BMJ Open Smartphone-based ecological momentary music intervention to reduce stress in Turkish immigrant women: protocol

Stefanie Hirsch (), ^{1,2,3} Urs M Nater (), ^{2,3} Ricarda Mewes (), ^{1,3}

ABSTRACT

Background Immigrant women frequently encounter ethnic discrimination (ED) and/or stressful events in their daily lives. To mitigate the risk of resulting health impairments, we developed an ecological momentary music intervention (EMMI-T) to reduce psychological and biological stress levels in the daily lives of Turkish immigrant women. The feasibility of the EMMI-T was confirmed in a pilot study (n=20). Here, we present the protocol of our proposed study to investigate the effectiveness of the EMMI-T.

Methods Fifty Turkish immigrant women perceiving chronic ED will take part in the 35-day study. During all three study periods (ie, baseline, intervention and postintervention), participants will use a smartphone-based app to provide discrimination-related and stress-related data four times a day. Additionally, they will report every discriminatory and/or stressful event. During the intervention period, subsequently after such event-based data entries, participants will be allocated to either an intervention event (music listening for 10 or 20 min) or a control event (no music listening). Irrespective of event type, the app will signal 20 min after the initial event-based data entry for additional data collection. Every data entry will be accompanied by the collection of a saliva sample for analysis of biological stress markers (alpha-amylase, cortisol).

Analysis This intraindividual randomised design will allow us to test immediate (ie, before vs after music listening) and intermediate (ie, baseline period vs postintervention period) effects of the EMMI-T on psychological and biological stress levels. To test our hypotheses, we will use multilevel modelling.

Ethics and dissemination Positive ethical approval was given by the institutional review board of the University of Vienna (reference number 00575). The results of our study will be disseminated at conferences and submitted to a peer-reviewed journal.

Trial registration number NCT05829031.

A large body of research has demonstrated that ethnic discrimination (ED), the worse or unfair treatment because of one's ethnicity,¹ can exert a detrimental effect on both mental and physical health.^{2–5} For instance, meta-analyses have shown a significant association

STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ The ecological momentary music intervention can be readily employed in moments of perceived (ethnic) discrimination and/or other stressful events.
- ⇒ Data collection will be integrated into the daily lives of participants over an extended period (ie, 35 days) by the use of smartphones.
- ⇒ Stress will be assessed multimodally by measuring both subjective and biological (cortisol, alphaamylase) stress parameters.
- \Rightarrow The results may be biased in some way as we will employ convenience sampling.
- ⇒ Strict exclusion criteria necessary for biological analyses may introduce selection bias and thus limit the representativeness of our study.

of ED with various adverse health outcomes, including symptoms of psychological distress, reduced well-being, increased anxiety, depression, suicidal ideation and specific types of physical health problems and impaired general health.^{6–8}

Evidence suggests that the experience of stress is a crucial factor in linking perceived ED to resulting health impairments.⁹¹⁰ Within the framework of stress-coping models,^{11 12} ED can be conceptualised as a stressor that is both uncontrollable and unpredictable in nature.¹⁰ Accordingly, what matters is the subjective perception of being discriminated against, referred to as perceived ED.¹³ Like any other stressor, perceived ED can elicit immediate psychobiological stress responses, resulting in negative emotional states as well as biological changes,¹¹ with the latter determined by the activation of the hypothalamic-pituitary-adrenal (HPA) axis, the autonomic nervous system (ANS)¹⁴ and the immune system. HPA axis activity causes a cascade of neuroendocrine responses in the brain, resulting in elevated levels of circulating salivary cortisol (sCort).¹⁵ ANS activity can be detected in the form of elevated levels

To cite: Hirsch S, Nater UM, Mewes R. Smartphonebased ecological momentary music intervention to reduce stress in Turkish immigrant women: protocol. *BMJ Open* 2025;**15**:e090518. doi:10.1136/ bmjopen-2024-090518

Prepublication history and additional supplemental material for this paper are available online. To view these files, please visit the journal online (https://doi.org/10.1136/ bmjopen-2024-090518).

Received 26 June 2024 Accepted 24 March 2025

Check for updates

© Author(s) (or their employer(s)) 2025. Re-use permitted under CC BY-NC. No commercial re-use. See rights and permissions. Published by BMJ Group.

¹Outpatient Unit for Research, Teaching and Practice, University of Vienna, Faculty of Psychology, Vienna, Austria ²Department of Clinical and Health Psychology, University of Vienna, Faculty of Psychology, Vienna, Austria ³University Research Platform 'The Stress of Life (SOLE)— Processes and Mechanisms Underlying Everyday Life Stress', University of Vienna, Vienna, Austria

Correspondence to

Ricarda Mewes; ricarda.nater-mewes@univie. ac.at of the starch-degrading enzyme salivary alpha-amylase (sAA). $^{16}\,$

The aforementioned psychobiological stress responses facilitate allostasis, the organism's capacity to adapt to environmental challenges.¹⁷ However, chronic activation of the stress response systems can lead to allostatic load,¹⁷ which manifests as maladaptive psychobiological stress responses such as altered secretions of sCort^{14 15} and sAA.¹⁸ Findings suggest that such dysregulation may be the determining factor regarding ill health among immigrants.^{3 9 19} In this vein, the frequency with which immigrants experience ED in their daily lives is therefore likely to play an important role.^{8 10} Moreover, the frequent (ie, chronic) experience of ED in daily life may enhance the perceived stressfulness of challenging situations unrelated to ED^{20–22} and may also lead to blunted psychobiological stress responses following such events.¹⁹

To counteract ED in daily life, individuals use a range of coping strategies.²³ However, not all of these coping strategies are adaptive, and some may even perpetuate or exacerbate the negative effects of perceived ED.^{24 25} To maintain long-term health in immigrants, it is therefore crucial to investigate stress-coping interventions with the potential to immediately reduce psychobiological stress responses following discriminatory events. For the successful implementation of such interventions in daily life, it is important to acknowledge the uncontrollable and unpredictable nature of discriminatory events¹⁰ and to consider the amplifying effects of ED on the psychobiological stress responses to other stressful events.^{19–22} Consequently, interventions must be ready to use, adaptable to a range of stressors, and flexible in their application.

