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IL-10: A possible immunobiological component of positive mental health in refugees

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ABSTRACT

Objective: As the number of refugees continues to rise, there is growing concern about the impact from trauma exposures on their mental health. However, there is a limited understanding of possible biological mechanisms contributing to the substantial inter-individual differences in trauma-related outcomes, especially as it relates to positive mental health. Only sparse work has focused on the biology of positive mental health, including energy and sleep, in trauma-exposed persons. In this study, we analyzed cytokines in blood from newly arrived refugees with differential trauma exposures in relationship to self-reported energy, as a key marker of positive mental health.

Methods: Within the first month of arrival in the USA, 64 refugees from Iraq and Syria were interviewed. Refugees completed the clinical DSM-IV PTSD-Checklist Civilian Version (PCL-C), the Beck Anxiety Inventory (BAI), and the Hospital Anxiety and Depression Scale (HADS). Ten psychiatrically healthy non-refugee persons were used as healthy controls to compare levels of cytokines. Blood samples were collected at the time of the interview and subsequently analyzed for IL-1β, IL-6, IL-8, IL-10, and TNF-α concentrations.

Results: Energy correlated positively with current concentration ability and sleep quality, and negatively with stress, PCL-C, BAI and HADS scores (Spearman correlations, all $p<0.05$). Refugees had lower levels of IL-10 compared to controls ($p<0.05$). IL-10 levels in refugees correlated with higher energy levels ($p<0.01$).

Conclusions: Results suggest that self-reported energy is a key component of positive mental health in newly arrived traumatized refugees. Additionally, the anti-inflammatory cytokine IL-10 could be a marker of, or causally associated with positive mental health. A better understanding of the balance between pro- and anti-inflammatory states in highly traumatized individuals has the potential to create more targeted and effective treatments with implications for long-term health outcomes.

1. Introduction

A total of 135,647 refugees from Iraq and 455,825 refugees from Syria arrived in the United States of America (USA) between 2007 and 2016 [1]. Prior research on trauma exposed refugees, as well as soldiers returning from deployment, reveals immediate trauma-associated psychiatric sequalae [2,3]. Additionally, over time, a substantial proportion of trauma-exposed persons develop mental health disorders [4–6]. There is only limited understanding of what factors determine whether a person will eventually develop trauma-related mental health disorders or not. Moreover, there is a total lack of studies focusing on the biology of positive mental health, including in refugees [7–9]. One study reported a high prevalence of psychiatric disorders related to trauma and stress among Syrian refugees that were newly resettled in the USA [10]. Similarly, a study of over 350 newly arrived Iraqi refugees seeking

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List of acronyms

BAI	Beck Anxiety Inventor
BMI	Body Mass Index
CES-D	Center for Epidemiologic Studies Depression Scale
CNS	Central Nervous System
CV	Coefficients of Variation
df	Degrees of Freedom
DSM-IV	Diagnostic and Statistical Manual of Mental Health Disorders IV
HADS-14	Hospital Anxiety and Depression Scale
HAMD	Hamilton Depression Rating Scale
IL-1β	Interleukin-1β
IL-6	Interleukin 6
IL-8	Interleukin-8
IL-10	Interleukin-10
PHQ-9	Patient Health Questionnaire-9
PCL-C	PTSD-Checklist Civilian Version
PDC	Percentage of People in Diagnostic Category
PTE	Percentage of Total Enrolled
MSN	Musculoskeletal and Nervous System Disorders
n	Number
pg/mL	Picograms per Milliliter
PTSD	Post-Traumatic Stress Disorder
SC	Spearman's Correlation
SD	Standard Deviation
SEM	Standard Error Mean
t	T-value
TNF-α	Tumor Necrosis Factor-Alpha
USA	United States of America

asylum in the USA reported around 50% prevalence of emotional distress, anxiety and depression [11]. Thus, there is a need to develop more sensitive screening instruments along with biological markers of vulnerability to identify subjects at increased risk for later development of trauma-related mental health disorders. The at-risk subjects could potentially undergo preventive treatment [12], as well as continued monitoring. Such screening needs to encompass evaluation of not only mental health but inflammatory marker assessments reflective of healthy and pathophysiological states associated with trauma exposure.

