Protocol

Ecological Momentary Assessment of Midlife Adults' Daily Stress: Protocol for the Stress Reports in Variable Environments (STRIVE) App Study

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Abstract

Background: Daily stressors are associated with cognitive decline and increased risk of heart disease, depression, and other debilitating chronic illnesses in midlife adults. Daily stressors tend to occur at home or at work and are more frequent in urban versus rural settings. Conversely, spending time in natural environments such as parks or forests, or even viewing nature-themed images in a lab setting, is associated with lower levels of perceived stress and is hypothesized to be a strong stress "buffer," reducing perceived stress even after leaving the natural setting. However, many studies of daily stress have not captured environmental contexts and relied on end-of-day recall instead of in-the-moment data capture. With new technology, these limitations can be addressed to enhance knowledge of the daily stress experience.

Objective: We propose to use our novel custom-built Stress Reports in Variable Environments (STRIVE) ecological momentary assessment mobile phone app to measure the experience of daily stress of midlife adults in free-living conditions. Using our app to capture data in real time will allow us to determine (1) where and when daily stress occurs for midlife adults, (2) whether midlife adults' daily stressors are linked to certain elements of the built and natural environment, and (3) how ecological momentary assessment measurement of daily stress is similar to and different from a modified version of the popular Daily Inventory of Stressful Events measurement tool that captures end-of-day stress reports (used in the Midlife in the United States [MIDUS] survey).

Methods: We will enroll a total of 150 midlife adults living in greater Indianapolis, Indiana, in this study on a rolling basis for 3-week periods. As those in underrepresented minority groups and low-income areas have previously been found to experience greater levels of stress, we will use stratified sampling to ensure that half of our study sample is composed of underrepresented minorities (eg, Black, American Indian, Hispanic, or Native Pacific Islanders) and approximately one-third of our sample falls within low-, middle-, and high-income brackets.

Results: This project is funded by the National Institute on Aging from December 2022 to November 2024. Participant enrollment began in August 2023 and is expected to finish in July 2024. Data will be spatiotemporally analyzed to determine where and when stress occurs for midlife adults. Pictures of stressful environments will be qualitatively analyzed to determine the common

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elements of stressful environments. Data collected by the STRIVE app will be compared with retrospective Daily Inventory of Stressful Events data.

Conclusions: Completing this study will expand our understanding of midlife adults' experience of stress in free-living conditions and pave the way for data-driven individual and community-based intervention designs to promote health and well-being in midlife adults.

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Introduction

Daily stressors are associated with cognitive decline and increased risk of heart disease, depression, and other debilitating chronic illnesses for midlife adults [1-5]. Daily stressors tend to occur at home or at work and are more frequent in urban versus rural settings [6-8]. Conversely, spending time in natural environments such as parks or forests, or even viewing nature-themed images in a lab setting, is associated with lower levels of perceived stress and is hypothesized to be a strong stress "buffer," reducing perceived stress even after leaving the natural setting [9-12]. The role that natural environments can play in reducing stress arousal is particularly important when considering that neighborhoods with high poverty rates and higher proportions of racial or ethnic minorities have less access to green space and higher exposure to stressful elements such as abandoned buildings and crime [13-15]. However, many studies of daily stress have not captured environmental contexts and relied on end-of-day recall instead of in-the-moment data capture. With new technology, these limitations can be addressed to enhance knowledge of the daily stress experience [16].

In the United States, midlife adults are staying in the workforce longer and are engaging in higher levels of physical activity than previous generations, potentially extending their interactions with elements of the built and natural environments that influence their experience of daily stress [17,18]. Recent evidence has revealed that age-related linear increases in perceptions of well-being observed during past periods of economic prosperity have not continued during more recent, less economically prosperous times [19]. The seismic and unpredictable economic and social changes brought about by the COVID-19 pandemic have greatly altered the experience of daily stressors in the built and natural environment, a trend that is likely to continue well into the future [20].

