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So what I'm stressed? A qualitative study examining caregivers' reactions to emerging biomarkers of stress

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ABSTRACT

Background: Caregivers of adults with cancer often report significant distress yet remain difficult to engage in supportive services. While the field of Psychosomatic Medicine has continued to identify important markers of physiologic stress, and demonstrated disruption in these markers in caregiver populations, no research has investigated whether biomarker information on caregivers' reaction to stress could impact their willingness to address their ongoing distress.

Methods: Here, we report on a qualitative study ($N = 17$) in which we conducted individual interviews with cancer caregivers to explore their key attitudes towards, and subjective experience of, mock stress biomarker data. A total of 17 caregivers of patients (M age = 56.1 years; $SD = 12.3$) with primarily metastatic brain tumors (glioblastoma) were interviewed regarding four commercially available biomarkers (telomere length; hair cortisol, activity levels and heart rate variability). Once presented with information about stress biomarkers, caregivers were asked to discuss their subjective reaction *as if it was their own data* as well as their motivation and willingness to seek support after receiving such information. We identified and extracted relevant themes.

Results: Analysis utilizing the framework method revealed four emerging themes. The first theme described caregivers' ability to manage stress and willingness to engage with supportive services. Second, caregivers generally accepted the biomarker data but preferred it to be presented in a specific way. The third theme demonstrated that for some, biomarker data may actually increase their subjective distress (e.g., whether or not something could be done to improve their mental state). The last theme described how biomarkers were generally received as meaningful motivators that could increase caregivers' willingness to engage with supportive services.

Conclusions: In addition to the more general identified theme of CG's willingness to engage with additional support, we gained insights into caregivers' reaction to the stress biomarkers presented. Findings will set the stage for the utility of stress biomarker information and whether it influences cancer caregivers' willingness to address their distress and motivation to engage in supportive services.

1. Introduction

Almost two million adults are expected to be diagnosed with cancer this year (Byrne et al., 2022), adding to the more than 14.5 million cancer survivors in the United States (DeSantis et al., 2014). The ever-increasing number of cancer survivors translates into greater demands for caregivers (CGs) as patients transition from acute treatment to survivorship. Such unpaid service comes with a high cost to CGs, including financial strain (Arno et al., 1999), poorer health outcomes (Schulz and Beach, 1999) and, significant psychological burden (Pinquart and Sörensen, 2003). In fact, CG distress can often surpass that of the patient for whom they care (Girgis et al., 2013). Additionally, CGs are more likely to engage in unhealthy health behaviors, such as smoking or increased soda and unhealthy food consumption, (Hoffman et al., 2012) in the face of caregiving demands as they prioritize their

patient's health over their own (Williams, 2007). For these many reasons, it is critical to understand how the caregiving experience may put CGs at risk for increased morbidity and mortality (Schulz and Beach, 1999).

In order to provide CGs with additional evidence-based support, there has been increased attention toward developing interventions that address caregivers' burden, with over 100 trials conducted to date (Ferrell and Kravitz, 2017). Despite efforts to broaden availability of psychological services for people with cancer and CGs (Odom et al., 2023), uptake of these services remains relatively low (Mosher et al., 2013; Rhee et al., 2023; Strain and Blandford, 2002). CGs reported emotional concerns do not necessarily translate into willingness to participate in supportive interventions (Strain and Blandford, 2002). In brain cancer – in which CGs report high levels of distress (Rhee et al., 2023) – few are willing to participate in treatment center support

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(Downar et al., 2014). Retention among CGs in intervention studies remains quite challenging (Vanderwerker et al., 2005). These parallel broader trends in the general public where cancer patients reporting high distress are less likely to accept interventions offered (Brebach et al., 2016) and, similarly, distressed caregivers outside of cancer are less likely to complete behavioral interventions (Butz et al., 2012), or improve their own self-care (Lu and Wykle, 2007). This literature underscores the significant barriers of engaging CGs in research and psychosocial support.

