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Research Paper

Psychometric properties and factor structure of the Center for Epidemiologic Studies Depression scale 10-item short form (CES-D-10) in Aotearoa New Zealand children

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1. Introduction

Depression symptoms cause an enormous global burden at both individual level and socioeconomic level (Fabbri et al., 2018). In particular, youth depression is associated with various negative psychosocial outcomes such as poor academic performance, lower perceived social support and social impairment (Fergusson and Woodward, 2002; Naicker et al., 2013). Additionally, experiencing high depressive symptoms at a young age is associated with various negative physical health outcomes. Often the adverse health outcomes are indicated by significant declines in health-promoting behaviors (Ames et al., 2018) and increases in risky sexual and health behaviors (Luciana, 2013) including self-harm and suicidal behavior (Klimes-Dougan et al., 2018).

In addition to acute consequences for youth depression, experiencing high levels of depressive symptoms also add to the risk for long-term adverse health and behavioral outcomes as adults. Some of the adverse outcomes include unemployment, suicidal behavior (Hauenstein, 2003), poor treatment response, high recurrence rate of depressive episodes (Naicker et al., 2013), high risk of co-morbid mental health disorders (including anxiety, substance-related and bipolar disorders (Copeland et al., 2009; Fergusson et al., 2005)) and chronic illnesses (including cardiovascular disease, diabetes, asthma and arthritis (Katon, 2011)). Longitudinal studies have also found that 60–90% of adolescents with episodes of depression remit within one year (Dunn and Goodyer, 2006) and more than half of patients who remit, often develop depressive episodes within five years (Lewinsohn et al., 2000). From such findings, depressive episodes in childhood predict a range of adverse psychosocial difficulties and poor physical health as adults, resulting in significant social and economic costs as well as reducing individual's quality of life (Nemeroff, 2007). Hence, the clinical and public health need for screening for depressive symptoms at an early age is critical for early detection of mood disorders.

Recent data shows a rapid increase in youth depression rate by more than 60% between 2009 and 2017 (Twenge et al., 2019). Despite the significant health burden associated with depression-related disorders, studies have suggested that less than 50% of youths seek mental health treatment for the condition (Reavley et al., 2010; Leaf et al., 1996). In particular, mental health issues are prevalent among New Zealand youth but they are often left undiagnosed or untreated (Clark et al., 2014). This causes concern as Aotearoa New Zealand has one of the highest completed youth suicide rates in the developed nations (Stubbing and Gibson, 2019). Hence, valid measures to assess common mental health issues, such as depressive symptoms, are crucial in enhancing the well-being of New Zealand youth.

The original 20-item Center for Epidemiological Studies Depression Scale (CES-D;Radloff, 1977) is a common tool to assess the frequency of depressive symptoms in the general population. The CES-D-20 has been widely used in epidemiological studies and its psychometric properties have been well-established across various settings, age groups and populations (Moon et al., 2017; Vilagut et al., 2016). CES-D-20 has also been previously used in an Aotearoa New Zealand adolescent sample (Slykerman et al., 2020). However, limitations in the 20-item scale have been noted for younger children such as the scale being lengthy, poor factor loadings of some items and low inter-item correlations (Bradley et al., 2010). The briefer CES-D-10 has numerous advantages in young members of a large population-based cohort study as it can significantly reduce administration time, participant and response burden (Irwin et al., 2010), and increase the likelihood of questionnaire completion (Bradley et al., 2010).

The shortened 10-item CES-D-10 was initially derived and evaluated

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in older adult population by Andresen et al. (1994), in which a cut-off score of 8 or 10 was used for screening depressive symptoms. Since then, psychometric validation studies have been conducted in several settings with adolescent samples (Bradley et al., 2010; Kilburn et al., 2018), adults (Baron et al., 2017), older adults (Irwin et al., 2010; Mohebbi et al., 2018) as well as clinical populations such as those with psychiatric disorders (Björgvinsson et al., 2013), HIV (Zhang et al., 2012), spinal cord injury (Miller et al., 2008) and stroke (Williams et al., 2020). Of the few studies that have evaluated the psychometric properties of CES-D-10 in adolescents, CES-D-10 has been recognised as a suitable screening tool for depressive symptoms in adolescence at a population level with good psychometric properties (α= ranging from 0.70 to 0.85) (Bradley et al., 2010; Kilburn et al., 2018).

