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RESEARCH

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Evaluating the PCL-5 in China: new insights from its assessments over time and gender invariance

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Abstract

Background In the latest research, it is proposed that the intrusions symptoms of the structure of post-traumatic stress disorder (PTSD) were divided into internally-generated and externally-generated. Additional research is required to validate this emerging theory. Moreover, few studies have employed longitudinal data to further validate the novel 8-factor model.

Aim This study aims to explore the factor structure, gender invariance, and longitudinal invariance of the PTSD Checklist for DSM-5 (PCL-5) among children in post-pandemic era.

Methods A survey was conducted on 1861 children using the PTSD Checklist for DSM-5 (PCL-5), and 590 children were re-investigated over three months interval. The statistical analysis includes: Kolmogorov–Smirnov normality test, the missing rates and descriptive statistics of the study variables, confirmatory factor analysis, the gender measurement invariance, longitudinal measurement invariance, and correlation of each factor within the PCL-5.

Results Based on the DSM-5 criteria, the results indicated that 6.8% of the children in the sample exhibited symptoms suggestive of possible PTSD. The novel 8-factor model fits better than the DSM-5 model, DSM-5 dysphoric model, Dysphoric arousal model, Anhedonia model, Externalizing behaviors model, and Hybrid model. The measurement invariance results further indicated that the PCL-5 has strict invariance across gender and strong invariance across time.

Conclusion This study validated the novel 8-factor model of DSM-5 PTSD among children in the post-pandemic era and assessed the gender and longitudinal measurement invariance of the PCL-5. The novel 8-factor model of the PCL-5 is the best DSM-5 model of PTSD symptoms and has strict measurement invariance across gender and strong measurement invariance across time. The research results extended the theoretical framework and empirical research on the DSM-5 PTSD novel 8-factor model. Through this analysis, we hope to provide more accurate tools and strategies for the evaluation and intervention of post-traumatic stress disorder in children.

Keywords Posttraumatic stress disorder, DSM-5, Novel 8-factor model, Measurement invariance, Longitudinal invariance, Children in post-pandemic era

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Introduction

Post-Traumatic Stress Disorder (PTSD) is a clinical syndrome that persists (at least one month or more) after an individual experiences, witnesses, or is exposed to a life-threatening or seriously harmful event, manifesting as numbness, avoidance, negative emotions, and high alertness [1]. According to the DSM-5 [2], PTSD is included in a new section called "Trauma-and Stressor-Related Disorders". New diagnostic criteria for PTSD in children aged 6 and under have been added, indicating that children and adolescents are more developmentally sensitive. It stresses that adults and children/adolescents with PTSD should be treated differently [1]. The PTSD Checklist for DSM-5 (PCL-5) was used to evaluate the level of post-traumatic stress symptoms in trauma exposed individuals within the past month [1]. The PCL-5 is a self-reported measurement scale consisting of 20 items. The four subscales correspond to each symptom standard in DSM-5: intrusions (items 1–5); avoidance (items 6–7); negative cognitions and emotion alteration (items 8–14); alterations in arousal and reactivity (items 15–20). The PCL-5 adopts a 5-point Likert scale from 0 (not at all) to 4 (extremely), and the total score is obtained by adding the item scores. A PCL-5 total score of $\geq$33 points indicates a high likelihood of PTSD symptomatology; a higher total score indicates that the individual has more severe PTSD symptoms [1, 3].

PCL-5 is one of the few self-report instruments designed to assess the severity of PTSD symptoms based on the updated criteria outlined in DSM-5, and has shown good psychometric properties in many studies [4, 5]. Previous studies have suggested the existence of six different DSM-5 PTSD models: the DSM-5 model [6, 7], the DSM-5 dysphoric model [8], the Dysphoric arousal model [9], the Anhedonia model [10], the Externalizing behaviors model [11], and the Hybrid model [12], each of which has received support from researchers. The changes in these diagnostic criteria have led many researchers to re-examine the symptom structure of PTSD, attempting to explore models that more accurately reflect its essential characteristics. In this research context, some scholars have proposed the novel 8-factor mode, which is a new exploration of the structure of DSM-5 PTSD. It attempts to analyze PTSD symptoms from a more detailed dimension in order to more accurately understand and evaluate this complex psychological disorder. In the latest research, it is proposed that the intrusions symptoms of Criterion B were divided into internally-generated (IG, i.e., PTSD criteria B1-B3—intrusive trauma memories, nightmares, and flashbacks) and externally-generated (EG, i.e., criteria B4 and B5—trauma cue-related physiological and emotional reactivity), because IG is a vivid re-experience of specific past traumatic events in the present, while EG represents a broader range of pain responses [13]. For example, for children who have experienced car accidents, even if they do not want to recall scenes similar to vehicles in their daily lives, the images of the accident will involuntarily come to mind, which is a typical symptom of "IG" invasion. This phenomenon reflects the vivid reproduction of specific past traumatic events by children in the present, and is an internal psychological response. The symptoms of "EG" invasion are manifested as children who have experienced earthquakes suddenly experiencing accelerated heartbeat, rapid breathing, and extreme panic when they smell the unique dust smell of the ruins after the earthquake, or hear the sound of houses collapsing during an earthquake. This indicates that certain external cues can trigger strong physiological and emotional responses in children, which involve a wider range of painful experiences and are distinct from the "IG" invasion symptoms, collectively constituting the diverse manifestations of PTSD invasion symptoms. The novel 8-factor model has received support from some researchers [14–16]. However, more research is needed to test this new theory. Furthermore, the dispersed structure of the DSM-5 PTSD model may make the diagnosis of PTSD overly generalized [17], and existing research on PCL-5 has primarily been cross-sectional in design. Given that the potential structure of post-traumatic stress disorder symptoms may be modulated by the time of assessment of trauma exposure [18], further research using longitudinal data is clearly needed to validate the novel 8-factor model.

