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Research paper

Factor structure of the Chinese CES-D and invariance analyses across gender and over time among Chinese adolescents

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ABSTRACT

Background: Research findings on the factor structure and invariance of the Center for the Epidemiological Studies Depression Scale (CES-D) are inconclusive. Besides, very few studies have examined factorial invariance of the scale over time. Related studies based on Chinese adolescents are also sparse. This study attempted to examine the factor structure of the CES-D and its invariance across gender and time over a one-year period among adolescents in mainland China.

Method: A total of 3,010 adolescents (mean age = 13.16 years, 1,730 boys) completed a questionnaire including the CES-D at Wave 1 and 2,648 of them completed the same survey one year later. Exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) were performed to examine the factor structure of the CES-D. Factorial invariance of the resultant factor structure was tested using cross-sectional multi-group CFA (girls vs. boys) at Wave 1 and Wave 2 and longitudinal CFA (Wave 1 vs. Wave 2).

Results: EFA and CFA revealed a three-factor model of the CES-D, including "somatic complaints," "depressed affect," and "positive affect." Additionally, findings supported the factorial invariance across gender and over time for the three-factor model.

Limitations: Limitations of the present study included a lack of adolescents from different areas in mainland China (particularly rural areas) and only a one-year follow-up.

Conclusions: This pioneering study suggests that there are three stable dimensions of the CES-D in Chinese adolescents in mainland China which are invariant across gender and over time.

1. Introduction

As a common mental disorder, depression has become increasingly prevalent among adolescents in Western (Mojtabai et al., 2016) and Asian societies (Chi et al., 2020). According to World Health Organization (2019), depression is one of the main causes of adolescents' illness globally. Adolescents are in a vulnerable age group of depression because they have to adjust in many domains (Pallanti et al., 2006). Adolescent depression often coexists with various adverse developmental outcomes, such as low learning motivation and interests (Ludwig et al., 2015). Depression is also a risk factor for adolescent maladaptive behaviors, such as self-injurious and suicide intent (Balázs et al., 2013; Tam et al., 2018).

Timely diagnosis and early intervention require validated assessment tools. Among different measurements of depression, the "Center for Epidemiological Studies-Depression Scale" (CES-D) has been widely used (Radloff, 1977). The 20-item CES-D includes 16 items describing negative symptoms (e.g., "I felt depressed") and four items pertaining to positive perceptions (e.g., "I was happy"). Radloff (1977) reported four dimensions in the original study, including "depressed affect," "somatic complaints," "positive affect," and "interpersonal problem," with support from Western (Tatar et al., 2013) and Chinese studies (Cheng et al., 2012; Zhang et al., 2015).

However, there is support for alternative factor models. For example, Stansbury et al. (2006) revealed a one-factor solution of the CES-D after removing the four positive items, which was later supported by Edwards et al. (2010). Edwards and colleagues (2010) also demonstrated a two-factor model where the four positive items loaded on one factor and the remainders on the other factor, echoing the findings of Edman et al.'s study (1999) based on Filipino-Americans and Lee et al.'s (2008) study on Chinese adolescents. Wang and colleagues (2013) reported a three-factor structure of the CES-D containing newly defined "positive affect," "somatic complaints," and "depressed affect" dimensions. Similarly, Dick et al. (1994) reported a three-factor solution by

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combining depressed and somatic factors, given the strong correlation between them. Thorson and Powell (1993) revealed a five-factor solution based on a random sample of 400 adults. Ying et al.'s (2000) study also yielded a five-factor model using a sample of foreign-born Chinese American university students.

Based on the literature, there are several issues to be resolved. Firstly, the initial four-factor structure has been questioned. In fact, several alternative solutions have been identified in different populations (e.g., Edwards et al., 2010; Wang et al., 2013). Researchers also questioned the sensitivity of some items in the scale (Carleton et al., 2013). Besides, cultural differences in the factor structure are observed. For example, the "interpersonal problem" dimension was not identified in exploratory factor analysis (EFA) of some studies involving Asian populations (Jiang et al., 2019; Wang et al., 2013). Moreover, somatic symptoms and depressive affect were less distinct from each other among Chinese samples, reflecting Chinese people's unique experiences and manifestation of depression (Cheng et al., 2012; Ying, 1988).

Secondly, relatively few studies were conducted with adolescents. As the scale was initially developed to measure depression symptoms among adults, it is questionable whether the measure is valid in adolescent populations (Zhou et al., 2020a). Besides, adolescent depression has received relatively less attention because of inadequate information, insufficient well-trained workers in youth mental health sectors, and perceived weaker significance of adolescent depression compared to other lethal health concerns such as child mortality (World Health Organization, 2005). Adolescent depression has been a hidden problem in Chinese societies and under-researched compared to adult samples (Wang et al., 2013; Zhou et al., 2020a).