There is a dearth of studies where the biology of positive mental health involved in sustaining psychiatric health has been investigated in traumatized subjects, such as refugees. One study by our groups in this area used self-reported mental health in victims that had been kidnapped and had not developed PTSD compared with those who did. Resilience, as determined by an 8-item version of The Resilience Scale [13], were significantly higher in those that had not developed PTSD. This scale includes assessments of belief in one's self and not dwelling on things that are uncontrollable [13]. However, the biological mechanisms involved in resilience and positive mental health phenomena are largely understudied regardless of the population.

Positive mental health allows people to realize their full potential, cope with the stressors of life, work productively, and make meaningful contributions to their communities [14]. Positive mental health is a key component of resilience. Resilience is characterized by the dynamic resistance to distress and disturbance from traumatic and stressful life events or the adaptation to a new "normal" despite drastic changes in ones' environment [15–18]. While relatively little is known about physiological contributors to resilience [19], it is hypothesized that a central psychological contributor is energy (i.e., less fatigue). Gooding et al. (2012) analyzed measures of depression, hopelessness, general health and resilience in 120 people and found that low energy levels predicted decreased resilience regardless of the age of the participants [20]. Energy levels could be a contributor to resilience or an element of resilience and this needs to be evaluated in further studies. There remains a deficit in knowledge of what biological mechanisms contribute to positive mental health, psychological resilience and increased energy levels.

While there is a lack of published studies on energy levels in trauma-exposed refugees, decreased energy levels have been associated with adverse outcomes. Low energy levels are a hallmark of depression [21] and is a major cause of disability worldwide [22] with profound impact on society. Additionally, low energy levels are associated with anxiety, decreased sleep, and other psychiatric disorders that effect all people and refugees are especially vulnerable to these disorders [23,24].

In this study we determined pro- and anti-inflammatory cytokine levels in refugees that had a significant history of prior trauma exposure due to sustained war activities in the Middle East. The refugees were evaluated by a structured clinical psychiatric examination, accompanied by collection of blood, to better understand the biological correlates to mental health outcomes in this understudied but vulnerable population. We hypothesized that higher levels of the anti-inflammatory protein IL-10 in peripheral blood would be associated with higher perceived energy as well as better mental health outcomes for this vulnerable population. IL-10 is an anti-inflammatory cytokine that helps maintain tissue homeostasis and regulate inflammatory T-helper cells, which in uncontrolled inflammatory responses have been associated with cytokine storms able to cause pathologic conditions in both the central nervous system and periphery [25,26]. IL-10 has been shown to be protective in irritable bowel syndrome which is associated with other psychological disorders such as stress, anxiety and depression [27], as well as acting as a protectant in the CNS against damage to neurites and cortical neurons after injury [28]. We not only studied refugees with significant and sustained trauma exposures but also explored the refugees' IL-10 levels to those found in a non-psychiatric non-traumatized group in the USA to get a better understanding of the possible biological impact on IL-10 from trauma exposures.

2. Methods

2.1. Study design

This study was approved by Wayne State University, Michigan State University, and Van Andel Institute's Institutional Review Boards. The study took place between 2015 and 2016. The staff of the resettlement agency, that handled the orientation session for refugees that had arrived within the last month, informed refugees about the research study that took place in the Detroit metropolitan area. Those interested in learning more were asked to leave their name and contact information and were subsequently contacted by the research staff. At that time, refugees received additional information about the study. Inclusion criteria included being over 21 years of age, holding official refugee status in the USA and having been displaced from either Iraq or Syria. Those that met inclusion criteria and were still interested were invited to meet with the research team. Following the review of written and oral information about the study and opportunity to ask questions, the consent process was completed. The final study sample consisted of 40 refugees from Syria and 24 from Iraq. They were interviewed in Arabic using a structured previously validated survey, by a dual Arabic-English speaking and specially-trained research assistant with a bachelor's degree in psychology. Immediately following the completion of the interview, blood samples were drawn on-site by an accredited phlebotomist. Detailed demographic and somatic comorbidity information for both the refugee and control groups can be found on Table 1. This refugee population was part of a larger study focusing on mental health

Table 1
Characteristics of study participants.