Research on stress reduction interventions for individuals perceiving ED is still lacking. Existing studies primarily focused on treatments encompassing weekly individual or group sessions,^{26–33} including mindfulness-based interventions,^{26–29–31–34} a salutogenic health programme,²⁷ laughter therapy³⁰ or the development of adaptive cognitive coping skills.^{28–33} These approaches tend to be rather time-consuming, inflexible and may not be suitable for stressors other than perceived ED. Furthermore, it is left up to the individual to transfer and implement the newly acquired coping skills into daily life, which might delay the effects of the intervention.³²

These shortcomings might be addressed by using ecological momentary interventions (EMIs).³⁵ Such interventions are mostly delivered via smartphone apps and are flexible in terms of both time and location of usage.³⁵ Furthermore, they can be provided just-in-time, that is, at the precise moments when discriminatory and/ or stressful events occur.^{35 36} Existing smartphone-based interventions for immigrant populations largely focus on psychoeducation, mindfulness and/or relaxation techniques for stress reduction.³⁷⁻⁴⁰ Only in one of the cited studies³⁷ were participants provided with an on-demand coping toolkit for moments of acute stress (ie, just-in-time). Thus, most interventions may not be available at

the exact moments when discriminatory and/or stressful events occur, as they were not designed as just-in-time interventions. Furthermore, as previous studies did not consider the simultaneous measurement of subjective and biological stress markers, it is not possible to draw definitive conclusions regarding the effect of the individual interventions on different stress parameters. Taken together, evidence on just-in-time EMIs for stress reduction, which specifically target immigrants perceiving chronic ED, is lacking. Consequently, there is no evidence of effective and suitable intervention strategies for such EMIs.

One intervention strategy that is associated with particularly promising advantages in this regard is music listening, which is not only highly popular across different cultures,⁴¹ but also cost-effective and easy to administer. Thanks to smartphones and headphones, music listening is also almost completely flexible in terms of when and where it can be used.⁴² Importantly, the positive effects of music listening on subjective and biological stress parameters have been investigated in numerous studies, both in the laboratory^{43–49} and using ambulatory assessment.^{50 51} Studies employing music listening as an intervention in daily life have revealed positive changes in subjective stress levels after music listening,^{52–55} and recent evidence from our team suggests that music listening is a feasible intervention strategy for an EMI.⁵⁶

To understand the mechanisms underlying the potentially health-conducive effects of music listening, researchers have put forth a biopsychological mediation model,⁵⁷⁵⁸ which postulates that the stress response systems may serve as intermediaries in the relationship between music listening and stress-related health outcomes. Accordingly, music listening may elicit emotions, which subsequently modulate activity in distinct brain regions.⁵⁹ This modulation may result in the downregulation of HPA axis activity⁶⁰ as well as ANS activity,⁶¹ which may result in improved health outcomes over time.

In summary, previous research has demonstrated the efficacy of music listening as a strategy for stress reduction. Notably, these findings were observed in participants' everyday lives, outside of the controlled laboratory setting. However, the majority of studies did not include music listening in moments of acute stress. Furthermore, the interventions were not designed for immigrants and did not specifically target perceived ED alongside other stressful events. However, given its cost-effectiveness and potential benefits, evaluating the efficacy of music listening as a strategy for stress reduction in the daily lives of individuals perceiving chronic ED is particularly valuable.

PROPOSED STUDY

The proposed study will focus on Turkish immigrant women, one of the largest groups of non-EU citizens in Europe,⁶² including in Austria.⁶³ Furthermore, they are frequently targets of ED.⁶⁴ Studies have demonstrated that

Turkish immigrants are at increased risk of developing mental disorders and stress-related physical illnesses.⁶⁵⁶⁶ In this regard, it is important to consider gender-related and sex-related differences in experiences of discrimination,⁶⁷ with immigrant women more likely than men to experience discrimination based on both their ethnicity and their gender.^{68 69} Evidence suggests a dose–response relationship, insofar as the impact of discrimination on health increases with the number of types of discrimination experienced.^{70 71} Furthermore, sex differences in specific stress responses might be apparent⁷² that may be attributed to the differing hormonal states observed in men and women.⁷³ In consideration of these differences, we will limit our investigation to immigrant women.

Recognising the need for effective just-in-time interventions, we developed an ecological momentary music intervention (EMMI-T) to reduce stress in the daily lives of Turkish immigrant women. Responses to discriminatory and/or other stressful events in the context of stresscoping models informed the design of the EMMI-T. As it might not be sufficient to solely target perceived ED, we aimed to develop an intervention that is also suitable for other discriminatory and stressful events. We chose music listening as an intervention strategy in view of its beneficial effects on psychobiological stress as well as its inherent advantages (eg, popularity, easy and flexible application, low threshold and cost-effectiveness). Furthermore, we included the measurement of sCort and sAA to target the effects of music listening not only on subjective stress levels but also on HPA axis and ANS activity. We confirmed the feasibility of the EMMI-T approach in a pilot study. In the proposed study, we now aim to investigate the effectiveness of the EMMI-T.

Our hypotheses are as follows:

- 1. Immediate effect: music listening after an event of acute ED and/or a stressful event results in stronger reductions in subjective and biological (sCort and sAA) stress levels compared with no music listening.
- 2. Intermediate effect: a reduction in diurnal subjective and biological (sCort and sAA) stress levels can be observed from the baseline period to the postintervention period of the study.

METHOD

Participants

The sample size was calculated based on data from a pilot study in which a small interaction effect according to Cohen ($f^2 = 0.02$) was observed for music listening * measurement time point (immediate effect of the intervention). The power analysis was performed using the R package mixedpower.⁷⁴ Given the methodological similarities between the pilot study and the proposed main study, it is likely that the effect in the main study will be similarly small. The calculation yielded a statistical power (1-beta) of 0.98 (α =0.05) for a sample size of n=50 participants. Even when accounting for a potential attrition rate of 25% (as was the case in the pilot study), the statistical

power will remain sufficiently high, with a value greater than 0.80 (α =0.05).