The challenges of engaging CGs with psychosocial support are particularly concerning as there is also a substantial body of research demonstrating the physiological toll of caregiving. Studies exploring the impact of caregiving on various biomarkers of stress demonstrate effects across immune, endocrine (Lovell and Wetherell, 2011) and autonomic dysregulation (Teixeira et al., 2018). In caregivers of patients with brain cancer, caregivers demonstrate elevations in systemic inflammation (a marker of chronic stress and risk factor for cardiovascular problems) and disrupted hormonal patterns (Rohleder et al., 2009). Thus, while the research community has come to understand some potential mechanisms by which caregiving burden may be associated with negative health outcomes, engaging CGs to discuss these scientific findings and capturing their individual reactions to these insights remains unexplored.

The primary goal of this study was to explore caregivers' motivation toward seeking help and to investigating whether emerging biomarkers of stress would impact CGs willingness to engage in psychosocial support. We targeted a historically burdened group of caregivers – caregivers of patients with brain cancer - as an initial step toward connecting caregiver motivation to individual reaction to several emerging biomarkers. We specifically aimed to characterize caregivers' motivation to pursue supportive services and then discuss their reaction to several emerging biomarkers, considering these data were their own.

2. Methods

2.1. Sample

This study took place in large academic cancer center in the northeast United States. Caregivers of neuro-oncology patients were approached during the patients regularly scheduled clinic visits. They were contacted by either an advanced nurse practitioner, psychiatrist or social worker associated with their care. In some cases, a research assistant offered caregivers the opportunity to participate in the study after approaching their respective patient for participation in another ongoing study. All study procedures were reviewed and approved (ruled exempt from subsequent review by the Dana-Farber/Harvard Cancer Center Institutional Review Board) and data was stored on a HIPAA-compliant server.

Inclusion criteria included: 1) self-identified as the primary caregiver for an individual seen in the Dana-Farber Cancer Institute Neuro-oncology Center and 2) willingness to broadly discuss psychological distress and reactions to stress biomarker data. Exclusion criteria included: 1) inability to participate in an individual interview and 2) non-English speaking. All participants were offered a \$15 gift card for their participation.

2.2. Interview guide and study procedures

The principal investigator (TS) conducted Zoom interviews, all scheduled for 60 min and adhering to an interview guide developed by the authors to better understanding how caregivers respond to different biofeedback markers of stress [Appendix A]. During recruitment, the study purpose was described to all potential participants; specifically, the under-utilization of supportive programs, their experience of stress and their interaction or willingness to interact with supportive services in the past. Next, consented participants were asked about their

experience with filling out questionnaires related to distress (had they done this before; how they would react if a medical professional suggested that they were experiencing significant distress). We then proceeded to review the four stress biomarkers of interest. These were selected based on a review of biomarkers that were publicly available at the time of study initiation and corresponded to biomarkers previously examined in caregiver populations. These included 1) daily movement graphics from Fitbit,™ 2) Hair cortisol output from Rocky Mountain Analytical, 3) graphical representation of Teloyears™ and, finally, 4) summary of heart rate variability data from the HeartMath Institute. Additional information about the presented biomarker data can be found in Appendix. A brief introductory description of each biomarker was presented prior to the selected graphical representations of each stress marker [see Appendix A for full interview guide].

2.3. Mock biomarker data

Given the potentially sensitive nature of collecting these data directly (Torous and Roberts, 2017), we opted to present each biomarker as “mock” data and caregivers were asked to imagine if the output presented were their own. Specifically, pictures of output from each biomarker were shared over the screen and the following open-ended questions were posed: “Try to imagine that this person is you. If somebody showed this to you and said that they think this is a sign that you might be very stressed, how would you feel? Would this make you want to do something about your distress? How would this information compare to questionnaire results and the other tests in making you want to do something about your distress?”

2.4. Qualitative analyses

All interviews were digitally recorded, de-identified, and then transcribed by the company [ProductionTranscripts.com](https://www.productiontranscripts.com). An *a priori* code list based on the interview guide was created by the authors. Additional codes were then added to this original code list as authors began analyzing the data. All coding was conducted in Atlas.ti. Consensus coding was completed by authors TP and TS to ensure that agreement and accuracy was reached during the coding process.

The framework method (Gale et al., 2013; Srivastava and Thomson, 2008) was then used to identify emerging themes from the data. This was done by creating a framework matrix in Microsoft excel containing all codes from the codebook and all quotes pertaining to each code. This permitted authors to gain a robust overview of how each participant responded across all codes and how each individual code was received across all participants. Authors T.S and T.P then completed separate reviews of the data to determine which code groups appeared to be related for this data set to determine the emergent themes.