	Refugees (n = 64)	Controls (n = 10)
Demographics		
Age; Mean (+/−2SEM)	37.6 (2.9)	38.3 (7.7)
Gender; N (%)		
Females	46 (71.9)	6 (60.0)
Males	18 (28.1)	4 (40.0)
BMI; Mean ((+/−2SEM)	27.8 (1.5)	32.1 (6.3)
Somatic conditions		
Allergy/Asthma; N (%)	1 (1.6)	1 (10.0)
Cardiovascular; N (%)	6 (9.4)	2 (20.0)
Endocrine; N (%)	4 (6.3)	2 (20.0)
MSN; N (%)	0 (0.0)	3 (30.0)

±2 SEM, Standard error mean; BMI, Body mass index; MSN, Musculoskeletal and nervous system disorders; note for BMI n=60 as 4 refugees did not answer this question.

in forcibly displaced refugees (NIH R01 MH085793, PI Bengt Arnetz).

2.2. Assessment of psychiatric symptoms in refugees

The refugee sample consisted of persons from Iraq and Syria that had been forcibly displaced to the USA all having been defined by the USA as having refugee status. The amount of trauma exposure in their original homeland varied. The Arabic version of the Harvard Trauma Questionnaire was used to assess pre-displacement trauma exposure [29–31]. The Arabic version has been validated with an α of 0.97. The summary score ranged from a low 0 to a maximum trauma score of 39. In the current study the mean trauma exposure score was 12.09 (SD 6.02). For detailed information regarding mental health status of the refugee population, please see Ref. [30].

A survey on self-reported general health, demographics, and diagnosis was performed as well as specific diagnostic exams translated in Arabic. The original survey in English was translated by a certified, dual-speaking translator into Arabic. Another dual-speaking translator back-translated the survey into English. Subsequently, a dual Arabic-English speaking specially trained research assistant with a bachelor's degree in psychology previously mentioned, asked questions to participants in Arabic, and recorded the responses in the English version survey. Specifically, Structured Interview for the Diagnostic and Statistical Manual of Mental Health Disorders-IV (SCID) was performed for arrival assessment of mental health status. Post-traumatic stress disorder (PTSD) was measured by the PTSD-Checklist Civilian Version (PCL-C). Anxiety was measured with the Beck Anxiety Inventory (BAI). While both SCID and PCL-C versions are dated editions that have been updated, this study was conducted during that time period and we were fortunate enough to receive additional funding to look at inflammatory markers and needed to keep the same scales as the original study to allow for comparison. The mental health status of the refugee population at the time the current study had taken place is described in detail in Arnetz et al. [30]. Based on PTSD scale scores above 35, 27 out of a total of 64 refugees were likely to suffer from PTSD. Depression in the refugee population was measured with the Hospital Anxiety and Depression Scale (HADS-14, HADS). The mean score on the depression subscale was 6.31 (SEM +/- 4.35). The mean score on the Anxiety subscale was 13.02 (SEM +/- 11.3). Overall self-ratings of current health state (such as sleep, energy level, and concentration ability) were performed to determine both psychiatric symptoms and perceived positive mental health to the process of being a refugee since both outcomes are of relevance to assess an individual's ability to function and the impact on function from mental distress. The validated survey of self-rated questions included "How is your energy level right now?", "How is your stress level right now?" (stress rating), "How is your concentration right now?" and "How do you currently sleep?". Responses by participants were provided on a visual analogue scale by marking an "x" on the scale ranging from 0 (very low) to 100 (very high). We have previously validated these self-reported mental health surveys against the "gold standard" [32] and in refugees [33–35] as well as professions that experience high levels of stress [36–39]. Energy levels were only measured in the refugee cohort, and therefore could not be compared to the external healthy controls.