Therefore, we are aiming for a total sample of n=50 Turkish immigrant women who are currently living in Vienna (AT) and aged 18–65 years (see figure 1). Individuals will be considered as eligible for participation if they were born in Turkey themselves (ie, first-generation) or at least one of their parents (ie, second-generation). We will only include cisgender women with a score \geq 104 on the Everyday Discrimination Scale,⁷⁵ following the frequency-based algorithm introduced by Michaels and colleagues.⁷⁶ Therefore, only women who report experiencing chronic ED in their daily lives will take part in the study.

Various aspects of health are related to the psychobiological stress response, as a wide range of disorders and medications have modulatory effects on the stress systems. To avoid possible influences on biological stress markers (sCort and sAA) and to further ensure the appropriateness of our intervention for the sample, we defined the following exclusion criteria: insufficient Germanlanguage proficiency, a body mass index (BMI) below 18 kg/m² or above 30 kg/m², mental disorders (ie, current major depressive episode, lifetime psychosis or bipolar disorder, borderline personality disorder), medical conditions or medications known to affect endocrine or autonomic functioning, alcohol or substance abuse, pregnancy, breastfeeding, irregular menstrual cycle or impaired hearing.

Study design

Following an intraindividually randomised control approach,⁷⁷ we will investigate whether music listening in moments of acute stress and/or perceived ED in daily life reduces psychological and biological stress responses to a greater extent compared with alternative activities (ie, no music listening).

Weeks 1 and 5 will constitute the baseline and postintervention period, respectively. The smartphone-based app movisensXS (movisens GmbH, Karlsruhe, Germany) will be used for data collection. Three times per day (11 am, 3) pm and 7 pm), participants will receive a signal to answer a brief set of stress-related and discrimination-related items (ie, time-based data entries). Every data entry will be accompanied by the collection of a saliva sample for the analysis of sCort and sAA. Moreover, participants will be advised to report every discriminatory and/or stressful event that occurs (ie, event-based data entries) if the respective situation allows for a data assessment. When such events are reported, participants will again answer a brief set of stress-related and discrimination-related items and provide a saliva sample ('pre'). After 20 min, the app will signal for an additional data entry and saliva sampling ('post'). This subsequent data entry will allow us to determine the course of psychological and biological stress responses from directly after the event to 20 min later. Every evening, participants will be instructed to complete a daily evening assessment before going to bed (with a reminder sent at 9 pm). In this assessment, they



Figure 1 Complete study flow chart of the ecological momentary music intervention for Turkish immigrant women (EMMI-T).

will provide information on their subjective stress levels, perceived ED and further variables. If discriminatory and/or stressful events happened throughout the day, participants can provide detailed descriptions. To do so, participants are asked if they could provide detailed information on each discriminatory and/or stressful event. Therefore, an open-ended format will be employed, allowing participants to determine the extent of information to be shared. If certain details are perceived as too sensitive by study participants, they are not obligated to disclose them. Additionally, participants can provide information on discriminatory and/or stressful events that have occurred throughout the day, but where they were unable to trigger an event-based data entry due to situational circumstances (eg, workplace restrictions, when driving a car and during an appointment). Participants will not collect a saliva sample at this last data entry of the day.

During the intervention period (weeks 2–4), the timecontingent sampling protocol and the daily diary assessment of the baseline (and postintervention) period will be maintained. Following each event-based data entry, the app will randomly allocate participants, with a 50:50 ratio, to either the intervention event or the control event (see figure 2). Participants will be aware of the two conditions and the random allocation by the study app to either the intervention event or the control event.

Music listening intervention and control event

If assigned to an intervention event, participants will be given the choice between a duration of 10 or 20 min of music listening. While an initial study found that a minimum of 20 min of music listening was necessary to show significant stress-reducing effects, ⁵⁰ we have included the option of 10 min to increase the flexibility of the intervention. Individual music preference is an important factor to consider regarding the stress-reducing effects of music listening. ^{46 47} Furthermore, evidence suggests that relaxing music might be more effective than activating music. ^{44 46 48} Therefore, participants will be asked to create a personal, relaxing study playlist. If assigned to a control event, participants will be instructed to continue with their ongoing activities without music listening. We have decided against an active control condition due to



Figure 2 Schematic illustration of the ecological momentary music intervention (EMMI-T). During the intervention period, participants will be randomly assigned (50:50) to listen to their study playlist (ie, intervention event) or not (ie, control event) on reporting a stressful and/or discriminatory event (E1: 'pre'). If assigned to an intervention event, participants may choose a music listening duration of 10 or 20min. A postassessment (E2: 'post') will be included to capture effects on subjective stress levels and biological stress markers (salivary cortisol, salivary alpha-amylase).

the absence of empirical evidence on EMIs incorporating both effective and easy-to-use stress-reduction strategies for individuals perceiving chronic ED. Thus, the main goal of our proposed study will be to provide first evidence on the effectiveness of music listening. Consequently, the proposed study will entail a comparison of music listening with participants' usual behaviour following discriminatory and/or stressful events.

Irrespective of event type and music listening duration, the app will signal 20 min after the initial event-based data entry for additional data collection and saliva sampling (ie, post; see figure 2).

Procedure

We will recruit study participants by distributing flyers via Facebook (Meta Platforms, Menlo Park, USA), in public places, and through immigrant organisations. Interested individuals can email the study team to arrange an initial telephone interview, during which the inclusion and exclusion criteria will be screened. Eligible participants will be invited to our laboratory for a baseline appointment. Prior to this appointment, participants will receive an email with a personalised link for baseline questionnaires via the internet survey platform Unipark (Unipark EFS Survey, Globalpark, Cologne, Germany). Additionally, participants will be instructed on how to create their music playlist for use during the intervention period of the study.

At the baseline appointment, we will explain the aim and procedure of the EMMI-T in detail, including instructions on using the study app movisens.XS (movisens GmbH, Karlsruhe, Germany) on either the participant's own smartphone or a study smartphone, and on saliva sampling. Furthermore, we will save participants' music playlist in a Spotify premium account (Spotify AB, Stockholm, Sweden). The 35-day study period will begin on the following day. Throughout the study period, participants will receive weekly telephone calls from a member of the study team in order to discuss any potential problems with study participation and to promote participant adherence.