Children typically have a lower cognitive level compared to adults [19]. Their language communication ability is weaker, which makes it more difficult for them to express their thoughts and feelings precisely. Moreover, children's psychological states are more fragile [20], meaning they are more vulnerable to emotional distress and mental health issues. Childhood is a high-incidence stage of individual psychological health problems [21]. And the psychological trauma of children may increase the risk of cognitive defects [22], social dysfunction [23], anxiety [24], depression [25] and suicidal behavior [26]. Among child victims of physical or psychological trauma, 10% to 55% suffer from PTSD [27]. A meta-analysis study on PTSD in children and adolescents also found that about 15.9% of children experience PTSD after experiencing traumatic events [28]. The coronavirus disease 2019 (COVID-19) pandemic has had a profound impact on both the mental and physical health of the public [29]. Although COVID-19 has been declared over, such traumatic events may still lead to a significant increase in the proportion of people developing psychological problems [30]. Additionally, these events may heighten the risk of PTSD [31] and have potential long-term impacts on the mental health of the population [32]. A meta-analysis study recently found that the highest rate of PTSD among COVID-19 patients is 94% [33]. The prevalence rates of anxiety, depression, sleep problems and PTSD symptoms in children and adolescents were 26%, 29%, 44% and 48% respectively [34]. Children and adolescents have immature physical and mental development, with more delicate neurodevelopment [35] and lower tolerance for stress reactions, leading to easy emergence of psychological problems [36]. Some symptoms caused by PTSD, such as irritability and sleep disorders, have already affected the daily lives of children and teenagers [37]. In addition, due to separation from family members during the pandemic, children and adolescents may experience severe reactions of sadness, depression, and fear, ultimately leading to long-term adverse effects on their mental health and personal growth [38].

Measurement Invariance is an important prerequisite for comparing differences between different groups [39]. Although researchers have different definitions of measurement invariance in specific wording, they all share a common feature, which is that "the measurement results of the same attribute are consistent in different situations" [40]. These different situations include different populations and time points, and the equivalence at different time points is also known as longitudinal invariance [41]. The analysis of cross temporal effects of subsequent variables is only meaningful when the measurement tool satisfies longitudinal invariance. Research has shown that there are significant gender differences in PTSD among children, with female PTSD scores significantly higher than those of males [42, 43]. The gender differences in PTSD found in the above studies may be due to individual differences in how men and women respond to traumatic events, or may be a result of measurement instrument invariance issues [44]. For the novel 8-factor model, gender differences mean that different genders may perform differently on various factors. For example, in the "IG" factor, female may experience traumatic memories more frequently and strongly due to their more delicate emotions [45]; On the "EG" factor, there may be differences in the physiological and emotional response patterns of males and females to trauma cues, which may lead to different scores on this factor. If the model cannot accurately reflect these gender differences, it may affect the accuracy of PTSD symptom assessment for different gender groups. Therefore, it is crucial to verify the gender measurement invariance of the novel 8-factor model. Because only by ensuring that the model has measurement invariance in different gender groups can we guarantee that the differences between genders are real when using the model to assess PTSD symptoms, rather than being caused by measurement tool biases [40]. This helps researchers to more accurately compare the differences in PTSD symptoms between male and female, providing reliable evidence for gender specific interventions and treatments. In addition, existing studies on PCL-5 have mostly focused on cross-sectional designs, but the potential structure of post-traumatic stress disorder symptoms may be influenced by the time of trauma exposure assessment [18]. Longitudinal studies can track individual symptom changes at different time points and observe whether the novel 8-factor model is stable at different time spans. For example, over time, children's cognition and coping strategies towards traumatic events may change, which may lead to changes in the manifestation of various factors. If the model cannot maintain stability at different time points, there may be bias in the evaluation and diagnosis based on the model. Therefore, this study aims to investigate the reliability and validity of PCL-5 in the Chinese pediatric population, validate and explore the factor structure of the scale, determine the potential optimal DSM-PTSD structure, and test the measurement invariance of PCL-5 at gender and different time points.