In the midlife adult population, stress (or the lack thereof) plays an important role in the aging process. The relationship between various types of stress and alterations in cognitive functioning has been well documented, and there is growing evidence showing a relationship between daily stress in midlife and cognitive decline [2,3,21]. Perceived stress in midlife adults has also been closely linked with physical disability later in life [22,23]. A growing body of research has also found that perceived stress, particularly in the workplace, is closely related

to heart disease [24]. Furthermore, while individual health and wellness in midlife is no doubt important, longitudinal studies have shown that the health and wellness of midlife adults is also pivotal to others in their workplace, society in general, and in the lives of those in younger and older generations who often are socioeconomically dependent on midlife family members [25].

Midlife adults of different socioeconomic statuses and races are subject to structural inequality in their living environments. Those living in urban environments with higher levels of poverty and violence experience higher levels of environmental stress than those living in suburban or rural environments [15]. In particular, it is well documented that underrepresented minorities are exposed to environmental stressors more than nonunderrepresented minorities [26,27]. One explanation for racial differences in exposure to stressors is residential segregation, resulting in a predisposition for low-income minorities' exposure to environmental stressors such as traumatic events, urban decay, and poverty [28]. Minority and low-income midlife adults' exposure to environmental stressors has been linked to unhealthy behaviors like cigarette smoking [29], as well as myriad negative health outcomes [30].

In response to this research gap, we propose to use our novel custom-built Stress Reports in Variable Environments (STRIVE) ecological momentary assessment (EMA) mobile phone app to measure the experience of daily stress of midlife adults in free-living conditions. Using our app to capture data in real time will allow us to determine (1) where and when daily stress occurs for midlife adults, (2) whether midlife adults' daily stressors are linked to certain elements of the built and natural environment, and (3) how EMA measurement of daily stress is similar to and different from a modified version of the popular Daily Inventory of Stressful Events (DISE) measurement tool that captures end-of-day stress reports (used in the Midlife in the United States [MIDUS] survey) [31].

Completing this study will expand our understanding of mid-life adults' experience of stress in free-living conditions and pave the way for data-driven individual and community-based intervention designs to promote health and well-being in midlife adults. Potential interventions that could stem from our data include technology-based "just-in-time" interventions that account for spatiotemporal location, mindfulness-based interventions that incorporate environmental stress triggers, and community-based interventions designed to eliminate

environmental stressors that are commonly experienced by midlife adults (eg, congested areas).

Methods

Overview

In this stage 0 (of the NIH Stage Model for behavioral intervention development) study, we propose an interdisciplinary mixed method approach to examine the occurrence of daily stressors in the moment they occur for midlife adults in the built and natural environment using mobile and wearable technology. A total of 150 midlife adults will be enrolled in this study on a rolling basis for 3-week periods. Participants will meet with a researcher in person at the start and end of their 3-week study period. They will be provided with a smartphone preloaded with the STRIVE app and a Polar Unite smartwatch. They will be instructed to carry the phone and wear the watch for the 3-week duration of the study. Each enrolled participant will use one or more daily stress measurement tools in any given week, randomized to account for participant priming. In 1 week of participation, participants will complete the DISE by the Research Electronic Data Capture (REDCap; Vanderbilt University) survey every evening. In another week of participation, participants will use the STRIVE app to report daily stressors in real time and complete the DISE every evening. In another week of participation, participants will only report stressors in real time through the STRIVE app. Automated SMS text messages will be sent to participants each day to remind them of what they need to do to remain active in the study and provide survey links when needed.

Participants will be recruited from the greater Indianapolis area in Indiana. As those in underrepresented minority groups and low-income areas have previously been found to experience greater levels of stress, we will use stratified sampling to obtain a sample that is racially and socioeconomically diverse (Table 1). Income levels are defined as the bottom, middle, and top third of household incomes based on 2020 US Census percentiles (low income: <US $39,535; middle income: US $39,535-$85,076; high income: >US $85,076) [32]. Participants will be recruited with the assistance of the Indiana Clinical and Translational Sciences Institute recruitment concierge services and their community partnerships. Recruitment materials will be posted on community-based social media pages, on paper flyers in public community spaces, and through all communication channels operated by community health partners.