Despite the consistency in strong psychometric properties of the shorter CES-D-10 scale, the factorial structures are largely inconsistent. While some studies suggest a two-factor model (positive affect and negative/depressed affect) to be the best fit for adolescents (Bradley et al., 2010), youth samples (Kilburn et al., 2018) and older adults (Lee and Chokkanathan, 2008), others suggest that a three-factor structure (Cheng et al., 2006) and a unidimensional factor structure (Baron et al., 2017; González et al., 2017; Mohebbi et al., 2018) to be the best fitting model for older adults and adult populations, respectively. Another study with a psychiatric sample found that a unidimensional factor with co-varying two reverse-coded items (accounting for potential method effects), established the best model fit (Björgvinsson et al., 2013). In addition, one study with a caregiver sample conducted a Rasch analysis and found that item 5 "hopeful" could be dropped, although the authors cautioned against dropping the item due to the special characteristics of their caregiver sample (Andresen et al., 2013).

Despite the suitability of using CES-D-10 in younger populations to assess depressive symptoms, the psychometric properties and factorial structure of the CES-D-10 has not yet been investigated in New Zealand children. Moreover, there is conflicting evidence of the factor structure of CES-D-10. Taken together, the main goal of this study was to establish the factor structure and reliability of the CES-D-10 scale in a large ethnically diverse sample of children from Aotearoa, New Zealand. By using confirmatory factor analysis (CFA), we evaluated the following four CFA models: (1) A two-factor model (positive affect and depressed affect: (Bradley et al., 2010; Kilburn et al., 2018); (2) a one-factor model (Baron et al., 2017; González et al., 2017; Mohebbi et al., 2018); (3) a modified one-factor model (Björgvinsson et al., 2013) accounting for a positive construal response style by allowing cross-loadings of positively worded, reverse-coded items (5 and 8) onto the main factor); and (4) one-factor model without item 5 –'hopeful' (Andresen et al., 2013).

2. Methods

2.1. Participants

Participants were New Zealand children from a broadly representative community sample from the *Growing Up in New Zealand* study - a prospective cohort study of New Zealand children with expected delivery dates between 25th April 2009 and 25th March 2010. Participants were recruited via 6822 pregnant mothers to provide a socioeconomically and ethnically diverse cohort (Morton et al., 2014). Detailed description of the study's design and recruitment can be found elsewhere (Morton et al., 2013). In brief, mothers of the sample were recruited during pregnancy and selected from the geographical area containing about one third of the New Zealand birth population, covered by three contiguous District Health Board regions. There were no other inclusion or exclusion criteria (Morton et al., 2013). Based on data available from Statistics New Zealand from the period of 2006 to 2008, the demographic characteristics of the mothers in the cohort are comparable with those of all New Zealand parents on key parameters, specifically maternal age, ethnicity, parity and socioeconomic status (Morton et al., 2013). Furthermore, the *Growing Up in New Zealand* cohort showed generally close alignment to all New Zealand births between 2007 and 2010 on several birth characteristics and child sex (Morton et al., 2015).

More specifically, the data for the current study were collected as part of the Eight Year Data Collection Wave (8-year DCW; 2017–2019), in which 6571 children of the original cohort of 6853 children (96% of the baseline cohort) were eligible to participate. Of those that participated in the 8-year DCW (n = 5556), 4923 completed the CES-D-10 scale. At baseline, mothers of children that did not complete the CES-D-10 scale were more likely to be younger ($p < 0.001$), have fewer educational qualifications ($p < 0.001$) and self-identify with an ethnicity other than European ($p < 0.001$), in comparison to those mothers that did participate. They were also more likely to live in areas of high deprivation ($p < 0.001$).

The final sample for the current analyses consisted of 4923 children ($M = 8.57$, SD=0.41), in which 49% were Female. The cohort was made up of 41% European, 23% Māori (the indigenous people of New Zealand), 11% Pacific, 14% Asian, 2% MELAA (Middle Eastern, Latin American and African) and 9% other ethnicity.

2.2. Procedure

Ethical approval for the study was obtained from the Ministry of Health Northern Y Regional Ethics Committee (NTY/08/06/055). Written informed consent was obtained from all participating women. Longitudinal data collection in the study focuses on six inter-connected domains of child development: health and wellbeing; psychological and cognitive development; education; family and whānau (extended family); culture and identity; and neighborhoods and the societal context. Major face-to-face data collection waves have occurred during the late antenatal period, at nine months, at two years, and at eight years via computer assisted personal interviews (CAPI).