2.3. External controls

The levels of cytokines in the refugees were compared with those in a group of external healthy controls, initially recruited to a cross-sectional study to assess inflammatory markers in peripheral blood and its association to mood disorders, approved by Mercy Health Institutional Review Board, and previously published by the group [40,41]. External controls and refugees blood sampling procedure were performed the same (as described below). Blinded to cytokine data, we selected 10 subjects in that group that did not have any indication of current psychiatric disorders or symptoms. This was validated by SCID interviews as well as several assessment scales including: the Patient Health Questionnaire-9 [42], Hamilton Depression Rating Scale [43], and the Center for Epidemiologic Studies Depression Scale [44]. The blood samples from external controls were collected between July 9, 2012 and March 29, 2013, and frozen at −80 °C upon collection. Samples were subsequently thawed and represented the control in comparing inflammatory marker levels between controls and refugees. Demographic and somatic health information can be found on Table 1.

2.4. Blood sampling

Blood was drawn immediately after the interviews to mitigate the possible impact blood draw could have on a participant's self-reported mental health ratings. Samples were placed on ice and immediately transported to the laboratory where blood was centrifuged at 4 °C, plasma separated into aliquots, and frozen at −80 °C until later assessment.

2.5. Analysis of inflammatory factors

Pro- and anti-inflammatory cytokines were analyzed using plasma on the ultrasensitive electrochemiluminescent technology of the Meso Scale Discovery platform according to the manufacturer's protocol (MESO SCALE DIAGNOSTICS, LLC, Rockville, Maryland). Specifically, interleukin-1β (IL-1β), interleukin-6 (IL-6), interleukin-8 (IL-8), interleukin-10 (IL-10), and tumor necrosis factor-α (TNF-α) were analyzed using the Pro-inflammatory I multiplex panel on a Sector 6000 imager. The inter-assay coefficients of variation (% CV) for the cytokines are as follows: IL-1β (5.65%), IL-6 (5.13%), IL-8 (4.27%), IL-10 (4.34%) and TNF-α (4.19%). The lower detection limits of the cytokines are as follows: IL-1β (0.02 pg/mL), IL-6 (0.10 pg/mL), IL-8 (0.04 pg/mL), IL-10 (0.04 pg/mL) and TNF-α (0.24 pg/mL). Cytokines that were below the lower detection limits were recorded as 0 and included in the statistical analysis.

2.6. Statistical analysis

All statistical analyses were performed using IBM SPSS version 27, 2021 (International Business Machines Corporation, Armonk, New York, United States). The inflammatory variables IL-1β, IL-6, and IL-8 were not normally distributed and log transformed. Bivariate analyses were used to assess for correlations between self-rated measures and biological markers. Scattergram visualization was chosen since the small number of participants allowed for individual values to be displayed. Spearman's Rho was used for non-parametrical data whereas Pearson's R was used for parametrical data. When comparing inflammatory biomarkers between refugees and controls, we also used univariate least square regressions, controlling for sex, age, and BMI. However, since none of the co-variates was significant, and including co-variates did not

change findings in terms of differences in inflammatory biomarkers across the two study groups, we only reported findings based on Independent samples t-tests.

3. Results

3.1. Patient characteristics

Patient demographics and somatic morbidities are listed in Table 1. As there were no significant differences between the groups, covariates were not controlled in the linear analysis models. Furthermore, there was no significant correlation between any of the studied inflammatory markers and body mass index (BMI). As there were no significant differences between the groups, covariates were not controlled in the linear analysis models.