Thirdly, although the CES-D has been validated in different Chinese populations (Chi et al., 2020; Jiang et al., 2019; Wang et al., 2013), related research showed inconsistent factor structures. For example, Ying (1988) and Yen et al. (2000) respectively identified a three-factor solution with more overlaps between "somatic symptoms" and "positive affect" subscales based on a sample of Chinese Americans and a sample of Chinese university students. Cheung and Bagley (1998) identified a two-factor model based on Hong Kong adolescents with items of interpersonal problems separated from the remainders. Yang et al. (2015) identified a three-factor structure with 14 items of the CES-D, which included "positive affect," "interpersonal problems," and a factor combining somatic and depressive mood symptoms.

Finally, there is a severe lack of investigation of longitudinal validity of the CES-D. While it is commonly assumed that a given measure steadily reflects the same construct at different time points (Widaman et al., 2010), there is a need to examine whether the scale consistently measures the same construct over time (Millsap and Cham, 2012). For example, Verhoeven et al. (2013) stated that drastic cognitive developmental changes during adolescence might impact how adolescents perceive and report depressive symptoms, which would consequently influence the factorial invariance of depression measurement tools. Although there are longitudinal studies using the CES-D on Chinese adolescents (Lan and Wang, 2020; Zhou et al., 2020a), factorial validity of the measure over time has not been well addressed.

According to Chan et al. (2020), longitudinal invariance of the factor structure of an assessment tool has become an important issue in studying life span development. Prior testing on factorial invariance over time helps clarify whether the temporal change is attributed to true developmental change or to changes in the construct structure (Brown, 2015). For example, a recent study examining longitudinal invariance over twenty-year time provided solid support that the Negative and Positive Affect Scale (NAPAS) measured the same constructs as the samples aged over time (Chan et al., 2020). Existing Chinese research on adolescent development adopted this method to examine longitudinal invariance of scales, such as the Short Grit Scale (Luo et al., 2020) and Problematic Trait Inventory (Luo et al., 2019). However, to our knowledge, no research has been conducted to test longitudinal invariance of the factor structure of the CES-D in Chinese adolescents.

To address the above research gaps, the present study had three objectives. First, in view of the inconsistent findings on the factor structure of the CES-D and the lack of related research among Chinese adolescents, this study further clarified the factor structure of the CES-D among Chinese adolescents by using both "exploratory factor analysis" (EFA) and "confirmatory factor analysis" (CFA). The second objective of the present study was to test whether the factor structure derived from our study is invariant across gender. Although some studies suggested that adolescent girls reported higher levels of depressive symptoms than did adolescent boys, gender difference in the factor structure was not found in some studies (Jiang et al., 2019; Wang et al., 2013). Therefore, we expected that the CES-D would demonstrate factorial invariance across gender. Third, to provide evidence for the longitudinal validity of the CES-D, this study also tested factorial invariance of the CES-D over time. Based on previous findings (Motl et al., 2005), we hypothesized that the CES-D would demonstrate factorial invariance over a one-year interval among Chinese adolescents.

2. Method

2.1. Participants and procedure

A two-wave project on adolescent mental health was launched in September 2016 in mainland China. This project recruited Grade 7 and Grade 8 students from four secondary schools in four cities. The participants responded to a survey in their own classroom settings. A total of 3,010 adolescents completed the survey at Wave 1, among whom 57.48% (n = 1,730) were boys and 40.96% (n = 1,233) were girls, and the average age of the students was 13.16 ± 0.81 years. Among these adolescents, 2,648 completed the same survey one year later (i.e., Wave 2), which constituted the matched sample. Regarding the matched sample, 57.14% (n = 1,513) were boys and 41.88% (n = 1,109) were girls, and the average age was 13.12 ± 0.81 years at Wave 1. Attrition analyses revealed no significant differences in age and gender composition between the matched sample and the dropouts (Zhou et al., 2020a; Zhou et al., 2020b).

The "Human Subjects Ethics Subcommittee" at the authors' institution approved the study. Written informed consent was provided by the schools and parents before launching the project. Adolescents also signed the consent form before completing the questionnaires.

2.2. Measures

To measure adolescents' depressive symptoms, this study used the Chinese version of the CES-D, which has been extensively used globally (Radloff, 1977). The CES-D contains 20 items, among which 16 items assess negative symptoms (e.g., "I felt lonely" and "I felt depressed") and four items measure positive affect (e.g., "I enjoyed life" and "I was happy"). The respondents reported how frequently they experienced each of the symptoms during the past week using a 4-point scale with "0" indicating "rarely or less than 1 day," "1" representing "some of the time or 1–2 days," "2" indicating "a moderate amount of the time or 3–4 days, " and "3" indicating "most or all of the time or 5–7 days." The four items pertinent to positive affect were reversely coded prior to formal analysis of data. The Chinese CES-D scale has been widely adopted in Chinese research (Chi et al., 2020; Jiang et al., 2019; Liu et al., 2019; Wang et al., 2013).