Children's data from the 8-year DCW were collected via a hybrid set of tools including self-reports, observations and objective measures including anthropometric assessments and biological samples via both the child and the mother. While we recognize the importance of various measures and the relevance of both mother and child-reported data on child depressive symptoms, given the purpose of this paper, we only analyzed the CES-D-10 data from the 8-year DCW. The CES-D-10 was collected as part of a child questionnaire during the 8-year DCW interview in a self-report format.

Given that the child questionnaire was administered by multiple trained interviewers, to maintain reliability across all measures, children were encouraged to answer and interpret the CES-D-10 items on their own, without any adult input (including mother and interviewer).

3. Measures

3.1. The Center for Epidemiological Studies Depression 10 scale (CES-D-10)

The 10-item Center for Epidemiological Studies Depression Scale (CES-D-10) was developed through item-total correlations with the original 20-item scale (Andresen et al., 1994). Similarly, the 10-item Likert scale is primarily used to assess depressive symptoms experienced in the past week. Response anchors range from 0 (rarely or none of the time) to 3 (all of the time). After reverse-coding two positive affect items 5 (hopeful) and 8 (happy), the overall score is calculated by totalling all the items (Mohebbi et al., 2018). Hence, total scores can range from 0 to 30 (Baron et al., 2017), in which higher scores indicate higher frequency of depressive symptoms. Previous studies have found good psychometric properties for the 10-item scale including strong reliability, validity and internal consistency (Björgvinsson et al., 2013) and predictive accuracy ($k = 0.97, p < 0.001$) (Andresen et al., 1994). In the current study, the wording of the 10-items used the children's version from the 20-item Center for Epidemiological Studies Depression

Scale for Children (CES-DC; Weissman et al., 1980).

3.2. Sociodemographic variables

3.2.1. Socioeconomic status

The NZDep2013 Index was used to assess the socioeconomic status (SES). The NZDep2013 Index is an updated version of the NZDep2006 index, which is an area-level measure using socio-economic indicators from the 2013 New Zealand census (detailed descriptions can be found in Atkinson et al., 2014). In summary, NZDep 2013 index provides deprivation categories, which are derived from area-based measures of deprivations from households according to their geographic areas. Deprivation areas are divided into 'deciles' for the New Zealand population and vary from least deprived (decile 1) to most deprived (decile 10). In our study, SES was grouped into high (deciles 8–10), medium (deciles 4–7), and low (deciles 1–3) deprivation.

3.2.2. Ethnicity

Information on the children's ethnicity was collected by mother-report when the children were 4.5 years old. For a small number of participants that had missing data at 4.5 years ($n = 67$), we used the same information collected when the children were 9-months old. More specifically, mother-report ethnicity of children included information where mothers were asked what ethnic groups(s) their child belons to by referring to a list of 32 possible answers as well as an open ended 'Other, please specify' category (multiple responses were collected). In the current study, Level 1 ethnicity categorization was utilized, categorised into seven categories by external prioritization according to the Statistics New Zealand prioritization guidelines: European; Māori; Pacific Peoples; Asian; Middle Eastern, Latin American and African (MELAA); Other (Statistics New Zealand, 2004, 2005).

4. Data analysis

Structural equation modeling, using R version 1.3.1093 was used to run confirmatory factor analysis models. The chi-square statistic, goodness-of-fit index (GFI; Bentler, 1983), the comparative fit index (CFI; Bentler, 1990), Tucker–Lewis index (TLI) and the root mean square error of approximation (RMSEA; Browne and Cudeck, 1992) were employed as indices of fit for the models. The following cut-offs were used to assess the goodness of fit for adequate models: RMSEA of less than 0.06, CFI, TLI and GFI values >0.95 (Bentler and Bonett, 1980; Hu and Bentler, 1999) and SRMR values close to 0.08 or below (Brown, 2015).

4.1. Confirmatory factor analysis (CFA)

As previously mentioned, we tested four a-priori CFA models supported by previous literature. First, a two-factor model: Factor 1 – Positive affect, consisting of items 'hopeful' and 'happy'; and Factor 2-Depressed affect consisting of rest of the items 'bothered', 'trouble concentrating', 'depressed', 'effort', 'fearful', 'restless sleep', 'lonely' and 'not get going') (Bradley et al., 2010; Kilburn et al., 2018). Second, a one-factor model with all ten items (Baron et al., 2017; González et al., 2017; Mohebbi et al., 2018). Third, a modified one-factor model (Björgvinsson et al., 2013) - cross-loadings of positively worded, reverse-coded items ('hopeful' and 'happy') onto the main factor. Finally, a one-factor model without the 'hopeful' item (Andresen et al., 2013).

