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Postnatal depressive symptoms display marked similarities across continents

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Abstract

Background

Postnatal depressive symptoms measured by the Edinburgh Postnatal Depression Scale (EPDS) are reported to display measurement variance regarding factor structure and the frequency of specific depressive symptoms. However, postnatal depressive symptoms measured by EPDS have not been compared between women representing three continents.

Methods

A cross-sectional study including birth cohort samples from Denmark, Vietnam and Tanzania. Women were included during pregnancy at routine care sites. Depressive symptoms were self-reported 40-90 days postpartum using the EPDS. Exploratory and confirmatory factor analyses and generalized additive regression models were performed.

Results

A total of N=4,516 participated in the study (Denmark N=2,069, Vietnam N=1,278, Tanzania N=1,169). Factor analyses identified three factors (anhedonia, anxiety and depression) that were almost identical in the three study populations. The only variation between countries was that the item 'self-harm' loaded differently. Women from Tanzania and Denmark were more likely to have an EPDS total score above cut-off 12 (12.6% and 6.4%), compared to women from Vietnam (1.9%) ($p<0.001$). A low level of education was associated with significantly more depressive symptoms after adjusting for country ($p<0.001$).

Limitations

EPDS data was collected at a later time point in the Danish sample.

Conclusions

Postnatal depressive symptoms constitute a three-factor model across cultures including the factors anhedonia, anxiety and depression. The frequency of postnatal depressive symptoms differs between high-, medium-, and low-income countries. However, clinicians should bear in mind that low-educated women worldwide are more likely to experience postnatal depressive symptoms.

Introduction

Depression is the leading cause of disability worldwide and more than 80% of the global disease burden of depression affects people from low- and middle- income countries (World Health Organization, 2017). The lifetime prevalence of depression for women is 20%, approximately twice the lifetime prevalence for men (Kessler et al., 1994; Kuehner, 2017). The risk for female depression increases additionally in the perinatal period (Gavin et al., 2005; Munk-Olsen et al., 2006; Stevens et al., 2019) and postpartum depression affects one in ten new mothers (Howard et al., 2014). Depressed mothers are more likely to be irritable, hostile and disengaged when interacting with their offspring (Field, 2010; Lovejoy et al., 2000), which impairs cognitive skills of the child (Liu et al., 2017). Furthermore, maternal depression has severe effects on offspring emotional development (Liu et al., 2017; Murray et al., 1999) and it is associated with offspring growth deficits (Holm-Larsen et al., 2018; Surkan et al., 2011). Therefore, perinatal screening for depression is recommended in some countries (Accortt and Wong, 2017; Committee on Obstetric Practice, 2015; Meltzer-Brody, 2011).

The Edinburgh Postnatal Depression Scale (EPDS) is a commonly used self-report questionnaire (Cox et al., 1987) developed to screen for postpartum depressive symptoms (Gibson et al., 2009). The construct validity of EPDS has been documented in many countries and in clinical as well as population-based samples (Berle et al., 2003; Glaze and Cox, 1991; Murray and Carothers, 1990; Rubertsson et al., 2011; Small et al., 2007; Vivilaki et al., 2009; Wickberg and Hwang, 1996; Zubaran et al., 2010). The EPDS was originally believed to measure one single construct (or factor) of postnatal depression (Cox et al., 1987). However, it has been questioned, whether a unidimensional model constitutes the best fitting model for EPDS (Cunningham et al., 2015; Kozinszky and Dudas, 2015). Most studies examining the psychometric properties of EPDS identify two factors (Matthey, 2008; Mazhari and Nakhaee, 2007; Phillips et al., 2009) or three factors (Brouwers et al., 2001; King, 2012; Reichenheim et al., 2011; Ross et al., 2003; Small et al., 2007; Tuohy and McVey, 2008), and only one study supports a one-factor model (Berle et al., 2003). Usually, the two primary factors are characterized by depressive and anxiety symptoms, and when a third factor is identified, it adds either anhedonia or suicidality symptoms to the construct (Cunningham et al., 2015). The specific items included in each factor, and the weighing of the factors, varies across studies (Cunningham et al., 2015; Kozinszky et al., 2017).

The reported variation in EPDS dimensions suggests a lack of measurement equivalence (also called measurement invariance). Measurement equivalence exists when an instrument measures the same construct across various groups (Putnick and Bornstein, 2016). Although postnatal depression is a worldwide phenomenon (Norhayati et al., 2015), some studies report that the dimensions of EPDS differ between ethnic groups (Chiu et al., 2017) or across continents (Di Florio et al., 2017). However, the latter study showed EPDS measurement equivalence across ethnicity (Di Florio et al., 2017) and an Australian study found a pronounced consistency across samples that differed on language and cultural backgrounds (Small et al., 2007). A study also examined measurement variance across levels of education and found that the reporting of specific items varied significantly according to education level (Di Florio et al., 2017).

In summary, the literature indicates that the factor structure of EPDS is multidimensional and the majority of existing research finds measurement variance. However, we do not know whether the reported measurement variance of postnatal depressive symptoms is due to ethnic, cultural or educational differences or due to methodological issues like comparison of non-comparable samples. We aim to address this research question in a study of comparable samples of postnatal women from three countries (Denmark, Vietnam and Tanzania) that differ markedly regarding ethnicity and culture.

The aim of our study was to examine and compare the factor structure of postnatal depressive symptoms measured by EPDS in postpartum women from Denmark, Vietnam and Tanzania. Furthermore, we specifically wanted to test the fit of the EPDS 3-factor structure identified in a study by Chiu et al. to our data (Chiu et al., 2017). We also examined if country of origin or education level predicted high total EPDS score. Finally, we investigated whether there were differences in expression (frequency and severity) of specific depressive symptoms based on country of origin or education level.

Method

Study design

This was a cross-sectional study design. Data was collected from three population-based cohort studies in Denmark, Vietnam and Tanzania, - countries that are characterized by high, medium and low-income status, respectively. All three study populations were recruited from routine care sites as part of the standard health care offer in the respective countries.

Study population

The study population consisted of women who were part of one of the three pregnancy cohorts listed below. Inclusion criterion was completion of the EPDS questionnaire. Exclusion criteria were multiple pregnancies, still birth or child death before completion of the EPDS questionnaire.

