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Comparative analysis of models in confirmatory factor analysis: Exploring clinical applications and interpretation

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Abstract

To demonstrate the explainability of the scales with fewer dimensions instead of the number of existing dimensions by ensuring that the scale structures created by explanatory factor analysis (EFA) are verified with confirmatory factor analysis (CFA). Data from the Nutritional Behavior Scale in Children, answered by the parents of 204 children with autism spectrum disorder (ASD) were used. EFA was performed with the data obtained from the scale. In the next step, the explained variance percentages and dimensions were determined and the model goodness of fit indexes were calculated with CFA. The dimensions with the lowest explained variance percentages were removed from the model, respectively, and three different scale models were tested. The variance explanation percentage of the first eight-dimensional model created with EFA was calculated as 72.68%. The food fussiness sub-dimension was removed and CFA was applied to the model again and new indices were calculated. Finally, the emotional under-eating sub-dimension was excluded from the model, resulting in a six-dimensional Child Eating Behavior Scale (CEBS). Goodness-of-fit indices of the CFA model established with six dimensions were $\chi 2$ / df; 1.545, AIC; 715,433 and RMSEA; 0.052 was found. It has been shown that the eight, seven, and six-dimensional scale models constructed according to the percentages of variance explained for CEBS are sufficient to explain the sample and that the six-dimensional scale model can be used for CEBS. Our study is the first to use competing models in confirmatory factor analysis in reducing scale dimensions.

Keywords: CFA, EFA, competitive models, child eating behavior scale

Introduction

Structural Equation Modeling (SEM) analysis is much preferred in today's health, education, social, scientific and economic fields. It is a multivariate analysis technique used to examine established relationships based on the concept of causality, establish a model, and test the compatibility of the established model with the model's data structure [1-3]. SEM; is a multivariate analysis technique applied by considering the covariance structure between observed and unobserved (latent) variables in a data set [4-5]. SEM presents the results of multiple regression equations to the researcher at the same time. Unlike classical regression analysis, it also analyzes whether the data set used to test the relationships between variables conforms to the model. Regression errors cannot be included in the model because they cause bias in the results, but are included in the models established with SEM. Confirmatory factor analysis (CFA), one of the SEM analysis methods, is preferred to test the accuracy of the structures obtained after explanatory factor analysis (EFA). EFA has an exploratory view of the data, whereas CFA is structured to confirm EFA [6-8]. In the study, the accuracy of a new structure for the scale was modeled by using the Child

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Eating Behavior Scale (CEBS) with 8 sub-dimensions and using competitive models analysis with CFA. The structure of the sub-dimensions of CEBS was determined by EFA, the structure determined by CFA was verified, the sub-dimensions with the lowest percentage of variance explanation were removed from the scale, and new models were produced and competing models were obtained (bibliography added).

According to the explained variance percentage, the sub-dimensions with the least load were removed from the scale model, and the model fit indexes were calculated, thus the best model was determined. It has been shown that the number of existing sub-dimensions can be reduced with the calculated percentages of explained variance.

The main purpose of our study is to prepare and interpret new models by using the variance ratio explained in the models prepared with CFA, which is known by everyone. The scale data used in our study were obtained with clinical permission. The information and data of the scale used in the study were not preferred for clinical interpretation. The data used in our study were used only for the purpose of presenting statistical modeling, no clinical findings and interpretations were given. Therefore, our study has a statistical modeling purpose. In order to show that new models can be created and interpreted with advanced analysis findings for the frequently preferred CFA, analyzes were made and statistically interpreted by establishing three different models (added purpose of study).

Structural Equation Modeling (SEM)

Today, SEM is more popular due to the increase in computer programs and the convenience of analytical researchers. Factor analysis, frequently used in the fields of psychometrics and psychology; appears as a mixture of equality models used in the fields of genetics and econometrics [1-2]. With the results obtained by SEM analysis, it becomes very easy to analyze and interpret the complex structures between the variables [3]. One reason SEM is highly preferred is that it uses causal and relational screening models to reveal patterns between observable and unobservable (latent) variables. One of the most important benefits of SEM is increasing the intelligibility of the model by presenting the visual model to researchers in applied analyzes [4]. The most important concepts for the causal relationship established in SEM analyzes are the independence, direction and strength of relationships between variables (percentage of variance explained). While working as a continuation of SEM factor analysis models, it also examines the relationship between variables [3].