4.2. Measurement invariance

We planned to conduct measurement invariance testing if the best-fitting models were consistent with what has been found in previous literature and based on theoretical coherence. To test for measurement invariance, multiple group CFA was conducted. Configural, metric and scalar invariance was tested across child's gender, deprivation levels and child ethnicity.

Firstly, configural invariance was evaluated in which factor loadings and thresholds were free to vary across groups. Configural invariance is supported if each factor is associated with the same set of items across groups. Secondly, metric invariance was tested to see whether item loadings on each factor was invariant across groups. In metric invariance, the factor loadings were constrained to be equal across groups, but threshold were free to vary. This was to ensure that groups were interpreting and responding to items in the same manner. Metric invariance is supported if it is not significantly different from configural invariance. Lastly, scalar invariance (conditioned on metric variance) was tested to ensure that the observed mean group differences in items were due to the differences in constructs. This was tested by factor loadings and thresholds being constrained to be equal across groups. If scalar invariance model is not significantly worse than metric invariance, scalar invariance is supported. We applied previously employed model fit criteria to test for invariance: if ΔCFI between a constrained model and a less constrained model is equal to or less than 0.01, 0.015 or less in RMSEA, and 0.03 or less in SRMR, then we assumed that the models do not significantly differ and invariance is supported (Chen, 2007).

4.3. Internal consistency

Lastly, the Cronbach's alpha (α) was computed to determine inter-item reliability of items within each hypothesized factor as well as the internal consistency for the overall model. Cronbach's alpha coefficients (α) of 0.70 and above are considered acceptable in CES-D literature (Lee and Chokkanathan, 2008; Mohebbi et al., 2018; Weiss et al., 2015; Zhang et al., 2012). Additionally, McDonald's omega ω (McDonald, 2013) was calculated as a measure of general factor saturation and reliability. This coefficient estimates the extent that a latent construct represents the common variance of all items and can be interpreted according to Cronbach's alpha (Schweizer, 2011). Statistical significance was set at an alpha level of 0.05.

5. Results

The means, standard deviations and Cronbach's alpha for the CES-D 10 items can be found in Table 1.

5.1. Confirmatory factor analyses

The first proposed two-factor model via CFA did not converge. Therefore, we present summary of the factor loadings and model fit indices for the three a-priori CFA models, which can be found in Table 2.

For the first CFA model (Model 1; One-factor structure with all 10-items), all items loaded substantially onto one factor (above 0.3), except for item 5 'hopeful' (0.01). The GFI was above the cut-off point of 0.95 (0.98) but both CFI and TLI values were below the cut-off point of

Table 1
Items, Means (SD), and Cronbach's α for CES-D-10 items.

		Mean (SD)	α	α (if item deleted)
1	'Bothered'	0.71 (0.81)	0.66	0.66
2	'Trouble concentrating'	0.77 (0.84)	0.66	0.66
3	'Depressed'	0.68 (0.84)	0.65	0.65
4	'Effort'	1.18 (0.99)	0.66	0.66
5	'Hopeful'	1.16 (1.03)	0.73	0.73
6	'Fearful'	0.62 (0.89)	0.66	0.66
7	'Restless sleep'	0.84 (1.03)	0.67	0.67
8	'Happy'	0.43 (0.76)	0.67	0.67
9	'Lonely'	0.42 (0.77)	0.66	0.66
10	'Not get going'	0.79 (0.87)	0.65	0.65
	CES-D-10 Total	7.58 (4.57)	0.69	

Note. n = 4923. CES-D-10 item scores can range from 0 to 3. CES-D-10 total score can range from 0 to 30.

Table 2
Standardised factor loadings and model fit after CFA with the model including all items (Model 1), the model with correlated residuals between item 5 and item 8 (Model 2), and the model without item 5 (Model 3).

Item	Model 1	Model 2	Model 3
1. I was bothered by things that usually do not bother me	0.509	0.508	0.508
2. I felt like I could not pay attention to what I was doing	0.485	0.485	0.485
3. I felt down and unhappy	0.578	0.577	0.578
4. I felt like I was too tired to do things	0.491	0.492	0.491
5. I felt like something good was going to happen	0.013	-0.018	–
6. I felt scared	0.484	0.485	0.484
7. I did not sleep as well as I usually sleep	0.434	0.435	0.434
8. I was happy	0.342	0.341	0.341
9. I felt lonely, like I did not have any friends	0.493	0.492	0.492
10. It was hard to get started doing things	0.562	0.562	0.562
Reliability/Fit indices			
α	0.691	0.691	0.733
Ω	0.696	0.685	0.735
χ^2	560.074	167.061	246.248
df	35	34	27
RMSEA (90% CI)	0.055 (0.051-0.059)	0.037 (0.033-0.041)	0.041 (0.036-0.045)
SRMR	0.039	0.025	0.026
CFI	0.914	0.963	0.962
TLI	0.890	0.951	0.950
GFI	0.977	0.989	0.989