3.2. Energy levels and positive mental health in refugees

Energy levels correlated positively with plasma IL-10 concentrations (Spearman's correlation (SC), rho=0.27, p=0.040), concentration ability (SC, rho=0.43, p<0.001), and sleep quality (SC, rho=0.46, p<0.001). Moreover, energy levels correlated negatively with stress scores (SC, rho=−0.44, p<0.001), PCL-C sum (SC, rho=−0.35, p=0.005), anxiety score (BAI sum (SC, rho=−0.39, p=0.001)), and HADS sum (SC, rho=−0.47, p<0.001). Summary of Spearman's correlation results can be found on Table 2 below and Fig. 2. Explanation of the validated survey of self-rated questions can be found in section 2.2 Assessment of psychiatric symptoms in refugees.

3.3. Cytokine levels in plasma

We used Independent Samples t-tests to assess whether refugee status was associated with altered cytokine levels. IL-10 levels were significantly lower in refugees compared to controls (Independent t-test, t=2.61, p=0.011) (Fig. 1A). Furthermore, IL-10 levels correlated positively with energy level in refugees (Pearson Correlation, r=0.383, p = 0.003) (Fig. 1B). There were no other cytokines that were significantly associated with refugee status or energy level. Mean cytokine levels in plasma can be seen in Table 3.

4. Discussion

Results reveal that in newly arrived Middle Eastern refugees in the USA, self-reported energy levels were positively associated with levels of the anti-inflammatory cytokine IL-10, as well as with concentration and sleep quality, and negatively with stress ratings. All of these self-rated measures have been previously validated [38,45]. Moreover, levels of self-rated energy correlated inversely with the sum scores of: PTSD (PCL-C), anxiety (BAI) and depression (HADS). Additionally, refugees displayed significantly lower blood levels of the anti-inflammatory cytokine IL-10 compared to healthy external non-refugee controls, without known psychiatrically significant mental health symptoms. These novel observations suggest the possible role of immunobiological processes to positive mental health in traumatized individuals.

The observed correlations between energy levels and several clinical assessment scales, within the refugee population, are of potentially clinical importance since it may reflect the underlying phenotypic/symptomatic components of positive mental health. As such, we detected significant positive correlations between energy level and scores on scales assessing ability to concentrate score and sleep quality. Energy levels also correlated positively with blood levels of IL-10. In contrast, and in support of the health-promoting effects of IL-10, there were inverse associations between energy and the stress-, PTSD-, anxiety- and depression-scales. Decreased energy level in the form of fatigue is known to be associated with multiple psychiatric disorders including PTSD, anxiety, and depression [46–48]. However, fatigue is usually linked to increased pro-inflammatory cytokines [49], which we did not observe here. Therefore, this suggests that the phenomena of fatigue and the perception of a high self-assessed energy level may not be the opposite of a continuous fatigue to energy spectrum. Instead, these two phenomena may be governed by different biological mechanisms. We have previously reported the association between decreased energy level and decreased sleep quality and ability to concentrate [50]. The relationship between IL-10, fatigue, perceived energy, trauma, positive mental health and resilience is likely complex, and should be studied further to evaluate cause and effect and elements of each mental state. Similarly, it's not clear whether energy levels are a contributor to resilience, as suggested in the Introduction, or an element of resilience, as suggested in the Method section. It could be a combination of both. Energy, and related components studied here, e.g., sleep and concentration, might play a significant role in building personal resilience [51,52]. A person high in energy would be able to better concentrate on addressing a stressor. Furthermore, higher sleep quality is known to be an important resilience booster [53], and vice versa [54].

To our knowledge, the association between pro- and anti-inflammatory markers and positive mental health have not previously been studied, at least not in refugee populations. Our results give rise to the question of what biological differences exist between individuals who score higher on positive mental health and therefore are more likely to be resilient to trauma compared to those with increased vulnerability. These questions warrant further rigorous studies. We purport that rather than solely focusing on the pro-inflammatory pathways, increased attention should be directed towards anti-inflammatory processes. Specifically, our data suggest that the critical anti-inflammatory cytokine IL-10 might play a role in fostering biological well-being or resilience, as IL-10 was lower in the refugee population compared to healthy external controls, while positively correlating with energy levels.