After completion of the study period, we will reinvite participants to our laboratory to answer a set of final questionnaires and to hand over the saliva samples. Participants will be compensated according to the length of their study participation, with €120 being paid for full participation in the study.

Measures

Baseline measures

Participants will complete baseline questionnaires including sociodemographic information, different aspects of health, stress and ED, participants' music listening behaviour and personality traits. Details can be found in the online supplemental material.

EMI measures

The following measures will be used to investigate the primary outcomes of the study, that is, the effectiveness of the EMMI-T:

Change in momentary subjective stress (ie, immediate effect) will be investigated using the single item 'How stressed do you feel right now?', to be answered on a visual analogue scale ranging from 0 'not at all' to 100 'extremely'. Higher values indicate higher momentary subjective stress. The use of single items has been shown to be valid and reliable.⁷⁸ Assessments will take place as part of the

event-based data entries, that is, directly after a discriminatory and/or stressful event (pre) and 20min later (post).

Change in short-term neuroendocrine stress (ie, immediate effect). Participants will provide saliva samples for the analysis of sCort and sAA directly after a discriminatory and/ or stressful event (pre) and 20 min later (post). Participants will be asked to store the saliva samples either in a freezer or refrigerator at home during the study period and to hand them to the study team at the postassessment appointment, whereupon the samples will be stored at -30°C until transported to the local laboratory of the Faculty of Psychology, University of Vienna, Vienna, Austria. The concentration of sCort (in nmol/L) will be determined using a commercial luminescence immunosorbent assay (IBL-Tecan, Hamburg, Germany). To measure sAA activity (in U/mL), saliva samples will first be diluted at 1:400 using 0.9% saline solution,⁷⁹ followed by a kinetic colorimetric test and reagents obtained from DiaSys Diagnostic Systems GmbH (Holzheim, Germany).

Change in diurnal subjective stress from baseline period to postintervention period (ie, intermediate effect) will be assessed using the single item 'How stressed do you feel right now?', to be answered on a visual analogue scale ranging from 0 'not at all' to 100 'extremely'. Data of the three daily time-based data entries of the baseline period and the post-intervention period will be analysed.

Change in diurnal neuroendocrine stress from baseline period to postintervention period (ie, intermediate effect). Participants will provide a saliva sample three times per day, as part of every time-based data entry. Concentrations of sCort and sAA of the three daily time-based data entries of the baseline period and the post-intervention period will be analysed.

Control variables for biological measures. Given the potential influence of several biobehavioural variables on stress markers,⁷³ control variables will be assessed as part of each data entry (except for the daily evening assessment). These will include information on physical activity in the past 2 hours, sleep in the past 2 hours, food intake in the past hour and medication use. For 'post', the time frame of each control variable will refer to the last data entry. All variables will be coded as 0=no, 1=yes.

A full list of all EMA items delivered by the app movisensXS (movisens GmbH, Karlsruhe, Germany) and the secondary outcomes of this study can be found in the online supplemental material.

ANALYSES

To analyse the effectiveness of the EMMI-T, we will specify linear mixed-effects models with random intercepts using the R package lme4.⁸⁰ Observations (level 1) will be nested within participants (level 2). Momentary subjective stress, sCort and sAA activity will constitute the dependent variables. Model estimation will be performed using restricted maximum likelihood. In the case of missing values, we will explore if the missingness of the data follows missing at random or missing not at random. In case of missing not at random, we will include predictors of missingness as covariates in the respective models to adjust for potential bias. Additionally, we will perform sensibility checks (ie, comparisons of models with and without covariates) to assess the influence of these predictors on the respective outcomes.

To investigate the immediate effect of the EMMI-T (hypothesis 1), we will specify a first model for every outcome using data from the intervention period only. We will include measurement time point (coded as 0=pre, 1=post), music (coded as 0=no music listening, ie, control event; 1=music listening, ie, intervention event), and their interaction (measurement time point * music) as fixed factors on level 1.

To examine the intermediate effect of the EMMI-T (hypothesis 2), we will specify a second linear mixedeffects model per outcome. Here, we will use data of the three daily time-based data entries from the baseline period (coded as 0) and the post-intervention period (coded as 1). To investigate the main effect of study phase on the outcome variables, period will be included in our model as a fixed factor on level 2. In the event of zeroinflation of the outcome variable momentary subjective stress (as observed in the pilot study), we will model a negative binominal zero-inflated model using the R package glmmTMB.⁸¹

It can be assumed that the distributions of sCort and sAA activity will be skewed. In this case, we will use a base-10 logarithmic transformation to normalise the data. We will include the following level-1 control variables: medication use, food intake, beverage intake (ie, intake of both alcoholic and non-alcoholic beverages) excluding water/unsweetened tea, physical activity and sleep (coded as 0=no, 1=yes). Following recommendations for centring categorical covariates in multilevel models,⁸² we will centre these variables within clusters. At level 2, we will include age and BMI as continuous control variables, both centred at the grand mean.⁸³

Ethics and dissemination

The institutional review board of the University of Vienna approved both the EMMI-T pilot study and the proposed EMMI-T main study (reference number 00575). Participation will be voluntary and can be terminated at any time. Oral informed consent will be obtained during the telephone screening and written informed consent will be required from each participant at the beginning of the baseline appointment (the written Participant Consent Form can be found as online supplemental material, both in the original German version and an English translation). All data will be collected and stored in a pseudonymised manner. On completion of the study, all data will be anonymised. The results of this study will be disseminated at conferences and submitted to a peer-reviewed journal.

Trial status

Recruitment started in May 2023. The first participant started on 22 May 2023. Recruitment is expected to be

slow, but we aim to complete data collection in September 2025.