Note. Ω = McDonald's omega (McDonald, 2013). χ^2 = chi-square test; RMSEA = root mean square error of approximation; CI = confidence interval; SRMR = standardised root mean square residual; CFI = comparative fit index; TLI=Tucker Lewis Index, GFI= Goodness of fit index.

0.95 (CFI= 0.91, TLI= 0.89). RMSEA below the cut-off score of 0.06 (0.06) and SRMR was below the cut-off score of 0.08 (0.04). The Cronbach's alpha was just below the recommended <0.70 (0.69), and McDonald's Omega was just at the recommended value <0.70 (0.70). As indicated by the model fit indices, Model 1 did not fit the data adequately, as item 5 had a very low factor loading (0.01), the CFI and TLI were both below the cut-off point of 0.95, and Cronbach's alpha was below the recommended value of 0.70.

The second CFA model (Model 2; modified one-factor structure with positive-worded items, items 5 and 8 cross-loading onto the main factor) provided adequate model fit but poor factor loading of item 5 'hopeful'. All items loaded substantially onto one factor (above 0.3) except for item 5 (-0.02). The CFI and GFI were both above the cut-off point of 0.95 (0.97 and 0.99, respectively). RMSEA was below the cut-off score of 0.06 (0.03) and SRMR was also below the cut-off score of 0.08 (0.02). Although the model fit was adequate, like the previous CFA model (Model 1), item 5 did not load substantially onto the main factor. Hence, a one-factor structure CFA was conducted without item 5.

The third CFA model (Model 3: One-factor structure with all items except item 5) provided a better model fit. All items loaded substantially onto one factor (above 0.3), the CFI, GFI and TLI values were all above the cut-off point of 0.95 (0.96, 0.99 and 0.95, respectively). RMSEA was below the cut-off score of 0.06 (0.04) and SRMR was below the 0.08 (0.02). The Cronbach's alpha McDonald's Omega were both above the recommended <0.70 (0.73 and 0.74, respectively). Overall, Model 3 showed best model fit of the data. Hence, a one-factor structure without item 5 tends to provide the best model fit, out of the three CFA models.

5.2. Internal consistency

This study suggests that CES-D-10 is a reliable tool for assessing depression in older children. The value of the reliability coefficient for the models (Cronbach's alpha for Models 1,2,3 - α ranging from 0.69 to 0.73) is similar to Cronbach's alphas reported in other population-based CES-D validation studies of various cohorts. For the current children sample, we found that internal consistency was most appropriate for our Model 3 (α = 0.73; one-factor structure without 'hopefulness' item). This finding is consistent with previous studies with large sample sizes, such as α = 0.70 for previous population-level healthy community sample of dwelling older adults (n = 19, 114) (Mohebbi et al., 2018), and α = 0.71 in Singaporean older adults (n = 1013) (Lee and Chokkanathan, 2008). The Cronbach's alpha for Canadian adolescent sample (Bradley et al., 2010), clinically diagnosed populations such as HIV-positive (Zhang et al., 2012), psychiatric sample (Weiss et al., 2015), and a stratified sample of depressed patients and comparison controls (Irwin et al., 1999) showed higher α's ranging from 0.88 to 0.92.

While individual alphas were lower than 0.70 except for item 5 'hopeful', Radloff (1977) has previously has suggested not to place heavy emphasis on individual alphas due to the high internal consistency of the overall scale. However, α (if item deleted) showed that removing item 5 'hopeful' could notably improve the overall internal consistency of the scale (Table 1).

5.3. Measurement invariance

Given the poor model fit for Model 1, measurement invariance was only tested for Models 2 and 3.

The results for the measurement invariance can be found in Table 3. For gender (male and female), our results showed that configural and metric invariance were supported but measurement non-invariance was found for scalar invariance (ΔCFI ≥ 0.010) for both models 2 and 3. However, the ΔCFI value was just above the cut-off point of 0.010 (ΔCFI = 0.011). For deprivation (low, medium, high), configural, metric and scalar invariance were found across low, medium and high deprivation groups, supporting measurement invariance of both models 2 and 3. For ethnicity, (Māori, European, Pacific Peoples, Asian, MELAA, Other) configural and metric non-invariance were found between the different ethnic groups (ΔCFI ≥ 0.010) for both models 2 and 3.