Cohort 1 (Denmark)

The Danish cohort consisted of study participants from the Odense Child Cohort (OCC). OCC is a prospective birth cohort study with the overall aim to provide knowledge of risk factors for lifestyle diseases (Kyhl et al., 2015). The study was located in the Municipality of Odense in the Region of Southern Denmark, where the citizens have a social distribution similar to the total Danish population (Kyhl et al., 2015). A total of 4.8% of study participants were of non-Western origin. The OCC inclusion period was January 1st 2010 – December 31st 2012, and women were included from early pregnancy and up until 2.5 months postpartum. Recruitment took place at routine midwife, general practitioner or ultrasound examinations. Information about maternal age, parity, multiple pregnancies, live birth, education and postnatal depressive symptoms (measured by EPDS) was collected. EPDS data was collected three months postpartum using either paper or online questionnaires.

Cohort 2 (Vietnam) and 3 (Tanzania)

The Vietnamese and Tanzanian study populations originated from a larger research project: ‘The Impact of Violence on Reproductive Health in Tanzania and Vietnam’ (PAVE) (Manongi et al., 2017; Nhi et al., 2018; Rogathi et al., 2017; Sigalla et al., 2017; Tho Tran et al., 2018). The overall aim of PAVE was to examine the association between intimate partner violence and adverse pregnancy outcomes including postnatal depressive symptoms. PAVE was carried out simultaneously in Vietnam and Tanzania in the study period March 1st 2014 - December 31st 2015. Study participants were recruited from Dong Anh Hospital and Bac Thang Long Hospital in Dong Anh District (Vietnam) and Majengo Health Centre and Pasua Health Centre in Moshi District

(Tanzania), respectively. Less than five women from the Tanzania sample had not been raised in Tanzania. All Vietnamese women were born and raised in Vietnam.

Study participants were included from early pregnancy and up until gestational age 24 weeks in Vietnam and 30 weeks in Tanzania. Recruitment took place in relation to antenatal care visits at the health care facilities. Information about maternal age, parity, multiple pregnancies, live birth, education and postnatal depressive symptoms was collected. EPDS data was collected at face to face interviews 40 days postpartum.

Measures

Maternal postpartum depressive symptoms were measured using the EPDS (Cox et al., 1987) in all three study populations. The EPDS is a 10 item self-report questionnaire rated on a 4-point Likert scale. Each item is scored according to frequency/severity from 0 ('No, not at all'/'No, never') to 3 ('Yes, all the time'/'Yes, most of the time') providing a total score range of 0-30. An EPDS cut-off score above 12 is often used to identify women at risk for postnatal depression (Cox et al., 1987; Murray and Carothers, 1990).

The Danish version of EPDS has previously been used in a large Danish sample (Nielsen Forman et al., 2000), and the EPDS has been validated in other Nordic countries with similar cultures (Berle et al., 2003; Rubertsson et al., 2011). The Vietnamese version of the EPDS has been validated for women (Tran et al., 2011). The Tanzanian version of the EPDS was translated from English to Swahili by a native speaker, back-translated by a linguistic native speaker and then pilot-tested for the PAVE Study (Rogathi et al., 2017). Ten interviews were conducted to assess the quality of the translation and determine whether local women found the questions meaningful. Based on feedback from the interviewed women, a revised translation was developed and tested in another round of ten interviews, before being accepted as the final version used in the PAVE study.

Data analyses

The following covariates were included in the analyses due to their potential relation to postnatal depression: maternal age, parity, education level. Education was divided into three groups based on the distribution in each country to reflect the relative level of education. Low education level (1) was defined as: 'never attended school' or primary school in Tanzania, 'never attended school', primary or secondary school in Vietnam, and 'high school or less' in Denmark. Intermediate education level (2) was defined as: secondary school in Tanzania, high school in Vietnam, and high

school +1-3 years of education in Denmark. High education level (3) was defined as: ‘above secondary school’ in Tanzania, university/college in Vietnam, and high school + ≥ 4 years of education in Denmark. Since education levels are not constant but likely to vary by country, the absolute length of education in years was also used to validate analyses.

There is no consensus regarding the factorial structure of the EPDS scale. We therefore used exploratory factor analyses (EFA) and confirmatory factor analyses (CFA) to examine the factor structure of EPDS in each population and to investigate whether the structure differed between populations. CFA was carried out using one-, two-, and three-factor models. Three-factor models identified in the study by Chui and colleagues were also tested in the CFA (Chiu et al., 2017). Goodness-of-fit was examined in all models using root mean square error of approximation (RMSEA), Comparative Fit Index (CFI) and Tucker Lewis Index (TLI). For RMSEA, well-fitting models have a value < 0.08 (Hooper et al., 2008). For CFI and TLI, values ≥ 0.95 are preferred but values > 0.90 are considered acceptable (Hooper et al., 2008). Furthermore, R-squared values were determined for the observed variables of each model and modification indices and expected parameter changes were calculated. Post hoc, a multigroup CFA analysis was used to assess EPDS measurement invariance across countries.

A generalized additive regression model was used to test if the total EPDS score differed between the three populations and if it was affected by education level, maternal age or the number of preceding pregnancies.

Finally, we stratified scores on each EPDS item by education level. Pairwise comparisons (Dunn’s tests) were carried out for each item to compare single item scores between populations as well as education levels.

All analyses were performed in R 3.5.1 using the packages *gamlss* 5.1-0 for additive models, *lavaan* 0.6-2 for confirmatory factor analysis and *psych* 1.8.4 for exploratory factor analysis. Exploratory factor analysis was conducted using oblimin oblique rotation and the minimum residual factoring method. Confirmatory factory analysis was conducted using robust diagonally weighted least squares estimation.

Ethics statement

The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional guides on the care and use of laboratory animals.

The Danish study was carried out in accordance with the Helsinki Declaration II and was approved

by the Regional Scientific Ethics Committee, Southern Denmark (No. 20090130) and the Danish Data Protection Agency (No. 18/26657). The Tanzanian study received ethical approval from the Research Ethics Review Committee of Kilimanjaro Christian Medical University College (No. 592) and the Kilimanjaro Christian Medical University College Research and Ethical Review Committee (No. 664). The Vietnamese study proposal was approved by the Ethical Committee of Hanoi Medical University and the Ethical Committee of Hanoi Medical University (No. 137/HMU IRB Nov. 2013).

Results

Participant characteristics

Analyses were performed on the total sample (N=4,516) and separately for each of the three cohorts: Denmark (N=2,069), Vietnam (N=1,278) and Tanzania (N=1,169). The characteristics of the study participants are listed in **Table 1**.

Internal reliability of the EPDS scale was tested and found to be 0.82 (95% CI: 0.81-0.83) for the total sample, 0.84 (95% CI: 0.83-0.85) for Tanzania, 0.76 (95% CI: 0.74-0.78) for Vietnam, and 0.84 (95% CI: 0.83-0.85) for Denmark.