Method

Subjects and data collection

This study received approval from the ethics committee of the School of Psychology of Guizhou Normal University, and was carried out in accordance with the principles outlined in the Declaration of Helsinki and its subsequent revisions. This study obtained informed consent from all parents/guardians of the children. The research team placed a high emphasis on ensuring participant privacy and confidentiality, ensuring that all obtained data was exclusively utilized for research objectives. Before the survey, we used simple and age-appropriate language to ensure that each child could understand the meaning of every question. For example, for items related to "B1 (Repeated memories)", we would use examples relevant to children's experiences, such as "Do you sometimes think about a scary thing that happened to you over and over again, even when you don't want to?". During the testing process, we had trained researchers closely observing the children's reactions. If a child showed signs of confusion, such as hesitation, puzzled expressions, or asking for clarification, the researcher would approach the child privately and re-explain the question in a different way. Our researchers were also trained to create a comfortable and non-threatening environment to encourage the children to answer the questions as truthfully as possible.

A survey of children in Zunyi, Guizhou Province, China in October 2020 and April 2021. Zunyi is located in the southwest region and is neither a highly developed nor extremely backward area. Its level of development is at the national average level, which can represent the general situation in central and western China to a certain extent. In addition, the education department and schools in Zunyi City have provided strong support for this study, which can provide us with a relatively complete sample of students and data collection channels. And the research team has established good cooperative relationships with local schools, ensuring effective data collection and smooth research. A total of 2000 questionnaires were distributed. In order to ensure that the data could be matched effectively between the two times, a name column was set up in the questionnaire design, and it was noted that this information is only used for encoding later data, participants can voluntarily fill it out. After removing invalid questionnaires (regular or incomplete responses), 1861 questionnaires were collected for the first time, with an effective rate of 93.1%. Among them, there were 974 male students (52.3%), 887 female students (47.1%), and 10 missing values; age range from 9 to 13 years old (10.94 ± 1.07); 338 people (18.2%) in rural areas, 1402 people (75.3%) in urban areas, and 121 people's (6.5%) residential information are missing. According to a PCL-5 total score of ≥ 33 points, individuals may exhibit possible PTSD symptoms, indicating a need for further clinical evaluation. Out of 1861 samples, a total of 127 (6.8%) were identified as having potential PTSD symptoms based on the PCL-5 screening criteria. Conduct another survey on this group of students three months after the first survey, after the Paired Deletion Method was used to process the missing values, 590 valid questionnaires were finally matched. There were 279 (47.3%) males and 311 (52.7%) females; age between 10 to 12 years (10.83 ± 0.67); 54 rural residents (9.2%), 484 urban residents (82.4%), and 50 missing (8.5%).

Measures

The PCL-5 was used to evaluate the level of post-traumatic stress symptoms in trauma exposed individuals within the past month. The PCL-5 is a self-reported measurement scale consisting of 20 items [1]. The four subscales correspond to each symptom standard in DSM-5: intrusions (items 1–5); avoidance (items 6–7); negative cognitions and emotion alteration (items 8–14); alterations in arousal and reactivity (items 15–20). The PCL-5 adopts a 5-point Likert scale from 0 (not at all)) to 4 (extremely), and the total score is obtained by adding the item scores. A PCL-5 total score of ≥ 33 points indicates a high likelihood of PTSD symptomatology; a higher total score indicates that the individual has more severe PTSD symptoms. In this study, a validated Chinese version of the PCL-5 was used in the children [46, 47]. The Cronbach's alpha coefficient of the PCL-5 total scale and 4 subscales in this study were 0.91, 0.76, 0.62, 0.83, and 0.80, respectively.

Statistical analysis

Data were entered using EpiData software version 3.1 and analyzed by SPSS software version 25.0, Mplus software version 8.3. The statistical analysis includes: Kolmogorov–Smirnov normality test was conducted on 20 items of the PCL-5, which showed significant kurtosis and skewness values for each entry ($p < 0.001$), and the data were corrected for non-normality using Satorra-Bentler χ^2 (S-Bχ^2) because they did not conform to a multivariate normality distribution [48]. Lazar [49] classified data loss mechanisms into missing completely at random (MCAR), missing at random (MAR), and missing not at random (MNAR) based on research results. Among them, the MAR refers to the probability of missing data being only related to observed data and not to unobserved data. Therefore, during the data analysis phase, we performed Little's MCAR test on the data to determine if it was MCAR [50]. If the test result is not significant ($p > 0.05$), it indicates that the missing variable is of MCAR. If the test result is significant ($p < 0.05$), it indicates that the variable is of MAR. The test results show that, $\chi^2 = 90.110$, df = 20, p = 0.000, this indicates that the variables in this study are of the MAR type. The missing values were replaced with "9", and the Full-Information Maximum Likelihood Method (FILM) was used in the subsequent analysis to handle the missing values [51]. FILM can fully utilize all the information in the data and consider the uncertainty of missing values when estimating model parameters. Compared with other simple missing value processing methods (such as deleting missing value samples or mean interpolation), it can more effectively reduce information loss and improve the accuracy of parameter estimation [51]. This was followed by confirmatory factor analysis (CFA); then gender measure invariance and longitudinal measure invariance; and finally, correlation of each factor within the PCL-5.