2.3. Data analysis

We performed "exploratory factor analysis" (EFA), "confirmatory factor analysis" (CFA), and invariance tests across gender and over time in this study. EFA was performed using SPSS Version 26.0 while CFA and related invariance tests were performed using Mplus Version 8.5. For the selection of estimator in Mplus, ML ("maximum likelihood") or MLR ("maximum likelihood parameter estimates with standard errors")

estimations are appropriate for continuous variables while WLSMV ("weighted least squares with mean and variance adjustment") estimator is suitable for ordinal data. Because previous studies showed that the assumption of continuity of a variable requires a minimum of five response categories (Flora and Curran, 2004; Lubke and Muthén, 2004), and the CES-D items only had four response options, we used WLSMV estimator in CFA and invariance tests.

Four steps were involved in data analysis. First, a randomly split half sample of the data collected at Wave 1 (i.e., Sample A, $n = 1{,}505$) was used to run EFA to detect the factor structure of the CES-D. Similar to previous studies (Jiang et al., 2019; Wang et al., 2013), principal components analysis with oblique promax rotation was used.

Second, the other half sample (i.e., Sample B, $n = 1{,}505$) of Wave 1 data was used to run CFA, which compared the fit of several competing models with different factor structures, including the one identified from the present EFA and alternative models shown to have the best model fit in the previous literature (see Table 1). Specifically, a total of five models were included for comparisons. Model 1 is the original model containing four factors reported by Radloff (1977), including "depressed affect," "somatic complaints," "positive affect," and "interpersonal problem." This four-factor structure showed good model fit in various Chinese studies (Cheng et al., 2012; Zhang et al., 2015). Model 2 is a model including two factors, where the four positive affect items formed one factor and the other negative symptom items formed the other factor. This two-factor model has been supported in different populations (Edwards et al., 2010; Leykin et al., 2011) including Chinese adolescents (Lee et al., 2008). Model 3 represents a three-factor model identified by Wang et al. (2013) among mainland Chinese adolescents. In this model, the four positive affect items formed one factor, nine items formed "somatic complaints" factor, and the remaining seven items formed "depressed affect" factor. Model 4 is another three-factor model consisting of "positive affect," "interpersonal problem," and the third factor combining somatic symptoms and depressive mood (2015). Model 5 is also a three-factor model identified via EFA in the present study.

Table 1
Item mapping for tested competing models.

No	Item content	Model 1	Model 2	Model 3	Model 4	Model 5
1	I was bothered by things usually don't bother me	SC	DA	SC	DA	SC
2	My appetite was poor	SC	DA	SC	DA	SC
3	I felt that I could not shake off the blues even with help from my family or friends	DA	DA	SC	DA	SC
4	I felt I was just as good as others	PA	PA	PA	PA	PA
5	I had trouble keeping my mind on what I was doing	SC	DA	SC	DA	SC
6	I felt depressed	DA	DA	SC	DA	SC
7	I felt that everything I did was an effort	SC	DA	SC	DA	SC
8	I felt hopeful about the future	PA	PA	PA	PA	PA
9	I though my life had been a failure	DA	DA	SC	DA	SC
10	I was fearful	DA	DA	SC	DA	SC
11	My sleep was restless	SC	DA	SC	DA	SC
12	I was happy	PA	PA	PA	PA	PA
13	I talked less than usual	SC	DA	DA	DA	DA
14	I felt lonely	DA	DA	DA	DA	DA
15	People were unfriendly	IP	DA	DA	IP	DA
16	I enjoyed life	PA	PA	PA	PA	PA
17	I had crying spells	DA	DA	DA	DA	DA
18	I felt sad	DA	DA	DA	DA	DA
19	I felt that people disliked me	IP	DA	DA	IP	DA
20	I could not get "going"	SC	DA	DA	DA	SC

Note. DA = depressed affect; IP = interpersonal problem; PA = positive affect; SC = somatic complaints; Model 1 = Radloff's original four-factor model; Model 2 = a two-factor model in which all negative items were combined into an independent factor and the remaining four positive items formed a second factor; Model 3 = a three-factor model in which positive affect and two new factors merged from original depressed affect, interpersonal problem, and somatic complaints; Model 4 = another three-factor model with positive affect, interpersonal problem, and a new depressed affect factor including original depressed affect and somatic complaints; Model 5 = the three-factor model identified in the present exploratory factor analysis (EFA).

In line with previous practice (Shek et al., 2020; Zhu and Shek, 2020), the goodness-of-fit was evaluated by multiple fit indices, including chi-square (χ^2), "root mean square error of approximation" (RMSEA), "comparative fit index" (CFI), and "Tucker-Lewis index" (TLI). A general guideline is that RMSEA value $\leq .08$ and CFI and TLI values $\geq .90$ indicate adequate model fit (Kline, 2015). As the competing models were not nested models, we compared the "Bayesian information criterion" (BIC) instead of chi-square differences. Generally speaking, a 10-point difference in BIC ($\Delta BIC = 10$) suggests a 150:1 likelihood ($p < .05$) that the model having the lower BIC fits better to the data and $\Delta BIC > 10$ informs "very strong" evidence (Raftery, 1995). As Mplus does not give a BIC value when WLMSV estimator is utilized, the present study computed BIC values of the competing models by using MLR estimator (e.g., Wang et al., 2013).