IL-10 is an anti-inflammatory cytokine produced by almost all types of innate and adaptive immune cells [55], primarily by monocytes. Its roles include suppressing pro-inflammatory cytokine secretion, antigen presentation, and T cell activation [27,56,57]. IL-10 is not only well represented throughout the periphery but in the central nervous system (CNS) itself [58], and has been utilized as a neuroprotective agent in experimental models because of its potent anti-inflammatory properties with promising results [59,60]. Studies suggest PTSD is associated with neuronal loss [61–63]. Thus, an underlying mechanism for how IL-10 contributes to positive mental health and energy might involve neuroprotection. There is a small number of studies that indicate IL-10 might

Table 2
Bivariate correlations between self-rated measures and biological marker Interleukin-10 (n = 64).

	1	2	3	4	5	6	7
1. Energy	–						
2. Concentration	0.39**	–					
3. Sleep quality	0.43***	0.48***	–				
4. Trauma exposure	−0.13	0.04	−0.17	–			
5. PTSD	−0.27*	−0.30*	−0.49***	0.48***	–		
6. Depression	−0.36**	−0.19	−0.42**	0.50***	0.64***	–	
7. Interleukin-10	**0.35****	0.13	0.09	−0.05	0.05	−0.12	–

*p<.05, **p<.01, ***p<.001; PTSD, Post traumatic stress disorder.

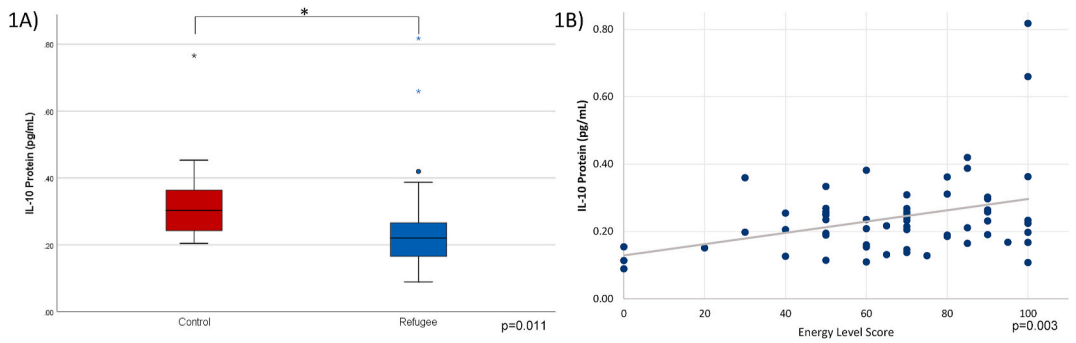

Fig. 1. 1A) Boxplot illustrating IL-10 protein was significantly higher in controls (n=10) compared to refugees (n=64). (Independent t-test, t=2.61, p=0.011), 1B) IL-10 correlated with energy levels in the refugee population only (n=64). (Pearson Correlation, r=0.383, p = 0.003).