Table 1. Study sample stratified by race and household income (N=150).

Race	Low income, n (%)	Middle income, n (%)	High income, n (%)
Black, American Indian, Hispanic, Native Pacific Islanders	25 (16.6)	25 (16.6)	25 (16.6)
White or Asian	25 (16.6)	25 (16.6)	25 (16.6)

Measurement of Stress With the STRIVE App

Study participants will be asked to carry the researcher's provided Android mobile phone with them at all times. The STRIVE app passively records the participant's GPS coordinates every 60 seconds throughout the data collection period (Table 2). Research participants are informed that their location is being tracked by the app. When participants experience a daily stressor, they are asked to open the app and provide a rating of their stress level, a description of the stressor, their preferred coping strategy, and optionally take a photograph of the environment where they experienced stress (Figure 1). Data input is kept to a minimum to reduce participant burden and burnout [33].

Table 2. All study measures.

Measurement tools	Measure
Pretest survey	
CDC[a] Healthy Days [34]	• Overall health
Godin Leisure-Time Exercise Questionnaire [35]	• Physical activity level
Portion of Behavioral Risk Factor Surveillance (BRFSS) [36]	• Substance use and abuse
Social Provisions Scale [37]	• Social support
UCLA[b] Loneliness Scale [38]	• Loneliness
Patient Health Questionnaire-9 (PHQ-9) [39]	• Depressive symptoms
Adverse Childhood Events Scale (ACES) [40]	• Early life stress
Economic Strain Model [41]	• Financial strain
Neighborhood Disorder Scale [42]	• Neighborhood safety
Real time measurements (all time-stamped)[c]	
STRIVE[d] app	• Per 60 second GPS coordinates (continuous) • Self-reported stress level (7-point scale) • Self-reported stressor (text-based) • Self-reported coping response (text-based) • Photo of stressful environment (JPEG)
Polar Unite Smartwatch	• Heart rate (continuous) • Activity level (continuous)
End-of-day recall DISE[e] measurements[c]	• Self-reported overall stress level (7-point scale) • Self-reported stressor type • Self-reported stress level by stressor (7-point scale) • Self-reported date

[a]CDC: Centers for Disease Control and Prevention.

[b]UCLA: University of California, Los Angeles.

[c]Additional measurements include demographics and health history.

[d]STRIVE: Stress Reports in Variable Environments.

[e]DISE: Daily Inventory of Stressful Events.

Figure 1. The Stress Reports in Variable Environments (STRIVE) app.

We have created a protocol to promote the safety of research participants during their reporting of daily stressors with the STRIVE app. If they cognitively appraise themselves as stressed and are in a situation in which it is unsafe to use their phones (eg, driving a car), they are asked to proceed to the nearest safe location before recording their experience. Participants will be asked to indicate when and where the stressor occurred if they are not reporting from the location in which the stress occurred in their later description of it. Many people go through a day without experiencing a stressor [43]; for days when this is the case, participants will be asked to indicate on their app that they had not experienced stress but were still actively participating in the study.

Measurement of Stress With the Modified DISE Tool

The DISE is recommended by the National Institute on Aging funded Stress Measurement Network for daily stress measurement. A modified version of the DISE will be administered through the REDCap survey each evening for 2 weeks of the study period. The modified version of the DISE includes questions about the number of times participants felt stressed over the course of the day, their overall stress level, and questions about specific stressor categories (eg, had an argument and had work stress) and how stressful each of those experiences was for the participant. The DISE was modified to allow for direct comparisons between STRIVE and DISE.