Third, after identifying the best fitting CES-D model, we tested factorial invariance across gender utilizing the full sample at Wave 1 ($n = 3{,}010$) and Wave 2 ($n = 2{,}648$). Following previous literature (Svetina et al., 2020; Thompson and Green, 2006), we first assessed data-model fit in each gender group, and then performed multi-group invariance tests sequentially. This included a) configural invariance test where all parameters were freely estimated (i.e., no constraints were imposed across gender), b) metric invariance test where factor loadings were constrained to be equal across boys and girls, c) scalar invariance test that additionally constrained observed item thresholds, and d) strict invariance test that further imposed equality on factor variances and covariances. If strict invariance was met, we further constrained latent means to investigate potential differences in the level of depressive symptoms between boys and girls. This procedure has been widely used for testing factorial invariance (Shek et al., 2020; Wang et al., 2013; Zhu and Shek, 2020). To compare these nested models, we examined changes in CFI (ΔCFI) and RMSEA (ΔRMSEA) between the more restrictive model and the comparison model instead of using chi-square difference tests through the "*DIFFTEST*" function in Mplus. This is because Chi-square difference tests are too sensitive to minor parameter changes in a large sample (Cheung and Rensvold, 2002; Meade et al., 2008). Based on recommendations in literature (Chen, 2007; Cheung and Rensvold, 2002), $\Delta CFI < .01$ and $\Delta RMSEA < 0.015$ indicate invariance across groups.

Fourth, we further tested longitudinal factorial invariance using the matched sample ($n = 2{,}648$) to evaluate whether the CES-D measures the same construct with the same structure over time. The same sequential invariance tests (i.e., configural, metric, scalar, and strict) were performed by constraining equality on corresponding parameters over two assessment occasions. Latent mean comparisons were also conducted to examine whether adolescents' depression varies over time. The same criteria ($\Delta CFI < .01$ and $\Delta RMSEA < 0.015$) was applied in this step.

3. Results

3.1. Exploratory factor analysis

EFA results revealed three components having eigenvalues larger than 1.0. The scree plot also supported retention of three factors,

explaining 54.50% of the total variance. The first, second, and third factor accounted for 37.39%, 11.41%, and 5.70% of the total variance, respectively (see Table 2). The first factor, a new "somatic complaints" factor, consisted of ten items that loaded on the original "somatic complaints" (Item 1, 2, 5, 7, 11, and 20) and "depressed affect" (Item 3, 6, 9, and 10) in Radloff's model. The second factor, a new "depressed affect" factor, comprised six items that belonged to the original "depressed affect" (Item 14, 17, and 18), "interpersonal problem" (Item 15 and 19), and "somatic complaints" (Item 13). The last factor included the four positive affect items. This three-factor structure identified in EFA is different from the factor structure reported by Radloff (1977). Particularly, "interpersonal problem" factor did not emerge, and related items loaded onto the new "depressed affect" (DA) factor.

In addition, three out of seven original DA items, such as "life had been a failure" and "felt depressed," were included in the new "somatic complaints" (SC) factor. Two items, Item 10 ("fearful") and Item 13 ("talked less than usual"), had double-loadings. Item 10 primarily loaded on the new SC factor (factor loading = 0.526) and peripherally loaded on the new DA factor (factor loading = 0.468). Item 13 primarily loaded on the new DA factor (factor loading = 0.448) and peripherally loaded on the new SC factor (factor loading = 0.369). The three-factor structure with a few cross-loading items appears largely consistent with previous Chinese findings (Wang et al., 2013; Yen et al., 2000). While some prior studies removed double-loading items (Jiang et al., 2019; Wang et al., 2013; Yen et al., 2000), we retained Item 10 and Item 13 and included them in their primarily loaded factors (i.e., the new SC and DA factors, respectively) in further analyses.

3.2. CFA and comparisons of competing models

Table 3 summarizes the results of CFA and comparisons of competing models based on the second half sample (i.e., Sample B) at Wave 1. As shown in Table 3, the two-factor model (Model 2), and one of the three-factor model (Model 4, where "positive affect" and "interpersonal problem" factors were separated from other items) did not fit the present data very well (RMSEA > 0.08). In contrast, the original four-factor model (Model 1), Model 3, and Model 5 demonstrated acceptable model fit (CFIs > 0.90, TLIs > 0.90, RMSEAs < 0.08). Nevertheless, the BIC value of Model 5 was lower than that of Model 1 (ΔBIC = 236.063 > 10) and Model 3 (ΔBIC = 86.704 > 10), providing "very strong" support for a better model fit of Model 5 in comparison to Model 1 and Model 3. In conclusion, Model 5 best fitted the present data (WLSMV $\chi^2_{(167)}$ = 1505.477, CFI = 0.950, TLI = 0.943, RMSEA = 0.073, BIC = 65376.797). Thus, Model 5 was used for further invariance tests across gender and over time.

Table 2
Factor loadings for exploratory factor analysis using the half sample A at Wave 1 (n = 1,505).