Exploratory factor analyses

Previous studies have suggested mainly two- or three-factor models for EPDS. EFA for two- and three-factor solutions were performed for the total sample and for each country and the results were compared (**Table 2**). The three-factor solutions for the total sample and each population consisted of: factor 1 anhedonia (items 1 'able to laugh', 2 'look forward'), factor 2 anxiety (items 3 'self-blame', 4 'anxious', 5 'scared'), and factor 3 depression (items 6 'overwhelmed', 7 'difficulty sleeping', 8 'sad', 9 'crying'). Item 10 (self-harm) loaded either on the anhedonia (Vietnam) or on the depression factor (Tanzania and Denmark). In the two-factor solutions, items 1 and 2 were correlated with items 7-10, and items 3-5 had higher loadings on the second factor. Item 6 (overwhelmed) correlated mostly with items 1,2,7-10 (Denmark and total sample) or items 3-5 (Tanzania and Vietnam).

Confirmatory factor analyses

Confirmatory factor analyses were carried out using one-, two-, and three-factor models, and fit indices (Comparative fit index (CFI), Tucker-Lewis index (TLI), root-mean-square error of approximation (RMSEA)) were used to compare model fits (**Table 3**). R-squared values for the observed variables of each model are reported in **Supplementary Table 1**. Initially we compared one- and two-factor models with the three-factor model (model A) reported for the total sample in the study of Chui and colleagues (Chiu et al., 2017). The three-factor model A resulted in a significantly better fit to our samples than the one- and two-factor models (Chi-squared $p < 0.001$). However, in the study by Chiu et al. item 6 ('overwhelmed') was included in the anxiety factor in the total population and the Hispanic population. The factor loadings of the African-American and White population on the other hand, was identical to the loadings identified in our exploratory factor analysis, where item 6 consistently was more correlated with the depression factor. A comparison of model A with the model identified in our EFA (model B), where item 6 loaded on the depression factor, confirmed that this led to a better fit in all our study populations. **Figure 3** shows the full CFA three-factor model B (all data). Modification indices and expected parameter changes are reported in **Supplementary Table 2**.

Post hoc, we tested if there was measurement invariance across countries for the best fitting EPDS model. A multigroup CFA was carried out using the same method as with the full data set (**Supplementary Table 3**). Two models were fitted, one unconstrained and one with constrained factor loadings for the three countries. ANOVA comparisons of the models revealed that the Chi-squared value for the constrained model was significantly higher (unconstrained Chi-squared = 439.27, constrained Chi-squared = 669.19, df difference = 14, $p < 0.001$), meaning that factor loadings differed between groups. The parameter loadings for each country are reported in **Supplementary Table 3**. Vietnam generally differed from Denmark and Tanzania by having lower covariances (0.25-0.35) between factors, higher covariances (0.80-0.89) for the observed variables of the anxiety factor, and a low covariance (0.53) of the "overwhelmed" variable of the depression factor, which was also observed in the EFA.

Predictors of high EPDS total score

Women from Tanzania and Denmark were more likely to have EPDS total scores above cut-off 12 (12.6% and 6.4%, respectively) compared to women from Vietnam (1.9%) (chi-squared $p < 0.001$) (**Table 1**). EPDS total scores were not normally distributed in the populations and multiple linear regressions did not result in normally distributed residuals. In order to identify predictors of EPDS

score, a generalized additive model was fitted to model the EPDS total score as a zero-inflated type I negative binomial distribution, using maternal age, parity, education level, and country as predictors (**Table 4**). Education level and country were coded as dummy variables, with country = Vietnam and education level = 1 (low) as the base levels. The results showed a statistically significant higher EPDS total score for women from Denmark and Tanzania compared to women from Vietnam ($p < 0.001$), when adjusting for age, parity and education level. The highest level of education (level 3) was associated with a significantly lower EPDS total score, when adjusting for country ($p < 0.001$). We also tested the association between education duration (length in years) and EPDS total score, which confirmed a negative correlation (coefficient=0.015, SE=0.005, $p = 0.0025$).

Specific EPDS items

Figures 1 and 2 illustrate the distribution of specific item scores (0-3) stratified by population and education (low, intermediate, high), respectively. The item scores showed some variability across populations (**Figure 1**). Vietnamese women generally had the lowest scores on most items, whereas Tanzanian women had the highest scores. There were however few exceptions, and the proportion of individuals with a high severity or frequency (defined as score 2 or 3) of specific items are listed in **Table 5**. Danish women were more likely to report high frequency/severity on the items ‘self-blame’ (pairwise comparison, Dunn’s test, $p < 0.001$) and ‘worry’ ($p < 0.001$), whereas they had the lowest scores on the item ‘difficult to sleep’ (< 0.001). Tanzanian women had the lowest scores on the item ‘worry’ compared to Danish ($p < 0.001$) and Vietnamese ($p = 0.002$) women. ‘Self-harm’ was a very rare postnatal symptom in all three samples (0.6%-1.3%) with non-significant differences between populations. The item scores stratified by education level showed a dose-response-like pattern, where the frequency/severity of all symptoms increased with decreasing education level (**Figure 2**). Pair-wise comparisons (Dunn’s test) were performed and education level 1 was associated with significantly higher scores on all EPDS items (except for self-blame) than education level 2 and 3 (results not shown).

Discussion

This study examined postnatal depressive symptoms in women from Denmark, Vietnam and Tanzania, representing three ethnic groups and high-, medium-, and low-income countries. As expected, the study participants from the three pregnancy cohorts differed in regard to various factors, including mean maternal age, parity and education level.

We found that a three-factor EPDS model consisting of anhedonia, anxiety and depression factors made the best fit for all three populations, and that the latent variable of one item (self-harm) was the only model difference. Factor loadings, however, were not equal between the three populations. The assumption of measurement invariance was therefore not fully met and the differences in EPDS scores between populations could be explained by variation in the interpretation of psychological phenomena. Bearing this in mind, we found that women from Vietnam reported less postnatal depressive symptoms than women from Denmark and Tanzania. Furthermore, low education level was associated with higher postnatal depression scores, also when adjusting for maternal age, parity and country of origin.