3. Results

We approached 68 potential caregivers for study participation, 17 of whom agreed to participate in the interview and consented to the study. Participants average age was 56.1 (± 12.3) years old. The majority of participants identified as Female (77.8%), identified as Caucasian (94.4%) and reported caring for a patient with glioblastoma (70.6%). Participants reported on average, dedicating 7.8 h each day to caregiving. Lastly, 70.6% of our participants had never previously sought psychological support in the past (Table 1).

3.1. Themes

Through our qualitative analysis we identified four important themes which are illustrated in Table 2: (1) Willingness to Engage in Supportive Care, (2) Biomarkers are accepted, but alone are not enough, (3) Biomarkers may increase stress in some cases, (4) Biomarkers as meaningful motivators, with HRV being most motivating.

Table 1
Caregiver demographics.

| Demographic Factor | |
|---|-------------|
| Age (M, SD) | 56.1 (12.3) |
| % Female | 77.8% |
| % Caucasian | 94.4% |
| Average hours of caregiving per day (M, SD) | 7.8 (8.3) |
| % that has "sought psychological support in the past" | 29.4% |
| % caring for a patient with glioblastoma | 70.6% |

3.2. Theme 1: willingness to Engage in Supportive Care

Many of our CGs discussed their previous engagement with or willingness to engage in psychosocial support. Many reported never having filled out a questionnaire about their distress, however, they followed that they would not only be willing to fill out a questionnaire, but also that if their provider suggested they seek support based on the results of that questionnaire that they would be open to pursuing support. For example, when asked if she were to fill out a questionnaire that indicated she was under distress whether she would seek help if suggested, participant 4 stated, "I trust my medical team and so I would do it." Another participant responded similarly stating, "It depends on how the suggestion is phrased. If it's a generic suggestion like, 'oh maybe it would be interesting to try this,' I would not do it. But if it is a, 'hey you have these symptoms and its very important that you go to somebody,' then I might do it." (Participant 7). This highlights the important role clinicians may play in the framing of psychosocial support. Additionally, these results indicate that many caregivers may be willing to pursue psychosocial support with the suggestion of their medical team. This finding is critical as our results also demonstrate a need for support among caregivers. For example, participant 6 stated "I think that as a society we don't acknowledge caregivers, we don't make space for them ... You go into a doctor's appointment and it's all about you listening about how to take care of the patient, nobody says, 'how are you doing?' or, 'what are you doing to stay healthy.'" Another participant remarked, "caregivers oftentimes don't pay attention to their own health and only prioritize the other patient's health" (Participant 1). Thus, participants shared that their well-being was not always acknowledged by health care providers, in addition to the internal barriers to prioritizing their own health.

3.3. Theme 2: biomarkers are accepted, but alone are not enough

Many CGs reported feeling that the presented biomarkers (Fitbit data, cortisol, heart rate variability, and telomeres) were acceptable, and even meaningful, markers of stress. However, many participants also reflected that although the biomarker data may intrigue them to seek psychosocial support, the presentation of the biofeedback data alone would not be enough to motivate them to take immediate action.

Several participants discussed the value of presenting biofeedback data and how it changed over time versus just simply presenting CGs with one isolated timepoint for that specific biomarker. For example, participant 6 stated that cortisol would "absolutely" motivate her to seek psychosocial support, but that she would, "hope there would be a follow-up test in six-months," "as a kindness ... to see what the trend was, if it had accelerated or if you're doing better, if the stress reducing activities were working."

Similarly participant 5 noted that the biomarkers would be more motivating if she saw "a pattern" in her results.

Other participants described how they felt the biomarker data was useful, however, if implemented in clinic they felt it would be critical for the data to be presented with a plan for how to correct the discussed biomarker. Participant 15 stated she would "believe" the cortisol data but would, "obviously like to find something to combat it, whether it be medicine, chemicals, and obviously a whole health thing would be best. But quick fixes, more treatments, something. I'd want to reverse it, if possible."