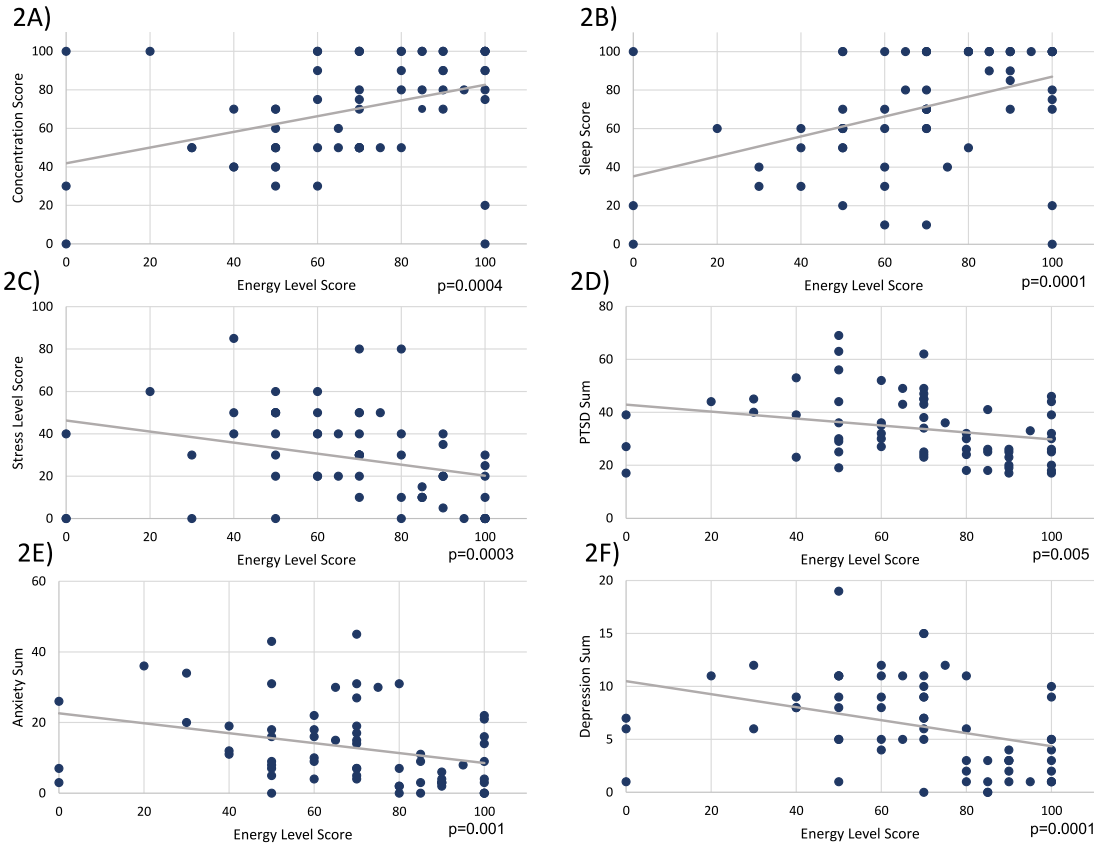

Fig. 2. Among refugees (n=64): 2A) Correlation between Concentration scores (self-rated from 1 to 100) and Energy scores (self-rated from 1 to 100) (Spearman's Correlation (SC), rho=0.43, p=0.0004), 2B) Correlation between Sleep scores (self-rated from 1 to 100) and Energy scores (self-rated from 1 to 100) (SC, rho=0.46, p=0.0001), 2C) Correlation between Stress scores (self-rated from 1 to 100) and Energy scores (self-rated from 1 to 100) (SC, rho=−0.44, p=0.0003), 2D) Correlation between PTSD sum scores (PTSD Checklist – Civilian Version, 17-item, highest score 85) and Energy scores (self-rated from 1 to 100) (SC, rho=−0.35, p=0.005), 2E) Correlation between Anxiety sum scores (Beck Anxiety Inventory, 21-item, highest score 63) and Energy scores (self-rated from 1 to 100) (SC, rho=−0.39, p=0.001), 2F) Correlation between Depression sum (Hospital Anxiety and Depression Scale, 14-item, highest score 21) and Energy scores (self-rated from 1 to 100) (SC, rho=−0.47, p=0.0001).

indeed be involved in trauma-related resilience mechanisms. In a study on urban violence and PTSD, the group that did not develop PTSD had higher levels of anti-inflammatory IL-10 in serum than those that developed PTSD. Importantly and in support of our thesis, the need to study anti-inflammatory pathways, is the findings that levels of the pro-inflammatory IL-6 did not differ between the two groups [64]. Additionally, if IL-10 is involved in biological resilience processes, one would not expect activation of the pro-inflammatory systems. Alternatively, IL-10 could be an early predictive marker prior to trauma-induced activation of inflammatory processes. Clearly, we lack critical data, especially from rigorously controlled studies. However, the present study suggests a need for such studies in the future.