Our factor analyses revealed three EPDS factors equivalent to: the anhedonia factor (item 1-2), anxiety factor (item 3-5) and depression factor (item 6-9), identified in other studies. The self-harm item (item 10) loaded either with the anhedonia (Vietnam) or the depression (Tanzania and Denmark) factor. Hence, the factors of postnatal depressive symptoms were strikingly similar across the three study populations. The consistency of EPDS factors across continents is rarely examined and to our knowledge not previously reported. A recent large-scale study compared US and European samples and found that the EPDS factors differed between continents, but not within Europe (Di Florio et al., 2017). However, it indicated that EPDS measurement equivalence existed across ethnicity (Di Florio et al., 2017), and a pronounced EPDS consistency across samples that varied on language and cultural backgrounds was also found in an Australian study (Small et al., 2007). Although the study by Di Florio et al. was large-scale, data was collected from seven different sites using different research protocols. According to the authors, ascertainment bias cannot be ruled out and it could potentially explain some of the discrepancies compared to our results based on birth cohort data.

The identification of a three-factor EPDS structure postpartum is in line with previous studies of African-Americans (King, 2012), Europeans (Chabrol and Teissedre, 2004; Petrozzi and Gagliardi, 2013; Pop et al., 1992; Toreki et al., 2013), and Vietnamese-born women (Small et al., 2007). Three studies have identified the exact same factor structure as we did: Two studies that examined English (Tuohy and McVey, 2008) and African-American (King, 2012) women postpartum but did not incorporate the item 'overwhelmed' because it exhibited cross-factor loadings, and a third study

that examined African-American, White and Hispanic women in the US, but only identified this factor structure for African-American and White women (Chiu et al., 2017). The latter study did not include the item 'self-harm' due to very low prevalence rates.

Women from Vietnam reported the least postnatal depressive symptoms and women from Tanzania reported the most. This is in line with a review concluding that African women have perinatal mental health problems at the same level or slightly higher than women from developed countries (Sawyer et al., 2010). The Vietnamese culture is characterized by a high level of practical support for mothers after birth and also a tendency not to express emotional distress (Gammeltoft, 2012; Stuchbery et al., 1998). Both could be explanations to our findings of low depression scores in Vietnamese women.

Low education level was associated with higher postnatal depression scores in all three countries. Other studies find an association between socioeconomic status and depressive symptoms in women of reproductive age (Chen et al., 2005; Kahn et al., 2000). The literature however presents mixed results regarding the specific influence of education on depressive symptoms, with some studies finding a correlation between education level and postnatal depression (Guintivano et al., 2018) as opposed to others (Adewuya et al., 2005). Also, it is suggested that the association between socio-economic status and postnatal depression is driven by income rather than education level (Segre et al., 2007).

The reporting of severity and frequency of specific items showed a dose-response-like pattern related to education level, where lower education was associated with increased severity and frequency of depressive symptoms. The relation between country of origin and severity and frequency of specific items was similar to that of the EPDS total score (Tanzania representing the highest and Vietnam the lowest item scores), except that Danish women experienced more frequent and severe 'self-blame' and 'anxious or worry' than both Vietnamese and Tanzanian women.

Limitations

Some limitations of this study need to be addressed. First, the study design was cross-sectional and we cannot draw causal conclusions. Second, although widely used, the Danish and Tanzanian EPDS versions have not yet been validated in large samples. Third, education level is not easily

compared across countries although we tried to address this by dividing education into levels that were meaningful for each country. And fourth, the EPDS data was collected 3 months (Denmark) or 40 days (Tanzania, Vietnam) postpartum, which could have influenced the comparability between the Danish population and the Tanzanian/Vietnamese populations. In addition, we did not have information on antenatal depressive symptoms and this level could differ between the countries. Finally, comparisons of populations representing three different countries, continents, economies, ethnic groups and cultures naturally lead to pronounced variation in distribution of socio-economic status, educational level and psychosocial context. Accordingly, the assumption of measurement invariance was not fully met in our study. However, in spite of these limitations, it is valuable to investigate similarities and differences in occurrence of psychopathology across cultures using the best possible data source. This study compares large-scale data from three continents, providing the extraordinary opportunity to compare depressive symptoms in postpartum women representing diverse socioeconomic levels, ethnic groups and cultures. Furthermore, the three samples were internally ethnically homogenous, and we therefore believe the findings of EPDS measurement equivalence to be robust. Finally, the data collection procedure was quite similar on all three sites recruiting pregnant women at routine care visits, and the samples are therefore very comparable apart from ethnicity and culture.

This is the first study to compare postpartum depressive symptoms in birth cohort samples from three different continents. We found cross-cultural measurement equivalence to the extent that the EPDS displayed a three-factor model consisting of anhedonia, anxiety and depression factors in all populations. However, EPDS factor loadings differed between populations, and the observed variation in EPDS scores could be due to robust differences in the presence of postnatal depressive symptoms but they could also reflect variation in interpretation of psychological phenomena. In all three populations, low education level was associated with more postnatal depressive symptoms in an inverse dose-response-like relationship. Hence, the association between postpartum depressive symptoms and poor education seems to be very solid in women from Europe, Africa and Asia. Given that both postpartum depression and socioeconomic factors have marked impact on the mental and physical health of mother and child (Barker et al., 2011; Cents et al., 2013; Liu et al., 2017), we recommend increased attention towards women with depressive symptoms postpartum. EPDS is a useful tool to identify these women and it provides results that are robust and comparable across cultures.

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Conflict of interest

None.