Item number	Item content	SC	DA	PA
7	I felt that everything I did was an effort	**0.813**	0.200	0.034
5	I had trouble keeping my mind on what I was doing	**0.765**	0.092	−0.022
6	I felt depressed	**0.760**	0.288	0.041
20	I could not get "going"	**0.632**	0.471	0.049
11	My sleep was restless	**0.603**	0.292	−0.003
9	I thought my life had been a failure	**0.596**	0.403	0.071
10	I was fearful	**0.526**	0.468	0.055
3	I felt that I could not shake off the blues even with help from my family or friends	**0.482**	0.365	−0.032
1	I was bothered by things usually don't bother me	**0.446**	0.317	0.010
2	My appetite was poor	**0.417**	0.277	−0.124
15	People were unfriendly	0.211	**0.795**	0.035
19	I felt that people disliked me	0.262	**0.790**	0.061
14	I felt lonely	0.254	**0.743**	0.038
18	I felt sad	0.454	**0.659**	0.072
17	I had crying spells	0.403	**0.666**	0.048
13	I talked less than usual	0.369	**0.448**	−0.100
12	I was happy	0.149	0.006	**0.816**
16	I enjoyed life	0.087	0.067	**0.813**
4	I felt I was just as good as others	−0.095	0.128	**0.692**
8	I felt hopeful about the future	−0.100	−0.090	**0.662**
Explained variance		37.39%	11.41%	5.70%

Note. SC = somatic complaints; DA = depressed affect; PA = positive affect.

Table 3
Model comparisons for tested models using the half sample B at Wave 1 (n = 1,505).

Model	WLSMV χ^2	*df*	CFI	TLI	BIC	RMSEA (90% CI)
Model 1	1700.227	164	0.943	0.934	65612.860	0.079 (0.076, 0.083)
Model 2	1884.200	169	0.936	0.928	65860.900	0.083 (0.079, 0.086)
Model 3	1583.046	167	0.947	0.940	65463.501	0.075 (0.072, 0.079)
Model 4	1836.040	167	0.938	0.929	65753.000	0.082 (0.079, 0.085)
Model 5	1505.477	167	0.950	0.943	65376.797	0.073 (0.070, 0.077)

Note. WLSMV = weighted least squares with mean and variance adjustment; df = degree of freedom; CFI = comparative fit index; TLI = Tucker-Lewis index; BIC = Bayesian information criterion; RMSEA = root mean square error of approximation; CI = confidence interval; Model 1 = Radloff's original four-factor model; Model 2 = a two-factor model in which all negative items were combined into an independent factor and the remaining four positive items formed a second factor; Model 3 = a three-factor model in which positive affect and two new factors merged from original depressed affect, interpersonal problem, and somatic complaints; Model 4 = another three-factor model with positive affect, interpersonal problem, and a new depressed affect factor including original depressed affect and somatic complaints; Model 5 = the three-factor model identified in the present exploratory factor analysis (EFA).

3.3. Factorial invariance across gender

As shown in Table 4, the tested model demonstrated acceptable model fit among boys and girls at both waves with CFI and TLI values above 0.90 and RMSEA values lower than 0.08 at Wave 1 but slighter higher than 0.08 (i.e., RMSEA = 0.084) at Wave 2. Subsequent invariance tests revealed equivalent model fit indices between all pairs of the more restrictive model and the comparison model (ΔCFI < 0.01and ΔRMSEA < 0.015 for all cases). These findings suggested that the present three-factor CES-D model under investigation had an acceptable degree of factorial invariance across gender. Specifically, the most restrictive model assuming equality on factor loadings, item thresholds, and factor variances and co-variances showed good fit indices at Wave 1 (WLSMV $\chi^2_{(394)}$ = 2485.483, CFI = 0.958, TLI = 0.960, RMSEA = 0.062) and Wave 2 (WLSMV $\chi^2_{(394)}$ = 2427.935, CFI = 0.957, TLI = 0.958, RMSEA = 0.074).

Latent mean invariance test also revealed equivalent fit indices (ΔCFIs < 0.01, ΔRMSEA < 0.015, see Table 4), suggesting latent mean differences between boys and girls were minimal. Further analyses revealed that when the latent means for "somatic complaints," "depressed affect," and "positive affect" factors were fixed to zero among boys for model identification, the latent means of the three factors among girls were 0.043 (p = 0.237), 0.073 (p = 0.076), and –0.097 (p < 0.01), respectively at Wave 1, and were 0.123 (p < 0.01), 0.031 (p = 0.509), and –0.092 (p < 0.01), respectively at Wave 2. The standardized effect sizes (Thompson and Green, 2006) between gender difference for the three factors were 0.058, 0.092, and 0.140, respectively at Wave 1, and were 0.152, 0.035, and 0.116, respectively at Wave 2, suggesting small differences (Cohen, 1988).

Table 4
Measurement invariance tests across gender based on the full samples at Wave 1 and Wave 2 and over time based on the matched sample.