Geospatial Analysis

We will fit spatiotemporal regression models to determine the impact of specific elements of the built and natural environment on daily stressors. Given the nature of our spatially dependent data, traditional regression-based approaches (eg, Poisson or negative binomial regression) violate the independence assumption required for generalized linear models. Ignoring the dependence of spatial data can underestimate standard errors, resulting in overly narrow confidence interval estimates and, consequently, incorrect statistical inference [44]. Thus, we will use spatiotemporal models that can simultaneously account for dependence (autocorrelation) in geospatial locations and temporal measurements. We will do this using Integrated Nested Laplace Approximation (INLA) models. Specifically, we will fit zero-inflated negative binomial INLA models, as these models can account for the many instances where stress experiences are not recorded (zero inflation) while still adjusting for the spatial and temporal autocorrelation of each measurement [45,46]. Importantly, the INLA modeling approach is robust as it can incorporate individual-level characteristics and group-level (ie, neighborhood) characteristics while adjusting for the spatial and temporal autocorrelation [47]. INLA uses a Bayesian paradigm, can fit offsets for any necessary weightings (eg, population size or number of measurements), is able to handle both point process (ie, singular latitude and longitude locations) and irregular lattice data (ie, polygons of parks and census tracts), and can analyze the individual impact of temporal, spatial, and spatiotemporal effects [46]. Through this analysis, we can identify the magnitude, direction, and impact of participant attributes (including data collected through the pretest survey and real-time collection of heart rate and activity level data from the Polar Unite watch), neighborhood features, and location characteristics on daily stressors.

Qualitative Analysis of Reported Stressors

We will conduct an analysis of data reported through the STRIVE app in a 2-step process including open and axial coding [48]. Open coding will be conducted twice: first to code stressors into stressor types and second to code mentions of elements of

the built and natural environment that played a role in the stressful experience. This open coding process will be conducted on qualitative responses to the question, "Please discuss what is causing you stress." In this open coding process, researchers will be versed in previous research categorizing daily stressors to identify themes in the data that may overlap with commonly experienced daily stressors identified in previous research [49]. Any new themes that emerge will be given new names and detailed descriptions. In the second axial coding step, researchers will analyze stressor and environmental characteristic themes to look for those that may be related to identify linkages, creating meta-categories for daily stressors that may be similar in nature. Then, the open and axial coding processes will be conducted on participant photographs that accompany stressor reports. Characteristics of the environment in which stress occurs will be coded for each participant photograph, allowing for triangulation among themes generated by text-based responses and participant photographs. This data triangulation will allow us to understand how daily stressors are related to specific elements of the built and natural environment.

Comparison of STRIVE and DISE Stressor Data

We will compare the number of stressors reported, the type of stressors reported, and the subjective severity of stressors reported by the same individual using the DISE and STRIVE app across 3 time periods. The 3 time periods are designed to differentiate between stand-alone use of each instrument and concurrent use of both instruments, as there is potential for these instruments to be complementary in terms of the scope and depth of data captured. Thematic coding of stressors reported through the DISE and STRIVE app will be conducted to allow for comparison between the two. All stressors will be coded into 7 categories specified by the DISE to retain consistency. Stressful events are categorized into 1 of 7 broad classifications organized by interpersonal tensions, work or education, home, finances, health or accident, network, and miscellaneous. As the unit of analysis of the DISE is the "day," we will conduct a repeated measures ANOVA to compare the number of stressors reported per day, the average subjective severity of stressors per day, and the type of stressors reported per day across the 3 modes of daily stress reporting, including an interaction of group (STRIVE or DISE) and mode (using only one or both together) to test if there is any effect on the reported stressors by use. A factor will also be included for the order receiving the conditions to account for carryover effects. Models will also be adjusted by demographic variables.

Ethics Approval

This study has been approved by the Indiana University Institutional Review Board (study number 1910712088). Informed consent has been and will be obtained from all research participants. A special document outlining when and where it is appropriate and safe to take photographs of stressful environments will be provided to all research participants, with a focus on protecting the privacy of others. Further, a document highlighting that study participants are not to report stressors in dangerous situations (eg, while driving a car) will be provided. Although we will make efforts to deidentify study data as much as possible, certain elements of data collected (eg, pictures and GPS coordinates) could be used to identify participants. Participants are informed of this risk and may choose not to report stressors or take pictures in situations where they are concerned about their confidentiality. Each study participant will be paid US $150 for their participation in the study.