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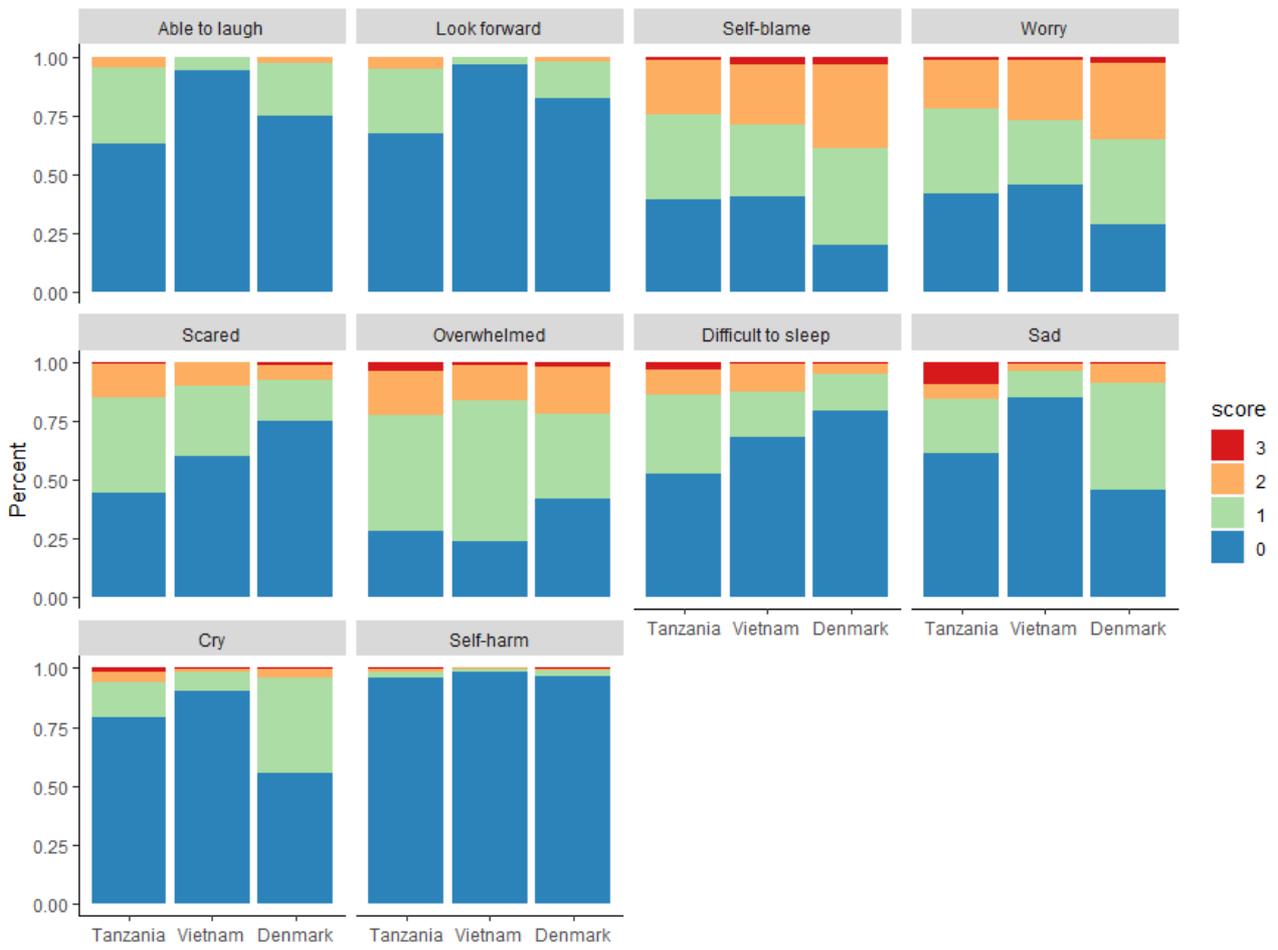


Figure 1. Scores on each EPDS item stratified by population
 (Item scores (0-3) are illustrated by color)

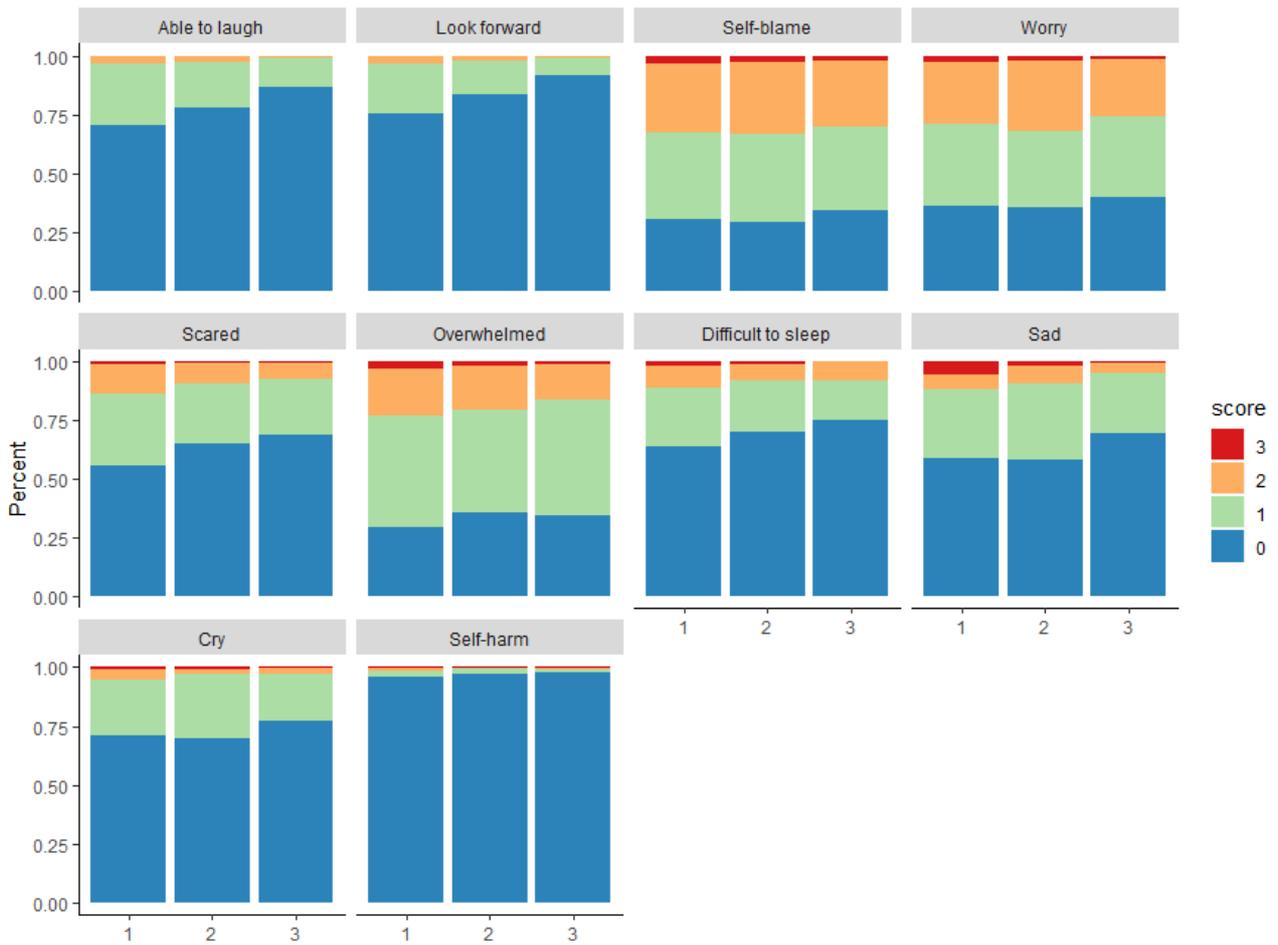


Figure 2. Scores on each EPDS item stratified by education level
 (Item scores (0-3) are illustrated by color, education level is illustrated by numbers (1=low, 2=intermediate, 3=high))