Our measurement invariance analyses indicate that we can make valid comparisons across SES and gender, in other words, males and females as well as individuals from low, medium or high SES are likely to answer the scale items in a similar manner. In contrast, measurement non-invariance found across multiple ethnicities indicate that there may be systemic ethnicity-based differences in the way CES-D-10 is being answered. Hence, the relationship between CES-D-10 and ethnicity at this stage for our sample remain inconclusive and the CES-D-10 should not be used to compare across different groups stratified by ethnicity.

6. Discussion

Youth depression contributes to numerous detrimental health and psychosocial outcomes. Therefore, psychometrically valid tools are required to assess youth mental health, including depressive symptoms, to understand and implement effective strategies to improve youth well-being. Although increasing evidence suggests that CES-D-10 is a valid and reliable tool to assess depressive symptoms in younger populations, earlier research has found that factor structures remain inconsistent across various population groups. Hence, using the data from the *Growing Up in New Zealand study*, comprising ethnically diverse cohort of eight-to-nine year old children in Aotearoa New Zealand, we validated the factor structure and internal consistency of the CES-D-10 scale.

Our analyses revealed that CES-D-10 is a reliable tool for assessing depression symptoms in children. Four confirmatory factor analyses (CFA) models were tested. We found that, firstly, the proposed two-

Table 3
Fit indices for invariance analyses for Model 3; one-factor structure without item 5, and Model 2 (in brackets); one factor structure with correlated residuals between item 5 and item 8, across child gender, child ethnicity and deprivation.

	RMSEA	ΔRMSEA	SRMR	ΔSRMR	CFI	ΔCFI
Gender						
Male	0.036		0.025		0.967	
	(0.034)		(0.025)		(0.966)	
Female	0.049		0.031		0.952	
	(0.044)		(0.029)		(0.953)	
1. Configural invariance	0.043		0.025		0.959	
	(0.039)		(0.025)		(0.959)	
2. Metric invariance	0.040	0.003	0.027	0.002	0.959	0.000
	(0.036)	(0.003)	(0.026)	(0.001)	(0.959)	(0.000)
3. Scalar invariance	0.042	0.002	0.030	0.003	0.948	0.011
	(0.039)	(0.003)	(0.029)	(0.003)	(0.949)	(0.010)
Ethnicity						
Māori	0.045		0.032		0.952	
	(0.043)		(0.032)		(0.949)	
European	0.039		0.026		0.966	
	(0.037)		(0.028)		(0.962)	
Pacific Peoples	0.053		0.042		0.920	
	(0.053)		(0.042)		(0.920)	
Asian	0.050		0.039		0.941	
	(0.045)		(0.038)		(0.944)	
MELAA	0.106		0.083		0.798	
	(0.090)		(0.080)		(0.825)	
Other	0.058		0.043		0.930	
	(0.052)		(0.042)		(0.932)	
1. Configural invariance	0.048		0.031		0.947	
	(0.044)		(0.031)		(0.946)	
2. Metric invariance	0.044	0.004	0.037	0.006	0.935	0.012
	(0.041)	(0.003)	(0.037)	(0.006)	(0.944)	(0.002)
3. Scalar invariance	0.043	0.001	0.040	0.003	0.934	0.001
	(0.040)	(0.001)	(0.040)	(0.003)	(0.935)	(0.009)
Deprivation						
Low	0.049		0.033		0.940	
	(0.047)		(0.033)		(0.936)	
Medium	0.042		0.028		0.961	
	(0.039)		(0.028)		(0.960)	
High	0.037		0.027		0.967	
	(0.033)		(0.026)		(0.968)	
1. Configural invariance	0.044		0.027		0.955	
	(0.041)		(0.027)		(0.954)	
2. Metric invariance	0.041	0.003	0.032	0.005	0.952	0.004
	(0.039)	(0.002)	(0.032)	(0.005)	(0.950)	(0.004)
3. Scalar invariance	0.039	0.002	0.033	0.001	0.949	0.003
	(0.037)	(0.002)	(0.034)	(0.002)	(0.947)	(0.003)