Results

This study will take approximately 24 months to complete and will take place between December 2022 and November 2024. Enrollment began in August 2023 and is expected to be completed by July 2024. We expect the following study findings:

1. A better understanding of where and when stressors occur for midlife adults in free-living conditions. We hypothesize that the quantity of stressors reported, type of stressors reported, and subjective severity of stressors reported by midlife adults will differ by location (eg, at home vs at a park) and time (eg, morning vs evening) throughout the built and natural environment.
2. An understanding of specific elements of the built and natural environment that contribute to midlife adults' daily stress. We hypothesize that distinct environmental characteristics (eg, abandoned buildings) will emerge as contributors to stress through the qualitative analysis of stressor descriptions and pictures of stressful environments.
3. An understanding of how the STRIVE-based EMA of daily stress is supplementary or complementary to the DISE. We hypothesize that, when reporting through the STRIVE app compared with when reporting through the DISE, midlife adults will report a greater number of daily stressors, a lower average stressor severity, and different types of stressors.

Throughout the study, we will present our research findings at relevant academic or professional conferences and publish peer-reviewed papers. We will also share our study findings with partner governmental organizations and nongovernmental organizations in the state of Indiana. These organizations will likely find our data useful for future community planning.

Discussion

Daily stress contributes to myriad negative health outcomes. Midlife adults are staying in the workforce longer than previous generations and are likely subject to greater environmental stressors than in the past. Technological advances, including smartphones and wearable technology, allow us to measure stress in situ, painting a clearer picture of how stress is experienced in real time. Our custom-built STRIVE EMA app allows us to reduce recall bias and geospatially locate stressors while simultaneously collecting health data (eg, heart rate, sleep, and physical activity), allowing for a clear picture of the role the built and natural environment play in the daily stress of midlife adults.

Completing this study will expand our understanding of midlife adults' experience of stress in free-living conditions and pave the way for data-driven individual and community-based

intervention designs to promote health and well-being in midlife adults: (1) technology-based "just-in-time" therapeutic interventions that account for spatiotemporal location, (2) mindfulness-based interventions that incorporate environmental stress triggers and stimuli, and (3) community-based interventions designed to eliminate environmental stressors that are commonly experienced by many midlife adults (eg, abandoned buildings, areas that often become crowded or congested, or other yet undiscovered stressful elements of the environment).

Acknowledgments

Data Availability

The data sets generated or analyzed during this study will be available from the corresponding author on reasonable request.

Conflicts of Interest

None declared.

Multimedia Appendix 1

Peer-review report from the Community Influences on Health Behavior Study Section, Healthcare Delivery and Methodologies Integrated Review Group, CENTER FOR SCIENTIFIC REVIEW (National Institutes of Health, USA).
[PDF File (Adobe PDF File), 151 KB-Multimedia Appendix 1]