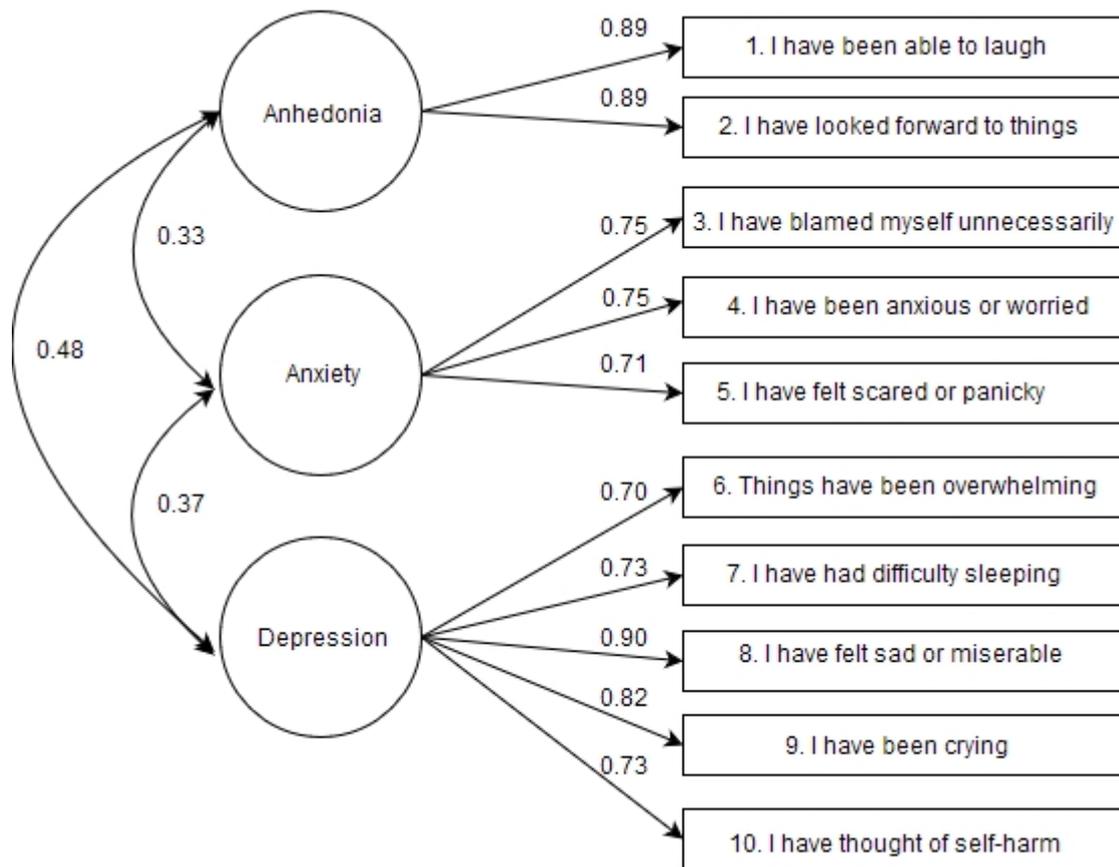


Figure 3. Confirmatory factor analysis of the three-factor model B (all data).
Standardized covariances are shown.

	All	Tanzania	Vietnam	Denmark
Sample size (N (%))	4516 (100)	1169 (25.9)	1278 (28.3)	2069 (45.8)
Maternal age (mean (SD))	28.41 (5.27)	26.68 (5.84)	26.76 (4.86)	30.44 (4.38)
Parity (mean (SD))	1.91 (1.14)	2.21 (1.28)	2.17 (1.35)	1.57 (0.74)
Total EPDS score (mean (SD))	5.12 (4.11)	5.80 (4.64)	4.07 (3.33)	5.38 (4.09)
EPDS score >12 (N (%))	304 (6.7)	147 (12.6)	24 (1.9)	133 (6.4)
Education level low/1 (N (%))	1507 (34.3)	711 (60.9)	248 (19.8)	548 (27.8)
Education level medium/2 (N (%))	1855 (42.3)	407 (34.8)	457 (36.5)	991 (50.4)
Education level high/3 (N (%))	1026 (23.4)	50 (4.3)	547 (43.7)	429 (21.8)
Education years (mean (SD))	12.49 (3.41)	8.55 (2.45)	12.86 (2.90)	14.60 (1.79)

Table 1. Characteristics of study participants

EPDS items		Three-factor model			Two-factor model	
		F1	F2	F3	F1	F2
All (N=4,516)	1. I have been able to laugh	-0.03	0.02	0.94	0.66	0.15
	2. I have looked forward to things	0.28	-0.05	0.50	0.68	0.10
	3. I have blamed myself unnecessarily	0.12	0.53	0.05	0.23	0.57
	4. I have been anxious or worried	-0.04	0.82	0.01	0.12	0.75
	5. I have felt scared or panicky	0.19	0.46	-0.02	0.21	0.54
	6. Things have been overwhelming	0.48	0.22	0.01	0.45	0.42
	7. I have had difficulty sleeping	0.57	0.12	-0.03	0.49	0.36
	8. I have felt sad or miserable	0.84	-0.03	0.02	0.72	0.32
	9. I have been crying	0.68	0	0.03	0.61	0.28
	10. I have thought of self-harm	0.37	-0.02	0.02	0.34	0.13
Tanzania (N=1,169)	1. I have been able to laugh	-0.04	0.86	0.04	0.71	-0.07
	2. I have looked forward to things	0.22	0.61	-0.03	0.75	-0.13
	3. I have blamed myself unnecessarily	0.10	0.24	0.38	0.12	0.55
	4. I have been anxious or worried	-0.03	0.05	0.8	-0.05	0.78
	5. I have felt scared or panicky	0.23	-0.08	0.52	0.11	0.52
	6. Things have been overwhelming	0.58	0.01	0.27	0.41	0.3
	7. I have had difficulty sleeping	0.66	-0.05	0.13	0.46	0.22
	8. I have felt sad or miserable	0.82	0.06	-0.08	0.73	0.10
	9. I have been crying	0.63	0.10	-0.02	0.61	0.10
	10. I have thought of self-harm	0.46	-0.02	-0.07	0.35	0.03
Vietnam (N=1,278)	1. I have been able to laugh	0.05	0.14	0.56	0.70	-0.07
	2. I have looked forward to things	0.03	-0.05	0.70	0.79	-0.12
	3. I have blamed myself unnecessarily	0.73	0.04	0	0.25	0.37
	4. I have been anxious or worried	0.81	0.02	-0.02	-0.04	0.70
	5. I have felt scared or panicky	0.73	-0.06	0.06	-0.04	0.69
	6. Things have been overwhelming	0.07	0.5	-0.18	0.37	0.48
	7. I have had difficulty sleeping	0.06	0.72	-0.10	0.40	0.37
	8. I have felt sad or miserable	0.03	0.67	0.17	0.65	0.18
	9. I have been crying	-0.09	0.55	0.22	0.57	0.16
	10. I have thought of self-harm	-0.02	0.11	0.49	0.33	0.08
Denmark (N=2,069)	1. I have been able to laugh	0.02	0.72	0.02	0.62	-0.07
	2. I have looked forward to things	-0.03	0.78	-0.03	0.57	-0.15
	3. I have blamed myself unnecessarily	0.14	0.04	0.48	0.01	0.74
	4. I have been anxious or worried	-0.06	-0.03	0.78	-0.02	0.82
	5. I have felt scared or panicky	0.09	0.06	0.50	0.01	0.67
	6. Things have been overwhelming	0.31	0.19	0.28	0.21	0.27
	7. I have had difficulty sleeping	0.38	0.23	0.14	0.43	0.30
	8. I have felt sad or miserable	0.86	0.02	0	0.66	0.18
	9. I have been crying	0.83	-0.03	-0.01	0.62	0.01
	10. I have thought of self-harm	0.15	0.13	0.09	0.55	-0.12