Note. Fit indices for Model 2 are in brackets. Δ = Fit index of constrained model – Fit index of less constrained model. Only the absolute value is given. A change of ≥ 0.010 in CFI, of ≥ 0.015 in RMSEA, of ≥ 0.030 in SRMR would indicate noninvariance; for testing intercept or residual invariance, a change of ≥ 0.010 in CFI, of ≥.015 in RMSEA or a change of ≥ 0.010 in SRMR would indicate noninvariance (Chen, 2007). CFI = Comparative Fit Index; RMSEA = Root Mean Square Error of Approximation; SRMR = Standardized Root Mean Square Residual.

factor CFA model (depressed affect and positive affect) did not converge. Consequently, the three following models were tested by CFA in the entire sample: (1) unidimensional factor structure with all 10-items; (2) unidimensional factor structure with correlated residual between positively-worded items – item 5 'hopeful' and item 8 'happy'; and (3) unidimensional factor with 9-items without item 5 'hopeful'. We found that model fit was not adequate for model 1: unidimensional factor structure with all 10-items.

Although the model fit for Model 2 (unidimensional factor structure with correlated residual between positively-worded items – item 5 'hopeful' and item 8 'happy) was acceptable, 'hopeful' item had a very poor factor loading and the reliability was just below the recommended value of α=0.70. This finding contradicts (Björgvinsson et al., 2013), who found that a one-factor model accounted for unique variance between the two positive items and had a good model fit with no issues with poor factor loadings and good internal consistency. However, given that this study had a smaller sample size (n = 379) and comprised a psychiatric sample, it is possible that the clinical sample had stronger factor loadings and internal consistency due to the homogeneity of sample characteristics – leading to less bias in scale item interpretation and less variance in construct validity.

A unidimensional factor structure without the 'hopeful' item was the best fit to our data (Model 3). This model showed excellent model fit, and reliability was above the recommended value of α=0.70. Although Andresen and colleagues (2013) has previously conducted a Rasch analysis and suggested that 'hopeful' item could be dropped, they concluded that, given their caregiver sample, item-level and scaling problems were likely to be generally minimal. In addition, our findings are inconsistent with two studies that found a two-factor model (positive affect and depressed affect) to be the best fit from their CFA analyses (Bradley et al., 2010; Lee and Chokkanathan, 2008), as well as three studies that supported a one-factor model with all items (Baron et al., 2017; González et al., 2017; Mohebbi et al., 2018).

The inconsistency in our factor structure results, in comparison to previous work, may be due to our current sample consisting of children. As previously mentioned, children were encouraged to interpret the scale items on their own. Given the psychometric difficulties of some items in CES-D-10, it is possible that results are reflective of the children interpreting the scale items in different ways. Additionally, it is possible that response bias may have occurred from children eight-to-nine-year of age in their possible lack of comprehension of the 'hopeful' item. This may have resulted in a reduction of construct validity in assessing depressive symptoms. Our current finding of the low factor loading of 'hopeful' item is consistent with previous findings with youth (Bradley et al., 2010) and adults (Baron et al., 2017) in which 'hopeful' item consistently performed poorly with low factor loadings in comparison to the other positively-worded 'happy' item. Bradley and colleagues (2010) found that when looking at 'Positive Affect' (PA) factor, most of the variance for the PA factor was derived from 'happy' item, with 'hopeful' item having a low factor loading (0.27).

One possibility of the low factor loading of the 'hopeful' item (I felt like something good was going to happen) in younger samples could be due to children's lack of cognitive capacity to interpret the 'hopeful' construct in future terms. In comparison to adult populations, it is less likely that children engage in significant amount of future thinking and planning. Hence, 'hopeful' may be a less valid in capturing depressive symptoms in children in comparison to adult populations. One study has noted that children's ability to think about the future events may be strongly restricted by temporal distance (Hudson and Mayhew, 2011). For example, thinking about the longer-term (e.g., next week) may require more cognitive resources than thinking about the shorter-term (e.g., tomorrow). Given that the 'hopeful' item does not clearly state a particular point in time (e.g., it is open to interpretation for when the children feel like something good is going to happen), it is possible that children's answers were constrained by temporal distance in thinking about a future event, reducing construct validity, and increasing bias in item interpretation.

Measurement invariance across gender, SES and ethnicity was accounted for our two models (Model 2 and 3). We found full measurement invariance for deprivation (low, medium, high), which indicates that both models can be used for overall analyses that include individuals with different levels of deprivation. For gender (male, female), we found configural and metric invariance but scalar noninvariance was found. Although this may suggest that there may be structural difference between how males and females were interpreting the scale items, the scalar invariance value was just above the recommended ΔCFI value. For ethnicity, we found measurement non-

invariance for both configural and metric invariance for ethnicity (European, Māori, Pacific, Asian, MELAA (including Middle Eastern, Latin American and African) and Other). Hence, at this stage, the proposed factor structures (Model 2 and Model 3) for CES-D-10 cannot be used to assess group differences between different ethnic groups in New Zealand. However, our recommendations are that analyses can involve direct comparisons of depression symptoms between children from different socio-economic backgrounds and genders.