	WLSMV χ^2	*df*	CFI	TLI	RMSEA (90% CI)	Comparison	$\Delta\chi^2$	ΔCFI	ΔRSMEA
Invariance tests across gender at Wave 1									
Boys (n = 1,730)	1604.183***	167	0.947	0.940	0.073 (0.070, 0.076)				
Girls (n = 1,233)	1139.803***	167	0.956	0.950	0.071 (0.067, 0.075)				
A. Configural invariance	2743.106***	334	0.952	0.945	0.072 (0.070, 0.075)				
B. Metric invariance	2810.821***	351	0.951	0.947	0.071 (0.069, 0.074)	B vs. A	81.094***	–0.001	–0.001
C. Scalar invariance	2737.082***	388	0.953	0.954	0.066 (0.064, 0.068)	C vs. B	94.829***	0.002	–0.005
D. Strict invariance	2485.483***	394	0.958	0.960	0.062 (0.060, 0.064)	D vs. C	102.589***	0.005	–0.004
E. Latent mean invariance	2134.642***	397	0.965	0.967	0.056 (0.054, 0.059)	E vs. D	9.774*	0.007	–0.006
Invariance tests across gender at Wave 2									
Boys (n = 1,513)	1902.484***	167	0.945	0.938	0.084 (0.081, 0.088)				
Girls (n = 1,109)	1448.930***	167	0.957	0.951	0.084 (0.080, 0.088)				
A. Configural invariance	3347.234***	334	0.951	0.944	0.084 (0.082, 0.087)				
B. Metric invariance	3427.969***	351	0.950	0.946	0.083 (0.081, 0.086)	B vs. A	88.933***	–0.001	–0.002
C. Scalar invariance	3334.238***	388	0.952	0.953	0.077 (0.075, 0.080)	C vs. B	83.561***	0.002	0.000
D. Strict invariance	2427.935***	394	0.961	0.962	0.070 (0.067, 0.072)	D vs. C	68.449***	0.009	–0.007
E. Latent mean invariance	2114.570***	397	0.966	0.967	0.064 (0.062, 0.067)	E vs. D	14.07**	0.005	–0.006
Invariance tests over time									
Wave 1	2622.438***	167	0.951	0.944	0.072 (0.070, 0.075)				
Wave 2	3241.149***	167	0.950	0.943	0.085 (0.082, 0.087)				
A. Configural invariance	4917.453***	705	0.958	0.953	0.048 (0.046, 0.049)				
B. Metric invariance	4999.906***	722	0.957	0.954	0.047 (0.046, 0.049)	B vs. A	98.235***	–0.001	–0.001
C. Scalar invariance	5013.493***	759	0.958	0.956	0.046 (0.045, 0.047)	C vs. B	87.400***	0.001	–0.001
D. Strict invariance	4412.106***	765	0.964	0.963	0.042 (0.041, 0.044)	D vs. C	14.005*	0.006	–0.004
E. Latent mean invariance	4222.301***	768	0.965	0.965	0.041 (0.040, 0.042)	E vs. D	32.323***	0.001	–0.001

Note. WLSMV = weighted least squares with mean and variance adjustment; df = degree of freedom; CFI = comparative fit index; TLI = Tucker-Lewis index; RMSEA = root mean square error of approximation; CI = confidence interval; $\Delta\chi^2$= change in chi-square (obtained from *DIFFTEST* in Mplus); ΔCFI = change in CFI; ΔRMSEA = change in RMSEA.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

3.4. Factorial invariance over time

As shown in Table 4, the proposed three-factor model fitted the data adequately at Wave 1 (WLSMV $\chi^2_{(167)}$ = 2,622.438, CFI = 0.951, TLI = 0.944, RMSEA = 0.072). At Wave 2, CFI and TLI values of the model were also above 0.90, but the RMSEA value was slightly greater than 0.08 (i.e., 0.085). For the invariance tests across Wave 1 and Wave 2, configural invariance was met (i.e., CFI = 0.958; TLI = 0.953; RMSEA = .052). As revealed by the values of ΔCFI (lower than 0.01) and ΔRMSEA (lower than 0.015) shown in Table 4, metric invariance, scalar invariance, and strict invariance of CES-D scores across time was supported. The strict invariance model imposing equalities on factor loadings, item thresholds, and factor variances and co-variances over time also fitted the data well (WLSMV $\chi^2_{(765)}$ = 4412.106, CFI = 0.964, TLI = 0.963, RMSEA = 0.042). Overall speaking, the present results suggested that the three-factor model of the CES-D was longitudinally invariant over a one-year period. Table 5 depicts the standardized factor loadings and other psychometric properties of the longitudinal factor model.

Regarding psychometric properties of the longitudinal model, the "average variance extracted" (AVE) for each factor at both waves was greater than 0.50, meaning that each latent factor accounted for over 50% of the total variance in the respective observable items and the three-factor structure had adequate convergent validity over time (Fornell and Larcker, 1981). Besides, the "composite reliability" (CR) values were greater than 0.80, coefficient α values were greater than 0.70, and the average inter-item correlations were higher than 0.40 for all factors at each time point, suggesting adequate internal consistency.