Table 2. Factor loadings of exploratory factor analyses (EFA) of EPDS for two- and three-factor models, stratified by population

(The highest loading of each variable among the factors is shown in bold)

	Model	Chi Squared	df	p	CFI	TLI	RMSEA (95% CI)
All	1-factor	1972.01	35	<0.001	0.893	0.863	0.138 (0.132-0.140)
	2-factor	1385.17	34	<0.001	0.923	0.898	0.117 (0.113-0.121)
	3-factor A	901.75	32	<0.001	0.946	0.925	0.100 (0.096-0.105)
	3-factor B	511.34	32	<0.001	0.970	0.958	0.075 (0.071-0.080)
Tanzania	3-factor A	212.90	32	<0.001	0.966	0.952	0.088 (0.080-0.097)
	3-factor B	147.51	32	<0.001	0.977	0.968	0.073 (0.064-0.082)
Vietnam	3-factor A	268.867	32	<0.001	0.941	0.916	0.093 (0.085-0.102)
	3-factor B	98.824	32	<0.001	0.980	0.972	0.053 (0.045-0.062)
Denmark	3-factor A	248.20	32	<0.001	0.977	0.968	0.079 (0.072-0.085)
	3-factor B	197.58	32	<0.001	0.982	0.974	0.070 (0.064-0.077)

Table 3. Confirmatory factor analysis (CFA) of EPDS, stratified by population

2-factor model: F1: 1,2,7,8,9,10; F2: 3,4,5,6.

3-factor model A (reported by Chiu et al. 2017): F1: 1,2; F2: 3,4,5,6; F3:7,8,9,10.

3-factor model B (identified in EFA): F1: 1,2; F2: 3,4,5; F3:6,7,8,9,10.

df: degrees of freedom, RMSEA: root-mean-square error of approximation, CFI: Comparative fit index, TLI: Tucker-Lewis index.

Robust estimates of CFI, TLI, and RMSEA are reported.

Parameter	Coefficient	SE	p-value
(Intercept)	1.582	0.065	<0.001
Tanzania	0.371	0.034	<0.001
Denmark	0.287	0.032	<0.001
Maternal age	-0.004	0.003	0.167
Medium education level (2)	-0.051	0.027	0.057
High education level (3)	-0.129	0.034	<0.001
Total parity	0.021	0.013	0.112

Table 4. Results of generalized additive model for EPDS score
(Vietnam and low education level (1) are considered base levels)

EPDS item	Tanzania (N=1,169) N (%)	Vietnam (N=1,278) N (%)	Denmark (N=2,069) N (%)
Able to laugh	51 (4.3%)	3 (0.2%)	64 (3.1%)
Look forward	60 (5.1%)	4 (0.3%)	41 (2.0%)
Self-blame	288 (24.6%)	368 (28.8%)	808 (39.1%)
Worry	256 (21.9%)	349 (27.3%)	724 (35.0%)
Scared	177 (15.1%)	131 (10.3%)	153 (7.4%)
Overwhelmed	260 (22.2%)	209 (16.4%)	454 (21.9%)
Difficult to sleep	159 (13.6%)	156 (12.2%)	105 (5.1%)
Sad	182 (15.6%)	49 (3.8%)	186 (9.0%)
Cry	69 (5.9%)	22 (1.7%)	80 (3.9%)
Self-harm	15 (1.3%)	8 (0.6%)	18 (0.9%)

Table 5. The proportion of high severity or frequency of depressive symptoms
(High severity or frequency is defined as item score 2 or 3)

	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Item 9	Item 10
1-factor	0.59	0.60	0.39	0.38	0.35	0.45	0.49	0.74	0.65	0.50
2-factor	0.63	0.63	0.53	0.78	0.67	0.52	0.47	0.47	0.43	0.57
3-factor A	0.80	0.79	0.47	0.48	0.43	0.57	0.54	0.82	0.68	0.54
3-factor B	0.80	0.79	0.56	0.57	0.50	0.49	0.54	0.80	0.68	0.50

Supplementary Table 1. R-squared values for the ten observed variables for each EPDS model.

Left hand side	Operator	Right hand side	Modification index	Expected parameter change (EPC)
Anhedonia	≈	I have blamed myself unnecessarily	16.1	0.119
Anhedonia	≈	I have been anxious or worried	64.73	-0.251
Anhedonia	≈	I have felt scared or panicky	13.91	0.105
Anhedonia	≈	Things have been overwhelming	1.87	-0.053
Anhedonia	≈	I have had difficulty sleeping	3.7	-0.084
Anhedonia	≈	I have felt sad or miserable	6.34	0.105
Anhedonia	≈	I have been crying	0.8	-0.039
Anhedonia	≈	I have thought of self-harm	3.34	0.123
Anxiety	≈	I have been able to laugh	3.31	0.085
Anxiety	≈	I have looked forward to things	3.31	-0.084
Anxiety	≈	Things have been overwhelming	36.12	0.176
Anxiety	≈	I have had difficulty sleeping	19.72	0.142
Anxiety	≈	I have felt sad or miserable	49.37	-0.235
Anxiety	≈	I have been crying	7.5	-0.091
Anxiety	≈	I have thought of self-harm	0.55	0.043
Depression	≈	I have been able to laugh	3.31	1.042
Depression	≈	I have looked forward to things	3.31	-1.035
Depression	≈	I have blamed myself unnecessarily	10.92	0.125
Depression	≈	I have been anxious or worried	90.32	-0.386
Depression	≈	I have felt scared or panicky	28.87	0.185
I have been able to laugh	≈	I have blamed myself unnecessarily	10.94	0.073
I have been able to laugh	≈	I have been anxious or worried	1.96	-0.032
I have been able to laugh	≈	I have felt scared or panicky	0.07	0.006
I have been able to laugh	≈	Things have been overwhelming	0.42	-0.013
I have been able to laugh	≈	I have had difficulty sleeping	4.68	-0.049
I have been able to laugh	≈	I have felt sad or miserable	1.58	0.026
I have been able to laugh	≈	I have been crying	0.61	-0.017
I have been able to laugh	≈	I have thought of self-harm	0.83	0.030
I have looked forward to things	≈	I have blamed myself unnecessarily	0.27	0.012