Patient and public involvement

As part of the pilot study, we conducted a comprehensive quantitative and qualitative evaluation of our study design. To this end, participants completed a postmonitoring questionnaire, and we carried out semistructured interviews to assess participant satisfaction with the EMMI-T approach as well as participant burden, and to gather information on possible improvements. Based on participant feedback, we have modified the study design. Changes include reducing the number of measurement time points, offering a choice of 10 or 20 min music listening duration and moving the time of the first measurement point to later in the day. With these modifications, we aim to further improve feasibility and reduce participant burden. The results of this study will be shared with interested participants and communicated to relevant stakeholders.

ANTICIPATED RESULTS

With our proposed study, we aim to investigate the effectiveness of the EMMI-T in reducing psychobiological stress levels in the everyday life of Turkish immigrant women. For this purpose, we will assess the effects of the EMMI-T not only on subjective stress, but also on biological stress levels (sCort, sAA). As stated, we expect immediate and intermediate effects of the EMMI-T on psychobiological stress levels. In detail, we expect that psychobiological stress levels will be lower after music listening (ie, intervention events) than after alternative activities (ie, control events; hypothesis 1). Furthermore, we expect psychobiological stress levels to be lower in the postintervention period of our study compared with the baseline period (hypothesis 2).

DISCUSSION

It is evident that immigrant women frequently encounter discriminatory and/or stressful events in their daily lives. However, there is a lack of empirical evidence on effective stress reduction interventions that can be readily applied in moments of acute stress and/or perceived ED. With our proposed study, we aim to contribute important evidence to this research gap by providing valuable insights into the effectiveness of the EMMI-T in terms of reducing stress in the daily lives of Turkish immigrant women.

The proposed study is based on the findings of a pilot study which we conducted to thoroughly investigate the feasibility of the EMMI-T and to gain initial insights into its effectiveness. Based on the findings, we concluded that the EMMI-T is feasible. Furthermore, the results indicated beneficial immediate and intermediate effects of targeted music listening on subjective stress levels. Therefore, we decided to investigate the effectiveness of the EMMI-T in a larger main study. The EMMI-T is highly flexible and adaptable. The intervention can be readily employed in daily life, not only in moments of acute stress, but also in the context of perceived ED. We will employ music listening as the intervention strategy, as this evidence-based stress reduction strategy⁸⁴ is utilised across numerous age groups and cultures, ^{41 85} and no learning is required in order to yield its benefits. The low-threshold nature of this method is reinforced by the accessibility of smartphones and online streaming services, which make music available at almost any time and place.⁸⁵

Unlike previous interventions, we will incorporate a multimodal assessment of stress by measuring both subjective and biological (sCort, sAA) stress parameters. This is a major strength of our study as it will allow for comprehensive conclusions regarding the influence of music listening in daily life on both psychological and biological stress systems simultaneously. As such, our findings will extend previous work by providing a more comprehensive understanding of the effects of music listening on different bodily stress systems. Furthermore, data from our proposed study will be collected from participants over an extended period (ie, 35 days), as they go about their daily lives. This will enhance the quality of our data by reducing measurement errors and biases that might otherwise be introduced through the sole use of crosssectional, retrospective data.³⁶

The chosen intraindividual randomised design will allow conclusions on a within-person level, if music listening is more beneficial for stress reduction than no music listening. By using this design, interindividual variability will be minimised, as every participant will serve as their own control. Additionally, a smaller sample size is required, which is particularly important when studying hard-to-reach populations. Another important advantage of this approach is that it guarantees that all participants will receive the intervention. Moreover, this design will allow participants to continue to use their usual coping strategies when assigned to a control event, providing valuable insights into the coping mechanisms commonly employed by the Turkish immigrants in our study. However, future studies may use the findings of the present study to design large-scale randomised clinical trials with an active control condition, thereby facilitating more precise conclusions on the effectiveness of the intervention in comparison to other activities.

Our results may be biased by a number of factors. First, we will employ convenience sampling, which may introduce selection bias. This will potentially compromise the representativeness of our sample and consequently limit the generalisability of our results. Additional factors that may affect the generalisability of our results may encompass certain participant characteristics. Notably, all study participants will be Turkish immigrants, female and likely to have an affinity for music listening, as baseline data from our pilot study suggest. Moreover, the exclusion criteria of insufficient German-language proficiency and various health conditions may unintentionally limit the representativeness of our study. Second, participants will be aware of the study aim, that is, the investigation of the effects of the music listening intervention on psychobiological stress reduction. Additionally, participants will be instructed to create a study playlist comprising songs they personally perceive as relaxing. These circumstances may introduce potential bias, as participants may anticipate stress reduction. This expectation may influence their subjective stress responses, thus potentially increasing the effects of music listening on subjective stress levels. Consequently, an observed reduction in subjective stress levels may, at least in part, reflect participants' expectations and cannot be solely attributed to the music listening activity itself. To address these potential biases, the proposed main study will include biological stress parameters (ie, sCort, sAA) as objective indicators of stress responses. However, it is noteworthy that some studies that controlled for a potential expectation effect by providing researcher-selected music also demonstrated a reduction in stress levels,^{48 86 87} thereby underlining that music listening itself, independent of expectation effects, has the potential to influence stress levels.

Furthermore, it is important to mention that recruitment for the pilot study was rather slow, and it is possible that the same issue may arise for the main study. One potential explanation is that immigrant women face structural barriers and discrimination that make them hard to reach.^{88,89}

To conclude, we aim to make an important contribution to the field of immigrant health by providing information on a well-evaluated, low-threshold stress reduction intervention for immigrant women perceiving chronic ED. Due to its innovative and flexible design, we anticipate a great potential of the EMMI-T approach not only for immigrant women, but also for other groups experiencing discrimination. The results of our proposed study will facilitate the development of further EMIs for stress reduction in daily life. Consequently, our results will not only be of scientific relevance, but will also have important clinical and practical implications.

Contributors SH: conceptualisation, methodology, writing—original draft; UMN: conceptualisation, methodology, writing—review and editing; RM: principal investigator, conceptualisation, methodology, supervision, writing—review and editing. Guarantor is RM. During the preparation of this work, the authors used DeepL Translate and DeepL Write (Deepl SE, Cologne, Germany) to translate the original German items utilised in the study (ie, EMA items) into English. Furthermore, as the authors of this manuscript are not native English speakers, the Al tool was used to correct certain sentences in the manuscript when there was uncertainty about grammar, spelling and/or terminology. This was done occasionally. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Funding The authors acknowledge open access funding provided by University of Vienna.