Table 2
Illustrative quotes across 4 identified themes.

| Participant Number | Quote |
|--|--|
| Theme 1: Engagement in care | |
| 4 | "sure", "I trust my medical team and so I would do it." |
| 7 | "It depends on how the suggestion is phrased. If it's a generic suggestion like, 'oh maybe it would be interesting to try this,' I would not do it. But if it is a, 'hey you have these symptoms and its very important that you go to somebody,' then I might do it." |
| 6 | "I think that as a society we don't acknowledge caregivers, we don't make space for them ... You go into a doctor's appointment and it's all about you listening about how to take care of the patient, nobody says, 'how are you doing?' or, 'what are you doing to stay healthy.'" "caregivers oftentimes don't pay attention to their own health and only prioritize the other patient's health" |
| 1 | "caregivers oftentimes don't pay attention to their own health and only prioritize the other patient's health" |
| Theme 2: Biomarkers are accepted, but alone are not enough | |
| 6 | "I think a follow-up test would be a kindness just so people didn't worry that they were continuing to do— and it doesn't necessarily have to be every year or after six months, but to see if you were still— what the trend was, if it had accelerated or if you're doing better, if the stress reducing activities were working" |
| 15 | "Obviously I believe it, because my hair is thinner than it used to be, something's affecting it. So I'd like to find < laughs> something to combat it, whether it be medicine, chemicals, and obviously a whole health thing would be best. But quick fixes, more treatments. I'd want to reverse it, if possible." |
| 5 | "...like if I saw that as a pattern, I'd say, "Hm, maybe I'm not as self-aware as I thought I was." |
| 7 | I think this one is probably the most impactful. However, how effective it's going to be depends on what comes with it. It would probably be more highly motivating especially if it comes with very clear tools and techniques on, "Hey, you should start doing these things," right? Because if it's telling that I'm too stressed, it's only going to make me more stressed, but if you say, "Hey, here's some things that you need to take a look at and when you noticing these, here are three things that you should do," |
| 8 | I think all the tests combined would probably be a better business case to know that, hey, here's your overall makeup. And here are some of the things that is contribute—we believe stress is contributing to some of these numbers. And when, you know, one test is one test. It's like playing the lottery. You know? You don't know how many times you're going to win. All these metrics and measurements combined would definitely make me more aware that there's something measurable going on in my mind and my body. |
| 9 | I don't think any one specific test alone should be used, I think yeah, a combination for sure. |
| Theme 3: Biomarkers as meaningful motivators, with HRV and Telomeres as most motivating | |
| 6 | I think that would be excellent, I mean and I think that because there are things you can do to reduce stress and it would be like a wakeup call. |
| 4 | I'd say, holy crap, I've got to do something. |
| 8 | "your heart is such an important organ in your body and [she] would be a little upset about that if there were long-term effects from [stress]." |
| 13 | "the stress on the heart, because I don't want to go anywhere, I want to make sure I'm here to take care of my wife, that's my main goal." |
| 7 | I think this one is probably the most impactful as a sort of a shock to the system kind of thing. I think the telomeres is more motivating than the other and here's why. The telomeres tell me, how do you say that, it's like— the telomeres, the way it's presented, you automatically deduct that you have shortened your lifespan even though that might not be true |
| 1 | I think this is a little more scary just because it has the age associated with it. |
| Theme 4: In some cases, biomarkers increase stress | |
| 3 | Stressed. < laughs> Obviously wanting to know more, and more being sort of trying to pinpoint where's the stress coming from. |
| 7 | "if I were to get something that said, 'hey you might be stress,' then I would probably start feeling stressed, even if I wasn't already feeling stressed, I would probably start feeling stressed about it." |
| 12 | Depressed. < laughs> Probably more stressed. Yeah, discouraged |
| 15 | Probably depressed, < laughs> somewhat. Nobody wants to age faster than we should. So, again, I would want to do something to turn that around. |

Participant 7 stated that although the telomere data was impactful that “how effective it’s going to be depends on what comes with it.” This participant further elaborated describing that the telomere data would be most effective if it was presented with “very clear tools and techniques to do” or even, “three things you can do” to reverse the irregularity.