I have looked forward to things	~~	I have been anxious or worried	8.94	-0.072
I have looked forward to things	~~	I have felt scared or panicky	0.02	0.004
I have looked forward to things	~~	Things have been overwhelming	0.25	-0.010
I have looked forward to things	~~	I have had difficulty sleeping	0.01	0.002
I have looked forward to things	~~	I have felt sad or miserable	1.68	0.027
I have looked forward to things	~~	I have been crying	0.56	-0.017
I have looked forward to things	~~	I have thought of self-harm	2.91	0.062
I have blamed myself unnecessarily	~~	I have been anxious or worried	29.98	0.111
I have blamed myself unnecessarily	~~	I have felt scared or panicky	88.62	-0.199
I have blamed myself unnecessarily	~~	Things have been overwhelming	5.39	0.039
I have blamed myself unnecessarily	~~	I have had difficulty sleeping	8.93	-0.057
I have blamed myself unnecessarily	~~	I have felt sad or miserable	0.69	-0.015
I have blamed myself unnecessarily	~~	I have been crying	6.28	0.046
I have blamed myself unnecessarily	~~	I have thought of self-harm	0.05	-0.008
I have been anxious or worried	~~	I have felt scared or panicky	9.65	0.062
I have been anxious or worried	~~	Things have been overwhelming	1.58	0.021
I have been anxious or worried	~~	I have had difficulty sleeping	2.75	-0.032
I have been anxious or worried	~~	I have felt sad or miserable	22.04	-0.088
I have been anxious or worried	~~	I have been crying	3.35	-0.034
I have been anxious or worried	~~	I have thought of self-harm	0.33	-0.020
I have felt scared or panicky	~~	Things have been overwhelming	35.52	0.105
I have felt scared or panicky	~~	I have had difficulty sleeping	126.39	0.199
I have felt scared or panicky	~~	I have felt sad or miserable	28.62	-0.112
I have felt scared or panicky	~~	I have been crying	35.58	-0.129
I have felt scared or panicky	~~	I have thought of self-harm	4.78	0.074
Things have been overwhelming	~~	I have had difficulty sleeping	78.98	0.148
Things have been overwhelming	~~	I have felt sad or miserable	25.11	-0.088
Things have been overwhelming	~~	I have been crying	41.35	-0.121
Things have been overwhelming	~~	I have thought of self-harm	15.62	-0.119
I have had difficulty sleeping	~~	I have felt sad or miserable	17.35	-0.077
I have had difficulty sleeping	~~	I have been crying	59.86	-0.162
I have had difficulty sleeping	~~	I have thought of self-harm	0.02	0.004
I have felt sad or miserable	~~	I have been crying	137.11	0.193
I have felt sad or miserable	~~	I have thought of self-harm	0.6	-0.024
I have been crying	~~	I have thought of self-harm	2.38	0.047

Supplementary Table 2.

Modification indices and Expected Parameter Change (EPC) are standardized (Operator ==~ designates covariance between a latent and an observed variable, ~~ designates a covariance between two observed variables).

Denmark

Parameters	Estimate	Standardized	SE	z-value
Anhedonia				
Able to laugh	1	0,88		
Look forward	0,976	0,86	0,029	34,14
Anxiety				
Self-blame	1	0,734		
Worry	0,946	0,694	0,033	28,257
Scared	1,051	0,771	0,04	26,265
Depression				
Overwhelmed	1	0,76		
Difficult to sleep	1,083	0,823	0,027	39,741
Sad	1,244	0,945	0,024	51,346
Cry	1,168	0,888	0,023	50,688
Self-harm	0,932	0,708	0,053	17,543
Covariances:				
Anhedonia ~				
Anxiety	0,398	0,616	0,021	19,117
Depression	0,534	0,799	0,018	29,758
Anxiety ~				
Depression	0,426	0,763	0,017	25,46

Vietnam

Parameters	Estimate	Standardized	SE	z-value
Anhedonia				
Able to laugh	1	0,942		
Look forward	0,864	0,813	0,083	10,414
Anxiety				
Self-blame	1	0,816		
Worry	1,086	0,886	0,03	35,712
Scared	0,984	0,803	0,029	34,289
Depression				
Overwhelmed	1	0,533		
Difficult to sleep	1,526	0,813	0,096	15,908
Sad	1,733	0,924	0,109	15,917
Cry	1,451	0,773	0,098	14,836
Self-harm	1,581	0,842	0,15	10,537
Covariances:				
Anhedonia ~				
Anxiety	0,264	0,344	0,042	6,33
Depression	0,357	0,711	0,03	11,946
Anxiety ~				

Depression	0,254	0,584	0,02	12,582
Tanzania				
Parameters	Estimate	Standardized	SE	z-value
Anhedonia				
Able to laugh	1	0,837		
Look forward	1,093	0,915	0,045	24,142
Anxiety				
Self-blame	1	0,702		
Worry	1,03	0,723	0,047	22,049
Scared	1,018	0,715	0,049	20,757
Depression				
Overwhelmed	1	0,844		
Difficult to sleep	0,923	0,779	0,027	34,587
Sad	1,003	0,847	0,026	38,129
Cry	0,964	0,814	0,031	30,928
Self-harm	0,832	0,702	0,058	14,322
Covariances:				
Anhedonia ~				
Anxiety	0,316	0,538	0,026	12,189
Depression	0,486	0,688	0,027	17,706
Anxiety ~				
Depression	0,449	0,758	0,023	19,682

Supplementary Table 3. Multigroup Confirmatory Factor Analysis. (SE: standard error)