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting or dissemination plans of this research.

Patient consent for publication Not applicable.

Provenance and peer review Not commissioned; externally peer reviewed.

Supplemental material This content has been supplied by the author(s). It has not been vetted by BMJ Publishing Group Limited (BMJ) and may not have been peer-reviewed. Any opinions or recommendations discussed are solely those of the author(s) and are not endorsed by BMJ. BMJ disclaims all liability and responsibility arising from any reliance placed on the content. Where the content includes any translated material, BMJ does not warrant the accuracy and reliability of the translations (including but not limited to local regulations, clinical guidelines, terminology, drug names and drug dosages), and is not responsible for any error and/or omissions arising from translation and adaptation or otherwise.

Open access This is an open access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited, appropriate credit is given, any changes made indicated, and the use is non-commercial. See: http://creativecommons.org/licenses/by-nc/4.0/.

ORCID iDs

Stefanie Hirsch http://orcid.org/0000-0002-3924-7778 Urs M Nater http://orcid.org/0000-0002-2430-5090 Ricarda Mewes http://orcid.org/0000-0002-4724-9597

REFERENCES

- Contrada RJ, Ashmore RD, Gary ML, et al. Ethnicity-related sources of stress and their effects on well-being. Curr Dir Psychol Sci 2000;9:136–9.
- 2 Lewis TT, Cogburn CD, Williams DR. Self-reported experiences of discrimination and health: Scientific advances, ongoing controversies, and emerging issues. *Annu Rev Clin Psychol* 2015;11:407–40.
- 3 Panza GA, Puhl RM, Taylor BA, et al. Links between discrimination and cardiovascular health among socially stigmatized groups: A systematic review. PLoS One 2019;14:e0217623.
- 4 Potter LN, Brondolo E, Smyth JM. Biopsychosocial correlates of discrimination in daily life: A review. Stigma Health 2019;4:38–61.
- 5 Williams DR, Lawrence JA, Davis BA, et al. Understanding how discrimination can affect health. *Health Serv Res* 2019;54 Suppl 2:1374–88.
- 6 de Freitas DF, Fernandes-Jesus M, Ferreira PD, et al. Psychological correlates of perceived ethnic discrimination in Europe: A metaanalysis. Psychol Violence 2018;8:712–25.
- 7 Paradies Y, Ben J, Denson N, et al. Racism as a determinant of health: A systematic review and meta-analysis. PLoS One 2015;10:e0138511.
- 8 Schmitt MT, Branscombe NR, Postmes T, et al. The consequences of perceived discrimination for psychological well-being: A metaanalytic review. *Psychol Bull* 2014;140:921–48.
- 9 Berger M, Sarnyai Z. 'More than skin deep': Stress neurobiology and mental health consequences of racial discrimination. *Stress* 2015;18:1–10.
- 10 Pascoe EA, Smart Richman L. Perceived discrimination and health: A meta-analytic review. *Psychol Bull* 2009;135:531–54.
- 11 Clark R, Anderson NB, Clark VR, et al. Racism as a stressor for African Americans. A biopsychosocial model. Am Psychol 1999;54:805–16.
- 12 Lazarus S, Folkman S. Stress, appraisal and coping. New York: Springer, 1984.
- 13 Paradies Y. A systematic review of empirical research on selfreported racism and health. Int J Epidemiol 2006;35:888–901.
- 14 Chrousos GP. Stress and disorders of the stress system. Nat Rev Endocrinol 2009;5:374–81.
- 15 Schlotz W. Investigating associations between momentary stress and cortisol in daily life: What have we learned so far? *Psychoneuroendocrinology* 2019;105:105–16.
- 16 Nater UM, Rohleder N. Salivary alpha-amylase as a non-invasive biomarker for the sympathetic nervous system: Current state of research. *Psychoneuroendocrinology* 2009;34:486–96.
- 17 McEwen BS. Physiology and neurobiology of stress and adaptation: Central role of the brain. *Physiol Rev* 2007;87:873–904.
- 18 Nater UM, Rohleder N, Schlotz W, et al. Determinants of the diurnal course of salivary alpha-amylase. *Psychoneuroendocrinology* 2007;32:392–401.
- 19 Busse D, Yim IS, Campos B. Social context matters: Ethnicity, discrimination and stress reactivity. *Psychoneuroendocrinology* 2017;83:187–93.
- 20 Akdeniz C, Tost H, Streit F, et al. Neuroimaging evidence for a role of neural social stress processing in ethnic minority-associated environmental risk. JAMA Psychiatry 2014;71:672–80.