Moreover, the strict invariance model revealed that the stability coefficient (i.e., the correlation between one factor assessed at the two waves) for "somatic complaints," "depressed affect," and "positive affect" was 0.455 ($p < 0.001$), 0.460 ($p < 0.001$), and 0.446 ($p < 0.001$), respectively. Finally, longitudinal latent mean invariance test also revealed equivalent fit indices (ΔCFIs = 0.001, ΔRMSEA = –0.001, see Table 4), suggesting latent mean differences in the three factors between the two waves were negligible. Specifically, when latent means for "somatic complaints," "depressed affect," and "positive affect" factors were fixed to zero at Wave 1, latent means of the three factors at Wave 2 were 0.070 ($p < 0.01$), 0.039 ($p = 0.093$), and –0.059 ($p < 0.01$), respectively. The standardized effect sizes for the differences were 0.098, 0.052, and 0.085, respectively, also supporting the stability of the CES-D scores in the one-year period.

4. Discussion

This study attempted to test factor structure of the CES-D and its invariance across gender and over time among early adolescents in mainland China with several unique features. First, it utilized a Chinese adolescent sample, which has been under-researched in comparison to different adult samples in previous research (Wang et al., 2013; Yang et al., 2018). Second, different from most previous validation studies where the CES-D scores were treated as continuous variables (e.g., Heo et al., 2018; Suh et al., 2017; Yang et al., 2015), we treated the data as ordinal data and employed WLSMV instead of ML estimators in CFA. This is a more appropriate estimation procedure because CES-D items have less than five response options (i.e., four options), which makes the data violate the assumption of multivariate normality (Beauducel and Herzberg, 2006; Lubke and Muthén, 2004). This practice helps us achieve valid and reliable findings in CFA and it has been widely used in recent scale validation studies (Liu et al., 2017; Luo et al., 2019). Third, while some previous Chinese studies used CFA to check and compare factor structures (Cheng et al., 2012; Yang et al., 2015; Yang et al., 2018), we employed both EFA and CFA. It is essential to explore factor structure prior to performing CFA as EFA can help uncover a specific factor model in comparison to previously identified ones (Kim et al., 2011; Wang et al., 2013). Fourth, we extended invariance tests from multi-group (e.g., gender) analyses based on cross-sectional data to longitudinal analyses, which has been largely ignored in the existing literature on factor structure of the CES-D.

The present EFA yielded a three-factor structure, suggesting three dimensions of symptoms related to depression, including "somatic

Table 5
Standardized factor loadings and psychometric properties for the longitudinal invariance model of CES-D.

No	Item content	Wave 1			Wave 2		
		SC	DA	PA	SC	DA	PA
20	I could not get "going"	0.840			0.870		
6	I felt depressed	0.837			0.886		
7	I felt that everything I did was an effort	0.827			0.859		
10	I was fearful	0.795			0.836		
9	I thought my life had been a failure	0.752			0.785		
5	I had trouble keeping my mind on what I was doing	0.740			0.790		
11	My sleep was restless	0.703			0.754		
3	I felt that I could not shake off the blues even with help from my family or friends	0.700			0.772		
1	I was bothered by things usually don't bother me	0.580			0.640		
2	My appetite was poor	0.536			0.586		
18	I felt sad		0.895			0.929	
19	I felt that people disliked me		0.855			0.886	
17	I had crying spells		0.854			0.895	
14	I felt lonely		0.798			0.841	
15	People were unfriendly		0.778			0.839	
13	I talked less than usual		0.602			0.651	
16	I enjoyed life			0.883			0.902
12	I was happy			0.856			0.870
4	I felt I was just as good as others			0.568			0.623
8	I felt hopeful about the future			0.515			0.563
	Mean factor loading	0.731	0.797	0.706	0.778	0.840	0.740
	Average variance extracted	0.544	0.644	0.525	0.613	0.714	0.569
	Composite reliability	0.921	0.915	0.807	0.940	0.937	0.835
	Cronbach's α	0.878	0.848	0.732	0.903	0.876	0.781
	Mean inter-item correlation	0.419	0.485	0.404	0.483	0.544	0.471

Note. CES-D = The Center for Epidemiologic Studies Depression Scale; SC = somatic complaints; DA = depressed affect; PA = positive affect.

complaints (SC)," "depressed affect (DA)," and "positive affect (PA)." In other words, the fourth dimension, "interpersonal problem (IP)," that was identified in Radloff's (1977) original four-factor solution merged to the DA dimension. This finding is consistent with previous EFA results obtained in Chinese and other Asian populations, which also did not find the existence of the IP dimension (Heo et al., 2018; Jiang et al., 2019; Wang et al., 2013; Yen et al., 2000). In collectivistic societies such as China and Korea where harmonious relationships and acceptance in a group are highly valued, experiences of being disliked or treated unfriendly by other people are reasonably closely associated with one's negative affect. Besides, the findings are incongruent with previous CFA results, which suggested that the initial four-dimensional model fitted Chinese data well (Chen et al., 2009; Cheng et al., 2012). However, these studies failed to do model comparisons between the four-factor model and other competing models. In the present study, although the original four-factor structure also fitted the data adequately, it is not as good as the three-factor model derived from EFA. Similar results were reported by Wang et al. (2013).

