxiety symptoms among sexual minority adults. *Journal of Anxiety Disorders*. 2017;48:22-27.
52. Smith NG, Winderman K, King B, Obasi EM, Reitzel LR. The association of lesbian, gay, and bisexual identity facets with smoking dependence motives. *Nicotine and Tobacco Research*. 2017;20(3):388-392.
53. Smith NG, Hart TA, Kidwai A, Vernon JR, Blais M, Adam B. Results of a pilot study to ameliorate psychological and behavioral outcomes of minority stress among young gay and bisexual men.

Behavior therapy. 2017;48(5):664-677.

54. Smith NG, Hart TA, Moody C, et al. Project PRIDE: a cognitive-behavioral group intervention to reduce HIV risk behaviors among HIV-negative young gay and bisexual men. *Cognitive and Behavioral Practice*. 2016;23(3):398-411.
55. Reid, N., & Harrison, A. T. (2010). Post-release GPS tracking of hand-reared Irish hare *Lepus timidus hibernicus* leverets, Slemish, Co. Antrim, Northern Ireland. *Conservation Evidence*, 7, 32-38.
56. Paz-Soldan, V. A., Reiner Jr, R. C., Morrison, A. C., Stoddard, S. T., Kitron, U., Scott, T. W., ... & Vazquez-Prokopec, G. M. (2014). Strengths and weaknesses of Global Positioning System (GPS) data-loggers and semi-structured interviews for capturing fine-scale human mobility: findings from Iquitos, Peru. *PLoS neglected tropical diseases*, 8(6), e2888.
57. Carter, M. I., Cox, S. L., Scales, K. L., Bicknell, A. W., Nicholson, M. D., Atkins, K. M., ... & Votier, S. C. (2016). GPS tracking reveals rafting behaviour of Northern Gannets (*Morus bassanus*): implications for foraging ecology and conservation. *Bird Study*, 63(1), 83-95.
58. SAS Institute Inc. SAS (Version 9.4) [Computer Software]. Cary, NC: SAS Institute, Inc.; 2014.
59. Duncan, D. T., Chaix, B., Regan, S. D., Park, S. H., Draper, C., Goedel, W. C., ... & Hickson, D. A. (2018). Collecting mobility data with GPS methods to understand the HIV environmental riskscape among young black men who have sex with men: A multi-city feasibility study in the deep south. *AIDS and Behavior*, 22(9), 3057-3070.
60. Goedel, W. C., Reisner, S. L., Janssen, A. C., Poteat, T. C., Regan, S. D., Kreski, N. T., ... & Duncan, D. T. (2017). Acceptability and feasibility of using a novel geospatial method to measure neighborhood contexts and mobility among transgender women in New York City. *Transgender health*, 2(1), 96-106.
61. Wing, M. G., Eklund, A., & Kellogg, L. D. (2005). Consumer-grade global positioning system (GPS) accuracy and reliability. *Journal of forestry*, 103(4), 169-173.
62. Fuller, D., Shareck, M., & Stanley, K. (2017). Ethical implications of location and accelerometer measurement in health research studies with mobile sensing devices. *Social Science & Medicine*, 191, 84-88.
63. Duncan, D. T., Park, S. H., Goedel, W. C., Sheehan, D. M., Regan, S. D., & Chaix, B. (2019). Acceptability of smartphone applications for global positioning system (GPS) and ecological momentary assessment (EMA) research among sexual minority men. *PloS one*, 14(1), e0210240.
64. Madera, S. L. R., Díaz, N. V., Pibernus, A. R., Padilla, M., Guzzi, A. V., Rodríguez, G. R., & Bockting, W. (2017). Exploring the feasibility and acceptability of biomarker collection for hiv infection and chronic stress among transwomen in Puerto Rico. *Revista Puertorriquena de psicologia*, 28(2), 268,
65. Cook, S. H., Juster, R. P., Calebs, B. J., Heinze, J., & Miller, A. L. (2017). Cortisol profiles differ by race/ethnicity among young sexual minority men. *Psychoneuroendocrinology*, 75, 1-4.
66. Lambert, N. L., Fisher, M., Imrie, J., Watson, R., Mercer, C. H., Parry, J. V., ... & Dean, G. L. (2005). Community based syphilis screening: feasibility, acceptability, and effectiveness in case finding. *Sexually transmitted infections*, 81(3), 213-316.