<u>d</u>

- 21 Goreis A, Nater UM, Mewes R. Psychological consequences of chronic ethnic discrimination in male Turkish immigrants living in Austria: A 30-day ambulatory assessment study. *Ann Behav Med* 2024;58:111–21.
- 22 Ong AD, Fuller-Rowell T, Burrow AL. Racial discrimination and the stress process. J Pers Soc Psychol 2009;96:1259–71.
- 23 Griffin EK, Armstead C. Black's coping responses to racial stress. J Racial Ethn Health Disparities 2020;7:609–18.
- 24 Brondolo E, Brady Ver Halen N, Pencille M, et al. Coping with racism: A selective review of the literature and a theoretical and methodological critique. J Behav Med 2009;32:64–88.
- 25 West LM, Donovan RA, Roemer L. Coping with racism: What works and doesn't work for Black women? *Journal of Black Psychology* 2010;36:331–49.
- 26 Bogart LM, Dale SK, Daffin GK, et al. Pilot intervention for discrimination-related coping among HIV-positive Black sexual minority men. Cultur Divers Ethnic Minor Psychol 2018;24:541–51.
- 27 Bonmatí-Tomas A, Malagón-Aguilera MC, Gelabert-Vilella S, et al. Salutogenic health promotion program for migrant women at risk of social exclusion. Int J Equity Health 2019;18:139.
- 28 Conway-Phillips R, Dagadu H, Motley D, et al. Qualitative evidence for Resilience, Stress, and Ethnicity (RiSE): A program to address race-based stress among Black women at risk for cardiovascular disease. Complement Ther Med 2020;48:102277.
- 29 Kalinowski J, Kaur K, Newsome-Garcia V, et al. Stress interventions and hypertension in Black women. Womens Health (Lond Engl) 2021;17:1–14.
- 30 Ko Y, Lee E-S, Park S. Effects of laughter therapy on the stress response of married immigrant women in South Korea: A randomized controlled trial. *Health Care Women Int* 2022;43:518–31.
- 31 Proulx J, Croff R, Hebert M, et al. Results of a mindfulness intervention feasibility study among elder African American women: A qualitative analysis. Complement Ther Med 2020;52:102455.
- 32 Saban KL, Motley D, Shawahin L, et al. Preliminary evidence for a race-based stress reduction intervention for Black women at risk for cardiovascular disease. Complement Ther Med 2021;58:102710.
- 33 Tran AN, Ornelas IJ, Perez G, et al. Evaluation of Amigas Latinas Motivando el Alma (ALMA): A pilot promotora intervention focused on stress and coping among immigrant Latinas. J Immigr Minor Health 2014;16:280–9.
- 34 Jones G, Castro-Ramirez F, McGuire T, et al. A digital music-based mindfulness intervention ('healing attempt') for race-based anxiety in Black Americans. J Med Internet Res 2023;25:e51320.
- 35 Heron KE, Smyth JM. Ecological momentary interventions: Incorporating mobile technology into psychosocial and health behaviour treatments. *Br J Health Psychol* 2010;15:1–39.
- 36 Shiffman S, Stone AA, Hufford MR. Écological momentary assessment. Annu Rev Clin Psychol 2008;4:1–32.
- 37 Garey L, Zvolensky MJ, Gallagher MW, et al. A smartphone-based intervention for anxiety and depression in racially and ethnically diverse adults (EASE): Protocol for a randomized controlled trial. *JMIR Res Protoc* 2022;11:e40713.
- 38 Heim E, Mewes R, Abi Ramia J, et al. Reporting cultural adaptation in psychological trials—The RECAPT criteria. *Clin Psychol Eur* 2021;3:e6351.
- 39 Ramos G, Aguilera A, Montoya A, et al. App-based mindfulness meditation for People of Color who experience race-related stress: Protocol for a randomized controlled trial. *JMIR Res Protoc* 2022;11:e35196.
- 40 Watson-Singleton NN, Pennefather J, Trusty T. Can a culturallyresponsive mobile health (mhealth) application reduce African Americans' stress?: A pilot feasibility study. *Curr Psychol* 2023;42:1434–43.
- 41 Mehr SA, Singh M, Knox D, et al. Universality and diversity in human song. Science 2019;366:eaax0868.
- 42 Krause A, North A, Hewitt L. Music selection behaviors in everyday listening. *Journal of Broadcasting & Electronic Media* 2014;58:306–23.
- 43 Fallon VT, Rubenstein S, Warfield R, et al. Stress reduction from a musical intervention. *Psychomusicology: Music, Mind, and Brain* 2020;30:20–7.
- 44 Gan SKE, Lim KMJ, Haw YX. The relaxation effects of stimulative and sedative music on mathematics anxiety: A perception to physiology model. *Psychol Music* 2016;44:730–41.
- 45 Groarke JM, Hogan MJ. Listening to self-chosen music regulates induced negative affect for both younger and older adults. *PLoS One* 2019;14:e0218017.
- 46 Jiang J, Zhou L, Rickson D, et al. The effects of sedative and stimulative music on stress reduction depend on music preference. Arts Psychother 2013;40:201–5.