The CFA assessed whether the data and models fit by comparing the Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), Standardized Root Mean Square Residual (SRMR), and Root Mean Square Error of Approximation (RMSEA). If RMSEA < 0.05, SRMR < 0.08, and CFI/TLI > 0.95 [52], then the model fits well. Nested models were performed using the S-Bχ^2 chi-square difference test [53]; Non-nested models are compared using the difference of Bayesian Information Criterion indices (ΔBIC) [54], that is, the difference between the BIC value of the best model and the BIC value of other models, and the magnitude of the difference is used as the basis for model selection: When $6 \leq \Delta BIC \leq 10$, the models with smaller BIC values get strong support,when $\Delta BIC > 0$, the models with smaller BIC values get very strong support. Because chi-square tests are very sensitive to sample size, the larger the sample size, the more significant the results of the chi-square test, and as the sample size continues to increase, even small changes can lead to significant differences [55]. Based on this, this study used the differences in model fit indices (ΔCFI, ΔTLI and ΔRMSEA) between groups as a reference measure of measurement invariance, with $|\Delta CFI/\Delta TLI| < 0.01$ and $|\Delta RMSEA| < 0.015$ [39, 56]. The Pearson correlation coefficient (r) was used to assess the correlation between the subscales of the PCL-5. Colton [57] indicated the following range for r: 0–0.25 = no or little correlation, 0.26–0.50 = average correlation; 0.51–0.75 = moderate correlation and 0.76–1.00 = high correlation.

Results

Descriptive statistics analysis

The results of the descriptive statistical analysis of the 20 items of the PCL-5 were shown in Table 1. The standardized factor loadings for each model of the PCL-5 were shown in Fig. 1. The factor loadings for each entry of the seven competing models of the PCL-5 (DSM-5 model; DSM-5 dysphoric model; dysphoric arousal model; externalizing behaviors model; anhedonia model; hybrid model; novel 8-factor model) ranged from 0.52 to 0.83, indicating that each of the seven competing models met the criteria.

Confirmatory factor analysis

The Confirmatory Factor Analysis (CFA) results for the seven competing models of the PCL-5 are presented in Table 2. All models demonstrated good overall fit according to the established criteria. Comparisons of nested and non-nested models based on examination of △BIC values (see Table 2) and difference χ^2 test (see Table S1 in the Supplementary Materials) consistently indicated that Model 7 provided the best fit among all tested models. Significant differences in fit indices were observed, with Model 7 outperforming others in terms of both nested and non-nested comparisons ($p < 0.05$). Consequently, Model 7 was identified as the optimal structure and was subsequently tested for gender and longitudinal measurement invariance.

Measurement invariance

Testing was conducted based on gender and time. In the gender invariance test, configural invariance, weak invariance, strong invariance and strict invariance are carried out. Firstly, the fit indices of each model met the psychometric requirements (CFI = 0.982, TLI = 0.976, SRMR = 0.031, RMSEA = 0.018), and the measurement invariance fit indices of gender were shown in Table 3, indicating that the configural invariance was satisfied and the configural invariance model can be used as the baseline model for the next test. Next, the factor loading invariance (weak invariance) was set, i.e., the loading invariance of the same indicator in both groups of male and female. The results showed that the fit results of the gender weak invariance test compared to the configural invariance test were + 0.001 and + 0.002 for ΔCFI and ΔTLI, respectively, and 0 for ΔRMSEA, satisfying the above index requirements, and this result supports the invariance of factor loadings for the same index across gender, i.e., weak invariance holds. On the basis of the weak invariance test, the intercept