References

1. Selye H. Stress in Health and Disease. Oxford: Butterworth-Heinemann; 2013.
2. Johansson L, Guo X, Waern M, Ostling S, Gustafson D, Bengtsson C, et al. Midlife psychological stress and risk of dementia: a 35-year longitudinal population study. Brain 2010;133(Pt 8):2217-2224 [FREE Full text] [doi: 10.1093/brain/awq116] [Medline: 20488887]
3. Rickenbach EH, Almeida DM, Seeman TE, Lachman ME. Daily stress magnifies the association between cognitive decline and everyday memory problems: an integration of longitudinal and diary methods. Psychol Aging 2014;29(4):852-862 [FREE Full text] [doi: 10.1037/a0038072] [Medline: 25365691]
4. Uchino BN, Berg CA, Smith TW, Pearce G, Skinner M. Age-related differences in ambulatory blood pressure during daily stress: evidence for greater blood pressure reactivity with age. Psychol Aging 2006;21(2):231-239 [doi: 10.1037/0882-7974.21.2.231] [Medline: 16768571]
5. Dunkley DM, Lewkowski M, Lee IA, Preacher KJ, Zuroff DC, Berg JL, et al. Daily stress, coping, and negative and positive affect in depression: complex trigger and maintenance patterns. Behav Ther 2017;48(3):349-365 [doi: 10.1016/j.beth.2016.06.001] [Medline: 28390498]
6. Goh J, Pfeffer J, Zenios SA. The relationship between workplace stressors and mortality and health costs in the United States. Manage Sci 2016;62(2):608-628 [doi: 10.1287/mnsc.2014.2115]
7. Anyan F, Hjemdal O. Stress of home life and gender role socializations, family cohesion, and symptoms of anxiety and depression. Women Health 2018;58(5):548-564 [doi: 10.1080/03630242.2017.1316343] [Medline: 28379114]
8. Gong Y, Palmer S, Gallacher J, Marsden T, Fone D. A systematic review of the relationship between objective measurements of the urban environment and psychological distress. Environ Int 2016;96:48-57 [FREE Full text] [doi: 10.1016/j.envint.2016.08.019] [Medline: 27599349]
9. Ewert A, Chang Y. Levels of nature and stress response. Behav Sci (Basel) 2018;8(5):49 [FREE Full text] [doi: 10.3390/bs8050049] [Medline: 29772763]
10. Wells NM, Evans GW. Nearby nature: a buffer of life stress among rural children. Environ Behav 2016;35(3):311-330 [doi: 10.1177/0013916503035003001]
11. Berman MG, Jonides J, Kaplan S. The cognitive benefits of interacting with nature. Psychol Sci 2008;19(12):1207-1212 [FREE Full text] [doi: 10.1111/j.1467-9280.2008.02225.x] [Medline: 19121124]
12. Brown DK, Barton JL, Gladwell VF. Viewing nature scenes positively affects recovery of autonomic function following acute-mental stress. Environ Sci Technol 2013;47(11):5562-5569 [FREE Full text] [doi: 10.1021/es305019p] [Medline: 23590163]
13. Casey JA, James P, Cushing L, Jesdale BM, Morello-Frosch R. Race, ethnicity, income concentration and 10-year change in urban greenness in the United States. Int J Environ Res Public Health 2017;14(12):1546 [FREE Full text] [doi: 10.3390/ijerph14121546] [Medline: 29232867]
14. Browning MHEM, Rigolon A. Do income, race and ethnicity, and sprawl influence the greenspace-human health link in city-level analyses? Findings from 496 cities in the United States. Int J Environ Res Public Health 2018;15(7):1541 [FREE Full text] [doi: 10.3390/ijerph15071541] [Medline: 30037037]

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15. Ewart CK, Suchday S. Discovering how urban poverty and violence affect health: development and validation of a neighborhood stress index. Health Psychol 2002;21(3):254-262 [doi: 10.1037//0278-6133.21.3.254] [Medline: 12027031]

16. Scott SB, Ram N, Smyth JM, Almeida DM, Sliwinski MJ. Age differences in negative emotional responses to daily stressors depend on time since event. Dev Psychol 2017;53(1):177-190 [FREE Full text] [doi: 10.1037/dev0000257] [Medline: 28026195]

17. Emslie C, Hunt K. 'Live to Work' or 'Work to Live'? A qualitative study of gender and work–life balance among men and women in mid-life. Gend Work Organ 2009;16(1):151-172 [FREE Full text] [doi: 10.1111/j.1468-0432.2008.00434.x]

18. Netz Y, Zach S, Taffe JR, Guthrie J, Dennerstein L. Habitual physical activity is a meaningful predictor of well-being in mid-life women: a longitudinal analysis. Climacteric 2008;11(4):337-344 [doi: 10.1080/13697130802239083] [Medline: 18645700]

19. Almeida DM, Charles ST, Mogle J, Drewelies J, Aldwin CM, Spiro A, et al. Charting adult development through (historically changing) daily stress processes. Am Psychol 2020;75(4):511-524 [FREE Full text] [doi: 10.1037/amp0000597] [Medline: 32378946]