- 47 Jiang J, Rickson D, Jiang C. The mechanism of music for reducing psychological stress: Music preference as a mediator. *Arts Psychother* 2016;48:62–8.
- 48 Sandstrom GM, Russo FA. Music hath charms: The effects of valence and arousal on recovery following an acute stressor. *Music Med* 2010;2:137–43.
- 49 Thoma MV, La Marca R, Brönnimann R, et al. The effect of music on the human stress response. *PLoS One* 2013;8:e70156.
- 50 Linnemann A, Wenzel M, Grammes J, et al. Music listening and stress in daily life—a matter of timing. Int J Behav Med 2018;25:223–30.
- 51 Wuttke-Linnemann A, Nater UM, Ehlert U, et al. Sex-specific effects of music listening on couples' stress in everyday life. Sci Rep 2019;9:4880.
- 52 Carissoli C, Villani D, Riva G. Does a meditation protocol supported by a mobile application help people reduce stress? Suggestions from a controlled pragmatic trial. *Cyberpsychol Behav Soc Netw* 2015;18:46–53.
- 53 Helsing M, Västfjäll D, Bjälkebring P, et al. An experimental field study of the effects of listening to self-selected music on emotions, stress, and cortisol levels. MMD 2016;8:187.
- 54 Innes KE, Selfe TK, Kandati S, *et al.* Effects of mantra meditation versus music listening on knee pain, function, and related outcomes in older adults with knee osteoarthritis: An exploratory randomized clinical trial (RCT). *Evid Based Complement Alternat Med* 2018;2018:7683897.
- 55 Kappert MB, Wuttke-Linnemann A, Schlotz W, et al. The aim justifies the means – Differences among musical and nonmusical means of relaxation or activation induction in daily life. *Front Hum Neurosci* 2019;13:36.
- 56 Feneberg AC, Nater UM. An ecological momentary music intervention for the reduction of acute stress in daily life: A mixed methods feasibility study. *Front Psychol* 2022;13:927705.
- 57 Thoma MV, Ryf S, Mohiyeddini C, *et al.* Emotion regulation through listening to music in everyday situations. *Cogn Emot* 2012;26:550–60.
- 58 Wuttke-Linnemann A, Feneberg AC, Nater UM. Music and health. In: Gellman M, ed. *Encyclopedia of behavioral medicine*. New York, NY: Springer, 2020: 1–5.
- 59 Koelsch S. Brain correlates of music-evoked emotions. *Nat Rev Neurosci* 2014;15:170–80.
- 60 Chanda ML, Levitin DJ. The neurochemistry of music. *Trends Cogn Sci* 2013;17:179–93.
- 61 Kreutz G, Quiroga Murcia C, Bongard S. Psychoneuroendocrine research on music and health: An overview. In: MacDonald R, Kreutz G, Mitchell L, eds. *Music, health, and wellbeing*. Oxford: Oxford University Press, 2012: 458–76.
- 62 Eurostat. Migration and migrant population statistics. 2019. Available: https://ec.europa.eu/eurostat/statistics-explained/index. php?title=Migration_and_migrant_population_statistics#Migration_ flows:_Immigration_to_the_EU-27_from_non-member_countries_ was_2.4_million_in_2018
- 63 Statistik Austria. Migration & Integration Zahlen Daten Indikatoren 2023. 2023. Available: https://www.statistik.at/fileadmin/user_upload/ MIG2023.pdf
- 64 Statistik Austria. Migration & Integration Zahlen Daten Indikatoren 2021. 2021. Available: https://www.statistik.at/fileadmin/publications/ Migration_und_Integration_2021.pdf
- 65 Mewes R, Asbrock F, Laskawi J. Perceived discrimination and impaired mental health in Turkish immigrants and their descendents in Germany. *Compr Psychiatry* 2015;62:42–50.
- 66 Sempértegui GA, Knipscheer JW, Baliatsas C, et al. Symptom manifestation and treatment effectiveness, -obstacles and -facilitators in Turkish and Moroccan groups with depression in European countries: A systematic review. J Affect Disord 2019;247:134–55.
- 67 Brownlow BN, Sosoo EE, Long RN, et al. Sex differences in the impact of racial discrimination on mental health among Black Americans. Curr Psychiatry Rep 2019;21:112.
- 68 Harnois CE. Are perceptions of discrimination unidimensional, oppositional, or intersectional? Examining the relationship among perceived racial–ethnic-, gender-, and age-based discrimination. *Sociol Perspect* 2014;57:470–87.
- 69 Seaton EK, Tyson K. The intersection of race and gender among Black American adolescents. *Child Dev* 2019;90:62–70.
- 70 Harnois CE, Bastos JL. Discrimination, harassment, and gendered health inequalities: Do perceptions of workplace mistreatment contribute to the gender gap in self-reported health? *J Health Soc Behav* 2018;59:283–99.

Open access

- 71 Vargas SM, Huey SJ, Miranda J. A critical review of current evidence on multiple types of discrimination and mental health. *Am J Orthopsychiatry* 2020;90:374–90.
- 72 Kudielka BM, Kirschbaum C. Sex differences in HPA axis responses to stress: A review. *Biol Psychol* 2005;69:113–32.
- 73 Strahler J, Skoluda N, Kappert MB, et al. Simultaneous measurement of salivary cortisol and alpha-amylase: Application and recommendations. *Neurosci Biobehav Rev* 2017;83:657–77.
- 74 Kumle L, Võ MLH, Draschkow D. Estimating power in (generalized) linear mixed models: An open introduction and tutorial in R. *Behav Res Methods* 2021;53:2528–43.
- 75 Williams DRYuYJackson JS, *et al.* Racial differences in physical and mental health: Socio-economic status, stress and discrimination. *J Health Psychol* 1997;2:335–51.
- 76 Michaels E, Thomas M, Reeves A, et al. Coding the Everyday Discrimination Scale: Implications for exposure assessment and associations with hypertension and depression among a cross section of mid-life African American women. J Epidemiol Community Health 2019;73:577–84.
- 77 Schmiedek F, Neubauer AB. Experiments in the wild: Introducing the within-person encouragement design. *Multivariate Behav Res* 2020;55:256–76.
- 78 Allen MS, Iliescu D, Greiff S. Single item measures in psychological science. *Eur J Psychol Assess* 2022;38:1–5.
- 79 Skoluda N, Dhrami I, Nater UM. Factors contributing to stability and instability in alpha-amylase activity in diluted saliva samples over time. *Psychoneuroendocrinology* 2020;121.
- 80 Bates D, Mächler M, Bolker B, et al. Fitting linear mixed-effects models using Ime4. J Stat Softw 2015;67:1–48.

- 81 Brooks ME, Kristensen K, van Benthem KJ, et al. glmmTMB balances speed and flexibility among packages for zero-inflated generalized linear mixed modeling. R J 2017;9:378–400.
- 82 Yaremych HE, Preacher KJ, Hedeker D. Centering categorical predictors in multilevel models: Best practices and interpretation. *Psychol Methods* 2021;28:613–30.
- 83 Enders CK, Tofighi D. Centering predictor variables in cross-sectional multilevel models: A new look at an old issue. *Psychol Methods* 2007;12:121–38.
- 84 de Witte M, Spruit A, van Hooren S, et al. Effects of music interventions on stress-related outcomes: A systematic review and two meta-analyses. *Health Psychol Rev* 2020;14:294–324.
- 85 International Federation of the Phonographic Industry (IFPI). Engaging with music 2023. 2023. Available: https://www.ifpi.org/ wp-content/uploads/2023/12/IFPI-Engaging-With-Music-2023_fullreport.pdf
- 86 Khalfa S, Bella SD, Roy M, et al. Effects of relaxing music on salivary cortisol level after psychological stress. Ann N Y Acad Sci 2003;999:374–6.
- 87 Maidhof RM, Kappert MB, Wuttke A, et al. Effects of participantselected versus researcher-selected music on stress and mood—The role of gender. *Psychoneuroendocrinology* 2023;158.
- 88 Erens B. Designing high-quality surveys of ethnic minority groups in the United Kingdom. In: FontJ, Méndez M, eds. Surveying ethnic minorities and immigrant populations. Amsterdam: Amsterdam University Press, 2013: 45–68.
- 89 Sulaiman-Hill CM, Thompson SC. Sampling challenges in a study examining refugee resettlement. *BMC Int Health Hum Rights* 2011;11:2.