Confirmatory Factor Analysis

Confirmatory factor analysis (CFA); It is an advanced multivariate analysis technique used to test the accuracy of a model belonging to predefined structures [5-6]. This enables the construct validity of the model to be tested by post-explanatory factor analysis (EFA) [7-9]. It presents the problems that occur in the CFA scale structures, which are frequently used in scale development studies, and the solutions to these problems. CFA shows not only the identified relationships, but also all possible relationships. CFA can also be used to perform goodness-of-fit tests for relationships between unobserved variables [10]. In CFA, the relationship between the variables is important and the coefficients of the relationships between the unobservable variables can be calculated. It is also analyzed whether the structure of a scale obtained by EFA is adequately represented by the specified number of factors [11]. While testing their hypotheses with the model they have established, researchers use it to examine the structures of the models between variables and factors [12-13]. CFA analyzes used in scale development studies are performed with the assumption that there are relationships of unknown direction between the variables [3]. At the beginning of the analysis, correlation or covariance matrices are created, the coefficients of the factors, the variances and covariances of the measurement error are calculated and the process is completed by establishing them according to the hypothesis of the researcher [14].

Arrows used to show relationships between observed and unobserved variables are called a path. The numbers in these paths indicate how much of the unobserved variable is explained by the observed variable and what effect it has. A high coefficient value is the most important indicator of a strong relationship between variable constructs [15].

Material and Methods

The study was carried out with the application of the families of 204 children who were treated for Autism Spectrum Disorder (ASD) in the Child and Adolescent Psychiatry outpatient clinic of Inonu University Faculty Child And Adolescent Psychiatry Outpatient Clinic. Hospital. The data of the study were obtained retrospectively with clinical permission. The sample size of at least 200 in the analyzes made with SEM was considered sufficient for the studies [2,8].(the information about sample size was added) Therefore, the minimum number of samples determined for the study is 200. 204 children who applied to the clinic were included in the study. The data of the study were obtained retrospectively (It was added that the nature of the study was retrospective).

Research Permission and Ethics Committee

Approval was obtained from Inonu University Health Sciences Non-Interventional Clinical Research Ethics Committee and with the protocol code 2018/9-21.

Inclusion and Exclusion Criteria

Children between the ages of 3-12 and without any additional psychiatric disease were included in the study. Celiac, diabetes etc. Children with diseases and factors that directly affect nutrition were excluded from the study. 204 children who applied to the clinic were included in the study.

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Data Collection Tools

In the study, the sociodemographic data form and the Child Eating Behavior Scale were answered by the children's parents.

Sociodemographic Data Form

The gender and age of the child, the age of the parents, their educational status and occupation, the educational status of the child and the income status of the family were obtained with the sociodemographic data form.

Child Eating Behavior Scale

Developed by Wardle et al. in 2001, it is a 35-item scale prepared to examine children's eating behaviors and answered by children's parents. The scale, which consists of 8 sub-dimensions, was prepared in a 5-point Likert type. The sub-dimensions included are; Enjoyment of food (1, 3, 4, 5, 22), emotional overeating (2, 13, 15, 27), desire to drink (6, 29, 31), satiety responsive (7, 17, 21, 24, 26, 30, 33), slowness in eating (8, 18, 34, 35), emotional under-eating (9, 11, 23, 25), food fussiness (10, 16, 32), food responsiveness (12, 14, 19,20,28). The Cronbach alpha value for the sub-dimensions of the scale was calculated between 0.71 and 0.91 [16].

The Turkish validity and reliability study was performed by Yılmaz et al. in 2011 and the Cronbah alpha value was calculated as 0.69. The child attaches importance to eating and likes to eat, enjoyment of food sub-dimension, overeating in cases of anxiety and sadness, emotional overeating sub-dimension, constantly wanting to drink beverages, desire to drink sub-dimension, the desire not to eat and the feeling of being full quickly satiety responsive sub-dimension, the desire to act slowly during the meal and not move is measured by the slowness in eating sub-dimension, when unhappy and anxious emotional under-eating sub-dimension, the liking of new foods are measured by the food fussiness sub-dimension, and the desire to eat a lot is measured by the food-responsiveness sub-dimension. The confirmatory factor analysis indices calculated for the scale were found to be RMSEA 0.049, GFI 0.854, AGFI 0.835 and CFI 0.95 [17].