Conceptually speaking, the resultant factor model in the present study is similar to some other three-factor models identified in previous research (Jiang et al., 2019; Wang et al., 2013; Yen et al., 2000). Specifically, some of the original DA items were integrated into the SC dimension. For example, in all these studies, the third ("I could not shake off the blues") and sixth ("I felt depressed") items originally under the DA dimension loaded on the new SC dimension. This finding reflects that Chinese adolescents tend to mingle "somatization" with "psychologization" of distress (Lee et al., 2008; Wang et al., 2013). It has been proposed that Chinese people tend to express mood less than their Western counterparts. However, somatic symptoms are more commonly displayed among Chinese people (Parker et al., 2001; Ryder et al., 2008). Traditional Chinese culture does not encourage the expression of psychological symptoms because doing so may threaten the harmony of a group, which is more valued than one's psychological needs in a collectivistic culture (Lee et al., 2008). Additionally, stigma associated with mental illness in Chinese societies may further suppress the expression of depressive symptoms (Xu et al., 2017; Yang et al., 2020). Nevertheless, although the factor model with all DA and SC items merged into one dimension also showed good model fit among Chinese adolescents (Lee et al., 2008; Wang et al., 2013), such a model (i.e., Model 4) did not fit the data very well in the present study. This finding suggests that there might be some changes in the way of conceptualizing and presenting distress among Chinese adolescents.

The present study showed that the three-factor model was invariant across gender and over time. Previous studies also reported factorial invariance of the CES-D among Chinese adolescents in mainland (Wang et al., 2013) and Taiwan (Cheng et al., 2012). These findings cumulatively suggest that girls and boys have the same interpretations of the CES-D items, making it meaningful and methodologically sound to compare mean levels of depression across gender. Regarding longitudinal invariance, it is noteworthy that although the CES-D has been utilized in longitudinal studies involving Chinese adolescents (Lan and Wang, 2020; Liu et al., 2020; Zhou et al., 2020a), longitudinal properties of the scale have not been well addressed. In this regard, our finding of strict longitudinal invariance of the CES-D adds great value to the extant literature and confirms that the scale indeed measures the same constructs related to depressive symptoms at different time points. The present finding suggests that the CES-D can be objectively used in longitudinal research involving Chinese adolescents.

Given the factorial invariance across gender and over time, further comparisons of latent means of CES-D factors between girls and boys and across time would yield meaningful information. The present study suggests that gender differences in CES-D scores are minimal in Chinese adolescents. This finding is in agreement with a recent meta-analysis which did not identify significant gender difference in the estimated depression prevalence among Chinese adolescents, despite a slightly higher prevalence among girls (Tang et al., 2019). The present study did not observe substantial changes in CES-D scores over a one-year period. This observation is inconsistent with the previous finding that the level of depressive symptoms increased gradually and significantly in early adolescence, among both Western and Chinese students (Natsuaki et al., 2009; Tang et al., 2019). While these studies considered overall depressive symptoms, the present study compared dimensional scores separately, which may cause the seemingly divergence. Given that the SC, DA, and PA scores among the present adolescent sample all showed a slight upward trend (the PA items were reversely coded, thus the negative value in comparison to zero actually indicated an increase in PA), it is plausible that the overall level of depression increased. Nevertheless, it is necessary to replicate and further verify the present findings in future studies.

Several limitations of this study should be noted. First, the current adolescent sample was recruited mainly from urban areas. As a result, the findings may not be fully applicable to Chinese adolescents in rural areas. It will be inspiring to employ both urban and rural Chinese

adolescents and further investigate factorial invariance of the CES-D in the two groups. Second, we only employed a two-wave data in investigating longitudinal invariance, it will portray a more holistic picture if longitudinal properties of the scale could be examined over a longer time span. Third, longitudinal invariance was tested among adolescents, and future research should also investigate longitudinal invariance of the CES-D among other populations (e.g., adults and elderly) in China.

Despite these limitations, the present findings suggest Chinese adolescents' manifestation of depression assessed by the CES-D was characterized by three symptom dimensions, which represented a better fitting factor model of the CES-D than the original four-factor one. Specifically, IP items in the original model merged to the new DA dimension while a few original DA items were integrated into the new SC factor. Moreover, the current model including three factors was invariant across gender and over a one-year period, suggesting a stable structure of depression symtoms among boys and girls and over time.

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Contributors

All authors contributed to and have approved the final manuscript.

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Xiaoqin Zhu: Conceptualization, Methodology, Investigation, Formal analysis, Writing – original draft, Writing – review & editing. **Daniel T.L. Shek:** Conceptualization, Methodology, Investigation, Writing – original draft, Writing – review & editing, Supervision, Funding acquisition. **Diya Dou:** Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

None.

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