Table 1 Descriptive statistics of the PCL-5 items

DSM-5 PTSD symptoms	M	SD	DSM-5 PTSD symptoms	M	SD
B1 (Repeated memories)	0.83	0.99	D4 (Negative feelings)	0.49	0.99
B2 (Repeated nightmares)	0.60	1.01	D5 (Loss of interest)	0.59	1.02
B3 (Flashbacks)	0.71	1.07	D6 (Feeling distant)	0.60	1.00
B4 (Upset when reminded)	0.68	1.13	D7 (Trouble positive feelings)	0.51	0.99
B5 (Physical reaction when reminded)	0.39	0.88	E1 (Irritable behavior)	0.69	1.11
C1 (Avoidance of thoughts)	0.59	1.03	E2 (Reckless behavior)	0.31	0.79
C2 (Avoidance of reminders)	0.48	0.97	E3 (Being super alert)	0.61	1.06
D1 (Trouble remembering)	0.19	0.64	E4 (Feeling jumpy)	0.85	1.19
D2 (Negative beliefs)	0.41	0.93	E5 (Difficulty concentrating)	0.63	1.03
D3 (Blame of self or others)	0.32	0.79	E6 (Trouble sleeping)	0.62	1.05

M = Mean value; SD = Standard Deviation

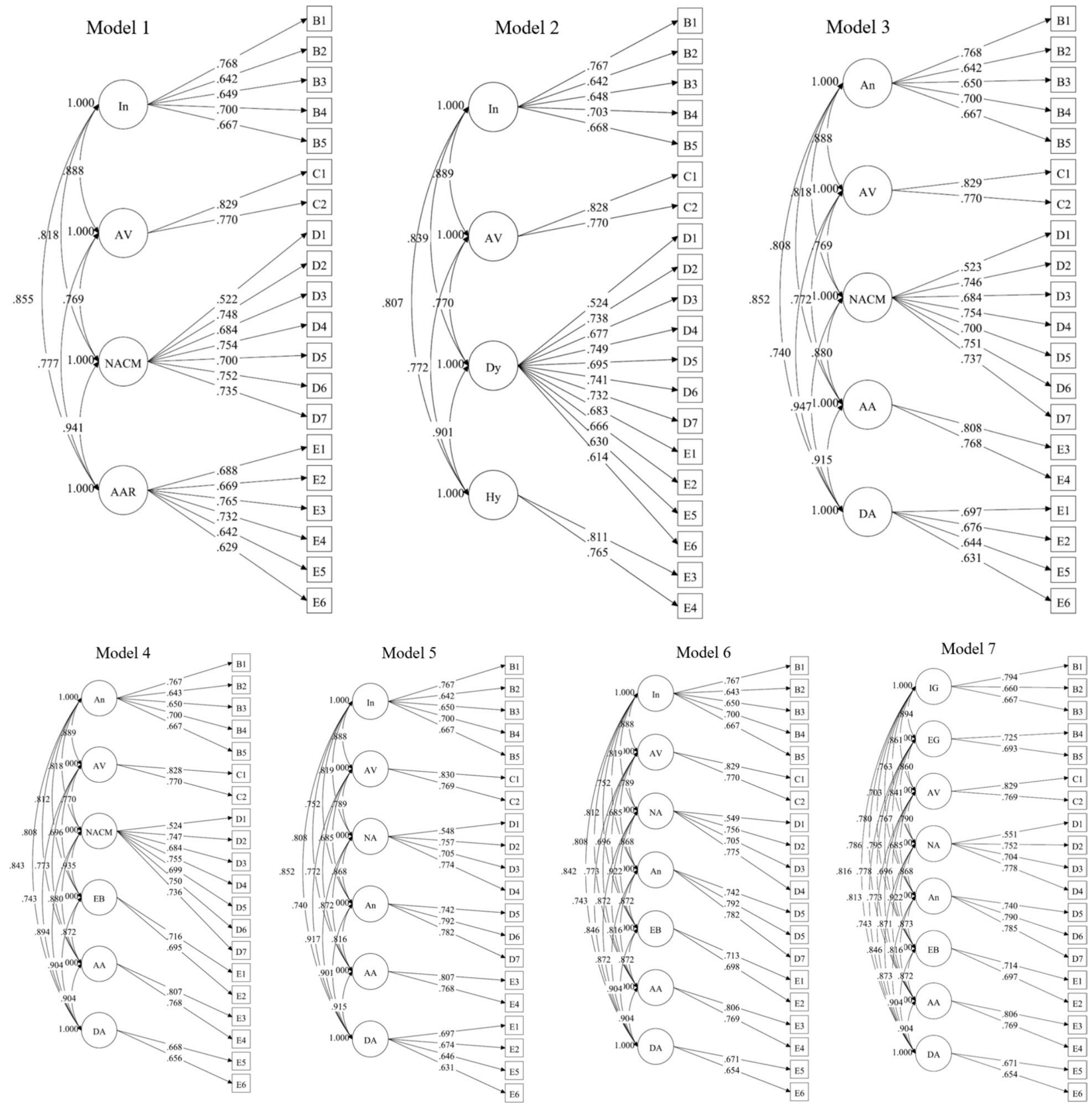

Fig. 1 The confirmatory factor model and factor loading of the PTSD Checklist for DSM-5 (PCL-5). Model 1 = DSM-5 model; Model 2 = DSM-5 dysphoric model; Model 3 = Dysphoric arousal model; Model 4 = Externalizing behaviors model; Model 5 = Anhedonia model; Model 6 = Hybrid model; Model 7 = Novel 8-factor model. In = intrusion; Av = avoidance; NACM = negative alterations in cognitions and mood; AAR = alterations in arousal and reactivity; Dy = dysphoria; Hy = hyperarousal; DA = dysphoric arousal; AA = anxious arousal; EB = externalizing behaviors; NA = negative affect; An = anhedonia; IG = internally generated; EG = externally generated. The same below