Statistical Analysis

The scale data set developed for the study was first subjected to multivariate normal distribution control using AMOS (Moment Structures) 23 program. Then, using the IBM SPSS 25.0 (Statistical Program in Social Sciences) Statistics package program, Explanatory Factor Analysis (EFA) was applied to obtain scale sub-dimensions, variance explanation percentages, KMO and Barttlet Test Results. One of the factor rotation methods, Varimax, was utilized to analyze data when using principal components analysis. The factor loadings matrix's columns are ranked in priority using the varimax approach, commonly known as maximum variability.

In the second stage, CFA analysis was performed using the AMOS program to control the scale structure provided by EFA. Dimensional eliminations were performed according to the low-value explained variance percentages found by EFA. The fit indices of the models prepared by testing 8-7-6 sub-dimensional scale structures were compared. The values found were compared with the information available in the literature, and it was checked whether the scale structure was preserved. By comparing the model indices found, the model that was sufficient for the scale was determined.

The level of significance (p) for comparison tests was equal to 0.05. Data values are expressed as numerical percentages. The reliability value of the scale was tested using Cronbach's α coefficient. Enjoyment of food was calculated as 0.81, emotional overeating 0.79, desire to drink 0.78, satiety responsive 0.77, slowness in eating 0.76, emotional under-eating 0.75, food fussiness 0, 74, food responsiveness - 0.73 and 0.82 according to the total scale.

Results

Sociodemographic Information

204 children were included in the study. Information about children and their families is given in Table 1.

Table 1. Sociodemographic information of children and families

Variable	Group	n	%
Gender	Girl	49	34.3
	Boy	155	76
Special Education	No	115	56.4
	Yes	89	43.6
Age of Mother	20 – 29	37	18.1
	30 - 39	138	67.6
	40 – 49	1	0.5
	50 – 59	1	0.5
Age of Father	20 – 29	4	2
	30 - 39	124	60.8
	40 – 49	65	31.9
	50 – 59	11	5.4
Education of Mother	Not Schooled	28	13.7
	Primary Education	91	44.6
	High School	52	25.5
	University and Upper Education	33	16.2
Education of Father	Not Schooled	1	0.5
	Primary Education	73	35.8
	High School	89	43.6
	University and Upper Education	41	20.1
Occupation of Mother	Unemployed	153	75
	Employed	51	25
Occupation of Father	Unemployed	11	5.4
	Employed	193	94.6

n; frequency, %; percent

While 49 (24.1%) of the children included in the study were girls, 155 (75.9%) were boys, 115 (56.4%) were not receiving special education and 89 (43.6%) were receiving special education (Table 1). (datas were controlled and fixed) Twenty-eight (13.7%) of the participating mothers and 1 (0.5%) of the fathers did not go to school. While the number of mothers who graduated

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from primary school is 91 (44.6%), the number of fathers is 73 (35.8%). While the number of mothers who graduated from high school was 52 (25.5%), the number of fathers was 89 (43.6%), while the number of mothers with a university degree or higher was 33 (16.2%) the number of fathers was 41 (20.1%) (Table 1).

Children's Eating Behavior Scale

Before EFA, Kaiser-Meyer-Olkin (KMO) and Barlett's Test of Sphericity were applied. Barlett's Test result was calculated as 4906.161 and KMO coefficient as 0.892 ($p<0.05$). Analyzes were carried out by evaluating the principal components analysis and component matrix table. The total variance explanied values of the scale sub-dimensions obtained as a result of EFA are given in Table 2.