It has been shown that low energy levels can reduce productivity [65] and deplete motivation which contributes to depression and marginalization [66]. This can have profound societal impacts. Not only would a better understanding of physiological changes occurring in newly arrived refugees help with identifying the best strategies to assist them but pairing this with policy changes would increase refugees' chances of succeeding in their host countries.

This study has both strengths and limitations. Its strengths include

Table 3
Biological markers in refugee and control groups.

	Refugees (n = 60)	Controls (n = 10)
	Mean (SEM)	Mean (SEM)
IL-1β (pg/mL)	0.11 (0.02)	0.07 (0.01)
IL-6 (pg/mL)	1.24 (0.38)	1.01 (0.23)
IL-8 (pg/mL)	3.92 (0.32)	4.96 (0.83)
IL-10 (pg/mL)	**0.24 (0.02)**	**0.34 (0.05)** *
TNF-α (pg/mL)	2.28 (0.11)	2.21 (0.21)

*p<.05; SEM, Standard Error of the Mean; Statistically significant differences from Independent Samples t-tests indicated in bold based on models adjusting for age and gender. 4 refugee samples were insufficient for testing, note n=60.

conducting this novel study in an underrepresented population of recently displaced refugees to the USA. Most prior work enrolled refugees that had already been residing in their new host country for a substantial amount of time making it difficult to isolate mental health effects from pre- and post-displacement (immigration) trauma. A limitation is this is only a cross-sectional snapshot of the refugee's journey and more longitudinal studies are warranted. Additionally, since we did not have the possibility to recruit a healthy population from the Middle East to constitute the control sample, and the control sample we had access to was a small group, there is a potential mismatch between the refugees and the controls selected for in this study. Despite the limitations of adding a relatively small reference group, there was added value as a reference group, to analyze how the levels are in relation to a non-refugee cohort. The control group's life history is unknown and people in this group may have had a history of trauma including forced migration unbeknownst to us. However, the possible impact of past traumas is likely limited since this analysis is about current distress and not past traumas that either group has experienced. There is a need to further elucidate the possible temporal impact from previous traumatic events on the distress response in refugees. However, that is beyond the scope of the present study. In addition, energy levels were not measured in the control group, limiting our ability to compare its associations to IL-10 in the controls. However, our findings that IL-10 was positively associated with energy levels in the refugee cohort specifically, supports the notion that IL-10 could be involved in positive mental health even in the absence of a control group. Importantly, the inclusion of the external controls allows some ideas as to the absolute levels of cytokines in trauma exposed refugees verse a USA control reference group. Future studies need to reproduce these findings in a larger group and look at possible differences across subtypes (e.g. history of depression, age, sex, etc.) and look at further immunobiological mechanisms such as pro-inflammatory C-reactive protein in greater detail. This is a promising starting point for moving forward in research on the immunobiological mechanisms underlying positive mental health in the face of trauma. Further studies should address the regulation of anti-inflammatory cytokines, as they are potentially associated with increased energy levels, positive mental health, resilience and improved symptomatology in mental disorders.

In this study, we found that energy levels, which are a key component of positive mental health, were positively associated with current concentration ability and sleep quality, and negatively with scoring on stress rating, PCL-C sum, BAI sum, and HADS sum. Additionally, in refugees, levels of cytokine IL-10 were positively associated with energy and positive mental health. Compared to psychiatrically healthy external non-refugee controls, the traumatized refugees had lower levels of IL-10. Hence, both perceived energy level and IL-10 may be important in the assessment of traumatized refugee's mental health and their overall positive mental state. These results warrant further analysis into the relationship between IL-10, positive mental health, resiliency, and trauma.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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