invariance (strong invariance) was set for each indicator in both groups of male and female separately. Each fit index suggests a good model fit. The results in Table 3 show that the strong invariance model for different genders compared to the weak invariance test (ΔCFI = -0.001, ΔTLI = 0, ΔRMSEA = 0), and the results indicate that strong invariance holds. Finally, the error variance invariance (strict invariance) was set, and the results in Table 3 show that the ΔCFI and ΔTLI were -0.001 and 0, respectively, and ΔRMSEA was 0, compared to the strong invariance test for different genders, indicating that the error variance invariance of

Table 2 Confirmatory factor analysis fit indicators for the PCL-5

Model	S-Bχ^2	*df*	CFI	TLI	SRMR	RMSEA	RMSEA90%CI	BIC
Model 1	391.493	164	0.967	0.962	0.030	0.028	0.025–0.032	79,315.027
Model 2	390.716	164	0.967	0.962	0.030	0.026	0.025–0.032	79,315.147
Model 3	362.121	160	0.971	0.965	0.029	0.027	0.023–0.031	79,272.760
Model 4	348.812	155	0.972	0.966	0.027	0.028	0.023–0.030	79,278.203
Model 5	283.236	155	0.981	0.977	0.025	0.022	0.018–0.026	79,114.196
Model 6	264.704	149	0.983	0.979	0.024	0.021	0.017–0.025	79,113.109
Model 7	234.071	142	0.987	0.982	0.022	0.019	0.015–0.024	79,094.801

S-Bχ^2 = Satorra-Bentler chi-square goodness of fit; df = degrees of freedom; CFI = comparative fit index; TLI = Tucker–Lewis index; SRMR = standardized root mean square residual; RMSEA = root mean square error of approximation; 90% CIs = 90% confidence intervals for RMSEA; BIC = Bayesian Information Criterion. In order to compare the model fitting indicators in more detail, the statistical values in this table are rounded to three decimal places, the same applies below

Table 3 Measurement invariance testing results of the PCL-5 across gender and time

Model	χ^2	df	CFI	TLI	SRMR	RMSEA	△CFI	△TLI	△RMSEA
Across gender (n = 1861)									
Configural invariance	367.114	284	0.982	0.976	0.031	0.018	–	–	–
Weak invariance	375.234	296	0.983	0.978	0.037	0.018	+ 0.001	+ 0.002	0
Strong invariance	392.040	308	0.982	0.978	0.038	0.018	− 0.001	0	0
Strict invariance	416.408*	328	0.981	0.978	0.040	0.018	− 0.001	0	0
Across time (n = 590)									
Configural invariance	818.376	600	0.962	0.951	0.039	0.026	–	–	–
Weak invariance	824.980	612	0.963	0.953	0.044	0.026	+ 0.001	+ 0.002	− 0.001
Strong invariance	839.070	624	0.963	0.954	0.044	0.025	0	+ 0.001	0
Strict invariance	988.152	644	0.941	0.928	0.050	0.032	− 0.022	− 0.026	+ 0.007

χ^2 = chi-square goodness of fit; df = degrees of freedom; CFI = comparative fit index; TLI = Tucker–Lewis index; SRMR = standardized root mean square residual; RMSEA = root mean square error of approximation; △TLI = TLI difference; △CFI = CFI difference; △RMSEA = RMSEA difference

each indicator holds across genders, i.e., strict invariance holds.

The results of the longitudinal measurement invariance were shown in Table 3. The configural invariance results indicate that all fit indices of the PCL-5 meet the measurement science requirements (CFI = 0.962, TLI = 0.951, SRMR = 0.039, RMSEA = 0.026) and can be used as the baseline model for the next step. The results of weak invariance (ΔCFI = +0.001, ΔTLI = +0.002, ΔRMSEA = -0.001) and strong invariance (ΔCFI = 0, ΔTLI = +0.001, ΔRMSEA = 0) were also supported. In contrast, strict invariance in the longitudinal measurement invariance was not supported (ΔCFI = − 0.022, ΔTLI = − 0.026, ΔRMSEA = +0.007).

Finally, we conducted a correlation analysis between the factors in the novel 8-factor model. The correlation between the factors of the PCL-5's novel 8-factor model is 0.685–0.904 (all $p < 0.001$), reaching a moderate degree of correlation.