Lastly, several participants noted that although each biofeedback marker was helpful, presenting multiple biofeedback markers together, rather than individually, might be most effective. Participant 8 stated “I think all the tests combined would probably be better ... All these metrics and measurements combined would definitely make me more aware that there’s something measurable going on in my mind and my body.” This finding was also reflected by participant 9 who said, “I don’t think any one specific test alone should be used, I think a combination for sure ...” going on, “... [Heart Rate Variability] in combination with the telomere test would be the clincher.”

3.4. Theme 3: biomarkers as meaningful motivators, with HRV and telomeres being most motivating

Our analysis also revealed that biomarkers may be meaningful motivators to encourage caregivers to pursue psychosocial support. In fact, nearly every participant expressed a clear preference for one or two specific biomarkers and described how motivating certain biomarkers could be in inspiring them to seek out psychosocial support. For example, participant 6 stated that if she received the telomere data that it would be “a wake-up call for her,” and participant 3 described the heart rate variability data as a “call-to action.” Similarly, participant 4 noted that she would say “holy & *\$# - I’ve got to do something” if she received an irregular telomere test.

Among the 17 participants, 10 (59%) noted that the heart rate variability biomarker would be the most motivating. Participant 8 stated heart rate variability biomarker was the most impactful because “your heart is such an important organ in your body and [she] would be a little upset about that if there were long-term effects [from stress].” Similarly, participant 13 stated that the biomarker for heart rate variability was most motivating because of “the stress on the heart, because I don’t want to go anywhere, I want to make sure I’m here to take care of my wife, that’s my main goal.” It is however important to note that several participants seemed to misinterpret the HRV data, believing it meant their heart was having an acute crisis. One participant even remarked stating that she thought “it [would be] really important to say, ‘this is stress. This is not showing you’re having a heart attack’” when presenting the HRV data (Participant 6).

The second most motivating biomarker ranked by participant feedback was the telomere test, which 6 participants expressed a preference for. Participant 7 described the telomere results as “the most impactful as sort of a shock to the system” and further described that the telomere data most motivating because, “the telomeres, the way it is presented, you automatically deduct that you have shortened your lifespan.” Participant 1 similarly described that “[the telomere data] is a little more scary just because it has age associated with it.” Taken together, this finding perhaps indicates that the impact of the telomere data may be related to its association with aging.

3.5. Theme 4: In some cases, biomarkers may increase stress

Although many of our caregivers reported that biomarkers could be motivating in inspiring them to pursue psychosocial support, we also found that, in many cases, the presentation of biomarkers might also increase stress or create difficult emotions within caregivers. For example, participant 3 stated that the cortisol data would make her feel “stressed” and that she would “obviously want to know more ... sort of trying to pinpoint where the stress is coming from.” Similarly, participant 7 stated, “if I were to get something that said, ‘hey you might be stress,’ then I would probably start feeling stressed, even if I wasn’t already feeling stressed, I would probably start feeling stressed about it.” Participant 15 even noted

that if would feel “probably depressed somewhat” if she received irregular telomere data because “nobody wants to age faster than we should.” Though also remarking, “would want to do something to turn that around.”

4. Discussion

To our knowledge, this study was the first of its kind to directly explore CG’s motivation to seek psychosocial support and whether stress biomarker data might impact their willingness to engage in supportive services. While the scientific community has long identified CG burden as impact to CG’s health (Liu et al., 2020) and made progress in developing supportive interventions (Treanor, 2020; Ugalde et al., 2019), understanding CG motivation to seek support is a critical piece in connecting CGs with psychosocial support. Emerging biomarkers of stress - increasingly available to the public - may provide an opportunity to discuss stress management with CG and might provide an opportunity to readily engage CGs in supportive services as engaging CGs in support remains challenging. Herein we explored how CGs willingness to pursue psychosocial support may be affected by stress biomarker data.

We began our qualitative inquiry by discussing CGs prior experience with mental health support. In concert with other literature (Reblin et al., 2022), we suspected that caregivers may identify barriers to engaging in mental health care for themselves - as our team has outlined models of barriers to psychosocial care more generally (Parmet et al., 2023) - but discovered that many CGs appeared to be willing to engage with psychosocial support. However, their openness was contingent on who presented the idea to them and how the idea was presented. Within the discussion of CGs and their willingness to engage with supportive care, this finding highlights the important role that physicians and other health care providers may play in curating an environment where CGs are more likely to accept supportive services.