Our study has several limitations. As previously described, the factor structures of Model 2 and 3 cannot be applied across multiple ethnicities which lacks applicability for further analyses. However, this is not surprising given that cultural differences can influence the expression and manifestation of depressive symptoms (Kilburn et al., 2018). There are several factors to note in evaluating depressive symptoms across multiple ethnicities. In addition to face-valid challenges such as achieving conceptual equivalence in depression across multiple ethnicities, ethnicity may also be confounded by other distal factors such as structural inequities (Williams and Mohammed, 2013). In particular, a previous study on mental health research in Aotearoa New Zealand compared clinical phenomena and therapeutic experiences between Māori (as previously mentioned, the indigenous people of New Zealand) and non-Māori. The authors noted that differences between the groups may be related to actual differences but they may also reflect inaccurate diagnostic tools and inadequate services provided by non-Māori clinicians when caring for Māori patients (Tapsell and Mellsop, 2007). Hence, we recommend an in-depth exploration of individuals presenting with depressive symptoms from different ethnic groups with mental health professionals with appropriate cultural knowledge and competency. Although current evidence for the association between depressive symptoms and ethnicity remain inconclusive, we present the critical need for future validation work on assessing the utility of CES-D-10 across various ethnicities, accounting for background factors and possible confounders.

Another limitation of the current study is a lack of clinical diagnostic measures of depression, in which the cut-off scores for those experiencing high depressive symptoms could not be identified. Given that current study used data that was already collected as part of the *eight-year Data Collection Wave* from the *Growing Up in New Zealand study*, it was not possible to collect any clinical diagnostic measures of depression due to ethical and timing issues. Hence, future studies will benefit from including clinical criteria of depression in children (e.g., DSM-5 and general practitioner diagnoses) in conjunction with CES-D-10 for establishing an appropriate cut-off score for detection of individuals who may have a higher risk of depression. Although CES-D-10 alone has been used as a diagnostic tool for both non-clinical and clinical samples, we do not recommend this approach as CES-D tool was developed for the purpose of screening for depression (Andresen et al., 1994).

Finally, given the complexity of accurately capturing depressive symptoms in children, we suggest additional methods to complement the child self-reported CES-D-10 in future studies, such as drawing tasks (e.g., Draw A Story; DAS (Silver, 1988)), and mother-reported depressive symptoms. Using appropriate tools to identify children who may be experiencing high depressive symptoms at an early age is critical to ensure that they are receiving the help that they need (e.g., referral to mental health services, other treatments for prevention of depressive symptoms to developing into full clinical depression).

Despite the limitations noted, CES-D-10, when compared to the original 20-item version, has numerous benefits. The 10 item is found to be reliable tool for assessing depressive symptoms in adolescents (Baron et al., 2017) and children in the current study. As a shorter and briefer instrument, CES-D-10 is less time consuming, reduces participant burden and cognitive load. Furthermore, there are several strengths to the current study. The large sample size ensures increased statistical power as well as ensuring that group numbers are large enough for measurement invariance testing across gender, ethnicity, and deprivation levels. The earlier factor analysis studies were limited by their smaller sample sizes as well as older and broader age range. Additionally, our findings are broadly generalizable to the current contemporary cohort of children living in Aotearoa New Zealand. We highlighted the importance of examining the factor structure and psychometric properties of CES-D-10, as well as conducting adequate validation of CES-D-10 tool in a specific age group in a context-relevant manner.

7. Conclusion

To our understanding, this is the first study to validate the factor structure of CES-D-10 tool in a large multi-ethnic cohort in a New Zealand context. Our findings suggest that CES-D-10 has good psychometric properties in 8- to 9-year-old children in New Zealand. Here, the CES-D-10 consists of one-factor and, without the 'hopeful' item, it is an adequate, reliable tool to use in children to screen for depressive symptoms. However, at this stage, we do not recommend comparing depressive symptoms across different ethnic groups in New Zealand using the current factor structure of CES-D-10. Despite the strength of the current study, more work is needed in further validation of the psychometric properties of CES-D-10 in children, particularly in examining the cultural differences. This will increase the utility and applicability of the CES-D-10 tool across a diverse group of children to be used for health-promoting purposes.

Author statement

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