Discussion

This study provides important theoretical and practical support for the assessment and intervention of PTSD by verifying the applicability of PCL-5's novel 8-factor model in Chinese children. The research results indicate that the novel 8-factor model has a good fitting effect in the pediatric population and exhibits strong measurement invariance in terms of gender and time. This discovery not only expands the theoretical framework of the DSM-5 PTSD model [13], but also provides a powerful tool for more accurate assessment of PTSD symptoms in children in practice [14–16]. The novel 8-factor model can more accurately reflect the psychological response characteristics of children in PTSD by distinguishing between internally-generated and externally-generated intrusions symptoms. In addition, the results of this study support PCL-5 as an effective screening tool that can help mental health professionals identify PTSD symptoms in children earlier and provide targeted interventions in a timely manner to reduce the negative impact of PTSD on children's long-term mental health.

Firstly, this study tested the reliability of the screening scale for post-traumatic stress disorder in children. The research results showed that the overall Cronbach's alpha values of the PCL-5 total scale and each subscale were acceptable [58]. Among the four subscales, the avoidance subscale had the lowest Cronbach's alpha value (0.62). This finding may be attributed to the smaller number of entries in the avoidance subscale compared to the other three subscales (k = 2) [59]. When there are fewer entries in the subscale, Cronbach's alpha values are less stable [60]. According to the DSM-5 criteria, 6.8% of subjects in the first sample observed possible PTSD symptoms, which is comparable to the values reported in non-clinical samples used in other studies [12, 46]. The CFA results show that all seven competing models perform well in terms of fit results, while the novel 8-factor model does produce a better fit to the data compared to the other models. Subsequently, the stability of the novel 8-factor model across gender samples and over time was further investigated, and the measurement invariance results supported the strict measurement invariance of the novel 8-factor model for the PCL-5 across gender and the strong measurement invariance across time. These findings provide further empirical support for the novel 8-factor model, and add support for measurement invariance regarding the underlying structure of DSM-5 PTSD symptoms in male and female samples and across time points.

The results of the study showed that the fit of the dysphoric arousal model was significantly better than the DSM-5 model and the DSM-5 dysphoric model, these results are consistent with the study of Carragher et al. [61], and further support the findings of several researchers [47, 62]. The results of the study found that the anhedonia model outperformed the dysphoric arousal model, in agreement with previous studies [10, 63]. In addition, the results of the study showed that the anhedonia model outperformed the externalizing behaviors model. This result is supported by some previous studies [47, 62], but is inconsistent with others [11, 61]. In the DSM-5 criteria for PTSD, negative alterations in cognitions and mood include an increase in negative mood and a decrease in positive mood (anhedonia); increased negative mood in turn includes the three symptoms of negative beliefs, distorted blame, and persistent negative mood states. The anhedonia model, on the other hand, includes symptoms such as reduced interest, emotional detachment, and inability to experience positive emotions. Watson [64] research suggests that positive/negative emotions are two distinct structures, i.e., the negative alterations in cognitions and mood is not a single structure, but is composed of two distinct structures. Finally, the novel 8-factor model of the PCL-5 was validated to be best suited to data from among children in post-pandemic era, thus extending the previous non-clinical studies that focused only on adults or college students [12, 61].

DSM-5 was released in 2013 and made significant changes to the PTSD standard (American Psychiatric Association, 2013). Over the past few years, an increasing number of CFA studies have been used to examine the underlying structure of DSM-5 PTSD symptoms, and several alternative models have been developed to challenge the DSM-5 four-factor model [65]. Before any comparison of scale scores across groups, the measurement invariance of the scales should be checked [40]. Therefore, this study examined the measurement invariance of the PCL-5 between different samples (gender) and different time points. Four models were progressively developed, namely, configural invariance, weak invariance, strong invariance and strict invariance. The measurement invariance results of gender supported strict invariance, indicating that the gender differences observed in the PCL-5 reflect the actual differences between males and females in post-traumatic stress disorder, rather than being caused by measurement inequality in the PCL-5 itself. This indicates that when using the novel 8-factor model of DSM-5 PTSD, the severity of PTSD status in males and females can be accurately compared. This result further enhances our understanding of gender differences in the DSM-5 PTSD novel 8-factor model and accumulates evidence for future research. The weak invariance results of longitudinal invariance indicate that the PCL-5 scale exhibits good stability in weak invariance tests, specifically manifested by small increases in CFI and TLI and small decreases in RMSEA. These changes are almost negligible, indicating that the model structure of the PCL-5 remains basically consistent at different time points, and the measurement error has not changed significantly, supporting the stability of the scale in cross time measurements. The strong invariance test further confirmed the invariance of the PCL-5 scale in terms of factor loading and intercept. The slight changes in CFI and TLI, as well as the no changes in RMSEA, indicate that the relative importance (factor loading) and baseline level (intercept) of each item on the scale remain consistent across different time points, providing a solid foundation for subsequent analysis and suggesting that PCL-5 can serve as an effective tool for comparing changes in psychological symptoms at different time points. Although the novel 8-factor model exhibits strict measurement invariance in terms of gender, strict invariance is not supported in terms of longitudinal measurement invariance. This may be due to subtle changes in the subjects' understanding, reaction patterns, or psychological states over time when faced with the same scale, resulting in slightly different interpretations of measurement errors or latent variables [66]. This is similar to the strong invariance model obtained in Wang et al. [67] longitudinal measurement invariance study of the Childhood Trauma Questionnaire (Short Form). This result indicates that although PCL-5 can maintain good stability and consistency at different time points, certain parameters of the model (such as error variance) may change over time under the strictest measurement standards. This change may be related to the psychological state of children at different time points, cognitive changes towards traumatic events, and the influence of environmental factors. From a practical perspective, this discovery suggests that when conducting longitudinal studies using PCL-5, we need to be cautious about cross temporal comparisons and analyses. For example, when evaluating the long-term changes in PTSD symptoms in children, it cannot be fully assumed that the model parameters are completely consistent at different time points. Therefore, it is recommended to combine other assessment tools or methods in longitudinal studies to gain a more comprehensive understanding of the developmental trajectory of PTSD symptoms in children. In addition, for studies that require high-precision measurements, further adjustments to the model or the use of more complex statistical methods may be necessary to correct potential measurement errors.