In addition to the more general identified theme of CG’s willingness to engage with additional support, we gained insights into caregivers’ reaction to the 4 stress biomarkers presented. First, we found a general acceptance of the stress biomarker data we presented. In fact, most participants reacted strongly to the biomarker data, articulating that the data would play a positive role in motivating them to engage with psychosocial support. This finding is especially relevant given that various studies have consistently demonstrated how CGs often do not pay attention to their own health (Liu et al., 2020). This is particularly compelling, given that national survey data suggests wearable use is related to increased physical activity in CGs (Mahmood et al., 2022), and that CGs report strong interest in smart watch monitoring in helping manage their patients pain (LeBaron et al., 2020). Interestingly, in our study, most CGs (59%) expressed a clear preference for HRV data when asked to compare across the presented biomarkers. In line with other qualitative work with heart monitoring in which participants felt these data could improve insight into their emotional experience (Byrne et al., 2022), and CGs rated a HRV monitoring and reporting protocol feasible, with high adherence rates (Schuler et al., 2023). We also found that although biomarkers appeared to be accepted as potentially meaningful motivators, that for them to truly have an impact they would be more meaningful if paired with additional information. Future work may leverage such combined monitoring to connect distressed caregivers with evidence-based interventions remotely.

Additionally, we also found that in some cases stress biomarker data could increase distress among CGs. Several participants described that if they were to receive concerning stress biomarker data that they would feel “depressed,” other participants stated that they would feel “more anxious” to learn that their biomarkers had been affected by their distress. This finding highlights the important role that framing may play in the presentation of stress biomarker data. As healthcare providers, it would be critical to consider the most effective, and sensitive, way to present this information to individuals, given that many individuals may react in a different way to the information they receive.

There are several notable limitations to discuss. First, the mock data

is likely less meaningful than an actual medical screening and may have biased participant interpretation. Additionally, we presented participants with extreme results on these tests (see Figures), and it is possible CGs may be less motivated by data that is only slightly abnormal. Further, most of our participants were Caucasian women, which undoubtedly limits the generalizability of these results. It is possible that sociocultural factors may influence individual receptivity to this stress biomarker data, and those differences should be further explored in future study. Finally, it is possible that our sample may have been impacted by selection bias, and particularly volunteer bias, as only 17 of the 68 caregivers recruited to this study chose to participate. We recognize that topics related to mental health may be stigmatized and could deter some from engaging in research. However, we also recognize that cancer caregivers have been historically difficult to recruit to research in general, due to time constraints, and the tendencies of caregivers to prioritize spending their time supporting their loved ones needs, above their own (Joshi et al., 2023). We suspect that this may likely explain the discrepancy between the number of caregivers invited to participate and those who followed through with participation, above selection bias, especially as we reached saturation and observed no outliers of topic in our data set.

In summary, overcoming individual-level barriers of motivation and time constraints will remain critical to advancing CG support. Our results suggest that CGs are willing to engage in mental health support, if brought up sensitively. Further, CGs may see emerging stress biomarkers as additional sources of motivation, with the important caveats that these will be more powerful when combined with other markers and such data should be handled sensitively given its potential to increase distress. Future work should address how CGs' experience with prior mental health may influence their receptiveness to additional support and explore the opportune way to present these data to CGs.

CRedit authorship contribution statement

Timothy S. Sannes: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Tamar Parmet:** Writing – review & editing, Writing – original draft, Validation, Project administration, Methodology, Investigation, Formal analysis, Data curation. **Miryam Yusufov:** Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Jodi Sutherland:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Data curation. **Jennifer Stefanik:** Writing – review & editing, Writing – original draft, Validation, Resources, Project administration, Methodology, Investigation, Data curation. **Nicole Andrade:** Writing – review & editing, Writing – original draft, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation. **Tamryn F. Gray:** Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Ilana M. Braun:** Writing – review & editing, Writing – original draft, Validation, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **William F. Pirl:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

Miryam Yusufov reports personal fees from Blue Note Therapeutics outside the submitted work. Ilana Braun receives funding by the Hans and Mavis Lopater Foundation. The other authors have nothing to disclose.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.bbih.2024.100783>.

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