20. Zandifar A, Badrfam R. Iranian mental health during the COVID-19 epidemic. Asian J Psychiatr 2020;51:101990 [FREE Full text] [doi: 10.1016/j.ajp.2020.101990] [Medline: 32163908]

21. Karlamangla AS, Miller-Martinez D, Lachman ME, Tun PA, Koretz BK, Seeman TE. Biological correlates of adult cognition: midlife in the United States (MIDUS). Neurobiol Aging 2014;35(2):387-394 [FREE Full text] [doi: 10.1016/j.neurobiolaging.2013.07.028] [Medline: 24011541]

22. Kulmala J, von Bonsdorff MB, Stenholm S, Törmäkangas T, von Bonsdorff ME, Nygård CH, et al. Perceived stress symptoms in midlife predict disability in old age: a 28-year prospective cohort study. J Gerontol A Biol Sci Med Sci 2013;68(8):984-991 [FREE Full text] [doi: 10.1093/gerona/gls339] [Medline: 23371968]

23. Ropponen A, Svedberg P, Koskenvuo M, Silventoinen K, Kaprio J. Physical work load and psychological stress of daily activities as predictors of disability pension due to musculoskeletal disorders. Scand J Public Health 2014;42(4):370-376 [doi: 10.1177/1403494814525005] [Medline: 24608095]

24. Li J, Zhang M, Loerbroks A, Angerer P, Siegrist J. Work stress and the risk of recurrent coronary heart disease events: a systematic review and meta-analysis. Int J Occup Med Environ Health 2015;28(1):8-19 [FREE Full text] [doi: 10.2478/s13382-014-0303-7] [Medline: 26159942]

25. Lachman ME, Teshale S, Agrigoroaei S. Midlife as a pivotal period in the life course: balancing growth and decline at the crossroads of youth and old age. Int J Behav Dev 2015;39(1):20-31 [FREE Full text] [doi: 10.1177/0165025414533223] [Medline: 25580043]

26. Sternthal MJ, Slopen N, Williams DR. Racial disparities in health: how much does stress really matter? Du Bois Rev 2011;8(1):95-113 [FREE Full text] [doi: 10.1017/S1742058X11000087] [Medline: 29887911]

27. Hatch SL, Dohrenwend BP. Distribution of traumatic and other stressful life events by race/ethnicity, gender, SES and age: a review of the research. Am J Community Psychol 2007;40(3-4):313-332 [doi: 10.1007/s10464-007-9134-z] [Medline: 17906927]

28. Williams DR, Collins C. Racial residential segregation: a fundamental cause of racial disparities in health. Public Health Rep 2001;116(5):404-416 [FREE Full text] [doi: 10.1093/phr/116.5.404] [Medline: 12042604]

29. Slopen N, Dutra LM, Williams DR, Mujahid MS, Lewis TT, Bennett GG, et al. Psychosocial stressors and cigarette smoking among African American adults in midlife. Nicotine Tob Res 2012;14(10):1161-1169 [FREE Full text] [doi: 10.1093/ntr/nts011] [Medline: 22367977]

30. Pieterse AL, Carter RT. An examination of the relationship between general life stress, racism-related stress, and psychological health among black men. J Couns Psychol 2007;54(1):101-109 [doi: 10.1037/0022-0167.54.1.101]

31. Almeida DM, Wethington E, Kessler RC. The daily inventory of stressful events: an interview-based approach for measuring daily stressors. Assessment 2002;9(1):41-55 [doi: 10.1177/1073191102091006] [Medline: 11911234]

32. Shrider EA, Kollar M, Chen F, Semega J. Income and poverty in the United States: 2020. United States Census Bureau. 2021. URL: https://www.census.gov/data/tables/2021/demo/income-poverty/p60-273.html [accessed 2022-02-22]

33. Shih PC, Han K, Poole ES, Rosson MB, Carroll JM. Use and adoption challenges of wearable activity trackers. Illinois Digital Environment for Access to Learning and Scholarship. 2015. URL: https://www.ideals.illinois.edu/handle/2142/73649 [accessed 2020-05-16]