In this study, there was a high correlation between certain factors in the novel 8-factor model, such as the negative effect factor and the externalizing behavior factor, the externalizing behavior factor and the dysmorphic avoidance factor. This high correlation may raise questions about the discriminant validity of the model. However, despite the high correlation, these factors still have a certain degree of independence conceptually, the negative effect factor mainly reflects children's emotional depression and decreased interest after trauma, while the externalizing behavior factor is more involved in impulsive and adventurous behavior. In addition, previous studies have also shown that there may be a high correlation between certain dimensions of PTSD symptoms, but this does not necessarily mean a lack of discriminant validity [10, 68, 69]. In fact, many studies have validated the effectiveness of these factors as independent constructs through external variables such as anxiety, depression, quality of life, etc. [11, 64, 70]. Therefore, although there is a high correlation between certain factors, the new 8-factor model proposed in this study still has certain theoretical and practical value. However, this issue also suggests that we need to further explore the relationships between these factors in future research, as well as how to better optimize the model structure to improve its discriminant validity. For example, more external validation variables can be introduced, or more complex methods such as Bayesian structural equation modeling can be used to further evaluate the stability and effectiveness of the model.

Overall, the PCL-5 has good reliability as a screening instrument for PTSD in children. The novel 8-factor model of the PCL-5 is the best DSM-5 model of PTSD symptoms and has strict measurement invariance across gender and strong measurement invariance across time.

Limitations

Although the sample from Zunyi City to some extent reflects the mental health status of children in central and western China, we are also aware of the limitations of the sample. For example, the results may not be fully applicable to other regions, especially economically developed areas or coastal cities. Future research can further validate the findings of this study in a wider range of regions and populations to improve the generalizability and applicability of the results. Moreover, in this study, although the PCL-5 questionnaire did not explicitly inquire about specific types of traumatic events, considering the time background of data collection (during and after the COVID-19 pandemic), the traumatic events that children may experience mainly include pandemic related stress (such as family member infections, isolation measures, school closures, etc.), family economic stress, and possible social environmental changes (such as community lockdowns, social isolation, etc.). In addition, some children may have experienced other types of traumatic events, such as natural disasters (such as earthquakes, floods, etc.) or other life stress events. Future research can further clarify the types and severity of traumatic events to more accurately assess the relationship between PTSD symptoms and specific traumatic events.

Supplementary Information

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Supplementary Material 1.

Supplementary Material 2.

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Author contributions
Tao Yang concepted the article, and analyzed the data and drafted the manuscript. Wei Chen checked the grammar and format of the manuscript. Qiaodan Lu and Qiufen Meng collected data and conducted preliminary processing. Haiyan Liu offered suggestions and guidance for revising the data analysis of this manuscript. The final version was approved by all authors.

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Data availability
The data for this study can be found in the supplementary materials.

Declarations

Ethics approval and consent to participate
This study received approval from the ethics committee of the School of Psychology of Guizhou Normal University, and was carried out in accordance with the principles outlined in the Declaration of Helsinki and its subsequent revisions. This study obtained informed consent from all parents/guardians of the children. The research team placed a high emphasis on ensuring participant privacy and confidentiality, ensuring that all obtained data was exclusively utilized for research objectives. All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000 (5). Informed consent was obtained from all patients for being included in the study.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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