34. Moriarty DG, Zack MM, Kobau R. The centers for disease control and prevention's healthy days measures—population tracking of perceived physical and mental health over time. Health Qual Life Outcomes 2003;1:37 [FREE Full text] [doi: 10.1186/1477-7525-1-37] [Medline: 14498988]

35. Godin G, Shephard RJ. A simple method to assess exercise behavior in the community. Can J Appl Sport Sci 1985;10(3):141-146 [Medline: 4053261]

36. Pierannunzi C, Hu SS, Balluz L. A systematic review of publications assessing reliability and validity of the Behavioral Risk Factor Surveillance System (BRFSS). BMC Med Res Methodol 2013;13:49 [FREE Full text] [doi: 10.1186/1471-2288-13-49] [Medline: 23522349]

37. Cutrona CE, Russell DW. The provisions of social relationships and adaptation to stress. Adv Pers Relatsh 1987;1:37-67

38.   Hughes ME, Waite LJ, Hawkley LC, Cacioppo JT. A short scale for measuring loneliness in large surveys: results from
       two population-based studies. Res Aging 2004;26(6):655-672 [FREE Full text] [doi: 10.1177/0164027504268574] [Medline:
       18504506]
39.   Kroenke K, Spitzer RL, Williams JBW. The PHQ-9: validity of a brief depression severity measure. J Gen Intern Med
       2001;16(9):606-613 [FREE Full text] [doi: 10.1046/j.1525-1497.2001.016009606.x] [Medline: 11556941]
40.   Wade R, Becker BD, Bevans KB, Ford DC, Forrest CB. Development and evaluation of a short adverse childhood experiences
       measure. Am J Prev Med 2017;52(2):163-172 [FREE Full text] [doi: 10.1016/j.amepre.2016.09.033] [Medline: 27865652]
41.   Pearlin LI, Menaghan EG, Lieberman MA, Mullan JT. The stress process. J Health Soc Behav 1981;22(4):337-356 [doi:
       10.2307/2136676]
42.   Ross CE, Mirowsky J. Disorder and decay: the concept and measurement of perceived neighborhood disorder. Urban Aff
       Rev 2016;34(3):412-432 [doi: 10.1177/107808749903400304]
43.   Almeida DM. Resilience and vulnerability to daily stressors assessed via diary methods. Curr Dir Psychol Sci
       2016;14(2):64-68 [doi: 10.1111/j.0963-7214.2005.00336.x]
44.   Waller LA, Gotway CA. Applied Spatial Statistics for Public Health Data. Hoboken, N.J: John Wiley & Sons; 2004.
45.   Rue H, Martino S, Chopin N. Approximate Bayesian inference for latent Gaussian models by using integrated nested
       Laplace approximations. J R Stat Soc Ser B Stat Methodol 2009;71(2):319-392 [FREE Full text] [doi:
       10.1111/j.1467-9868.2008.00700.x]
46.   Lindgren F, Rue H, Lindström J. An explicit link between Gaussian fields and Gaussian Markov random fields: the stochastic
       partial differential equation approach. J R Stat Soc Ser B Stat Methodol 2011;73(4):423-498 [FREE Full text] [doi:
       10.1111/j.1467-9868.2011.00777.x]
47.   Reich BJ, Hodges JS, Zadnik V. Effects of residual smoothing on the posterior of the fixed effects in disease-mapping
       models. Biometrics 2006;62(4):1197-1206 [doi: 10.1111/j.1541-0420.2006.00617.x] [Medline: 17156295]
48.   Creswell JW. Research Design: Qualitative, Quantitative, and Mixed Methods Approaches, Third Edition. Thousand Oaks,
       California: SAGE; 2009.
49.   Lincoln YS, Guba EG. Naturalistic Inquiry. Beverly Hills, Calif: SAGE Publications; 1985.

Abbreviations

DISE: Daily Inventory of Stressful Events
EMA: ecological momentary assessment
INLA: Integrated Nested Laplace Approximation
MIDUS: Midlife in the United States
REDCap: Research Electronic Data Capture
STRIVE: Stress Reports in Variable Environments