Table 2. Factors obtained as a result of Varimax and percentages of total variance explanation

Number of Factor	Eigenvalue (λ)	Variance (%)	Cumulative Variance (%)
Satiety responsive (1)	10.381	13.693	13.693
Food responsiveness (2)	4.824	12.402	26.095
Emotional overeating (3)	2.347	10.429	36.524
Enjoyment of food (4)	2.043	10.090	46.614
Slowness in eating (5)	1.750	8.029	54.643
Desire to drink (6)	1.510	6.359	61.002
Emotional under-eating (7)	1.208	5.940	66.942
Food fussiness (8)	1.161	5.126	72.068

Table 3. Calculated goodness of fit indices for models

Fit Indexes	Models by Size			Acceptance Ranges		Interpretation
	8	7	6	Good	Acceptable	
GENERAL MODEL FIT						
CMIN (Chi-Square Goodness of Fit, χ2)	766.77	653.72	517.43	The model with the smallest value is chosen.		It is a measure of similarity between variance and covariance matrices. The conformity of the observed covariance structure for the model and determined by its structure is tested.
p	0.001	0.001	0.001	$p < 0.05$		
CMIN / df	1.417	1.462	1.545	≤ 3	≤ 4 -5	The low calculated value indicates the similarity of the covariance structures. The number of samples is effective in calculating the index. Increasing the number of samples will cause a decrease in the χ2 value.
COMPARATIVE FIT INDEX						
NFI (Normed Fit Index)	0.842*	0.860*	0.881*	≥ 0.95	0.94 -0.90	In the absence of latent variables in the model, the independent and determined model compares the χ2 values. There is no χ2 distribution requirement.
CFI (Comparative Fit Index)	0.947*	0.950	0.954	≥ 0.97	0.95 -097	In the absence of latent variables in the model, the independence model compares the covariance matrices of the proposed model. It is sensitive to the number of samples.
IFI (Incremental Fit Index)	0.948	0.951	0.866*	≥ 0.95	0.94 -0.90	It is obtained as a result of calculating the NFI value with df. It removes the effect of the sample in the model calculations.
RMSEA (Root Mean Square Error of Approximation)	0.045	0.048	0.052	≤ 0.05	0.05 -0.08	It is aimed to calculate the error between the observed and calculated covariance matrices at a minimum level. It is sensitive to the number of samples and may cause rejection of the model to be accepted in case the sample size is small.
ABSOLUTE FIT INDEX						
GFI (Goodness of Fit Index)	0.832*	0.843*	0.851*	≥ 0.95	0.90 -0.95	It is an alternative for the value of χ2. It is calculated independently from the number of samples. It is also known as the sample variance explained by the model. It is similar to the R2 value calculated in multivariate regression.
MODEL COMPARISON FIT INDEXES						
ECVI (Expected Cross Validation Index)	4.990	4.334	3.524	Value smaller than the compared model		It compares the covariance matrices of the models with similar sample numbers with the calculated model. It is based on incompatibility between matrices.
AIC (Akaike Information Criterion)	1014.77	987.72	715.43	Value smaller than the compared model		It is used to make the estimation of the most appropriate model with the obtained data. It is preferred in arrangements in the number of parameter estimations.

With EFA, 8 sub-dimensional scale structures were obtained. The percentage of total variance explanation of the 8 sub-dimensions was calculated as 72,068%. While the highest percentage was found in the sub-dimension of satiety responsive (13.693%), the lowest percentage of variance explanation was observed in the sub-dimensions of emotional under-eating (5.49%) and food fussiness (5.126%) (Table 2). With the EFA, the original scale structure was provided and the distribution of the questions to the sub-dimensions was obtained.

Competing Models

The percentages of variance explained by the competing models for the selected models were considered. The first model was prepared with 8 sub-dimensions. After analyzing the model, it was found that the percentage of variance explained was the lowest in the sub-dimensions of emotional under-eating (5.49%) and food fussiness (5.126%), and the total percentage of variance explained was 61.002% when these two smaller

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dimensions were excluded (Table 2). Therefore, first, the food fussiness sub-dimension was removed and a second model with 7 sub-dimensions was developed. Then, the emotional under-eating sub-dimension was removed and a third model with 6 sub-dimensions was prepared. The indices and goodness of fit values of all three models were calculated and compared, and the most suitable model was selected. CFA was applied for the 8, 7 and 6 sub-dimension scale models, which were determined as the appropriate model selection.

Statistical significance in each model established in the study was tested with model goodness-of-fit indices. The percentage of variance explanation for each model was determined by the CFI value.

The Results of the Confirmatory Factor Analysis of the Child Eating Behavior Scale

Diagrams of the CNBS model with 8 sub-dimensions and 35 items, 7 sub-dimensions with 32 items and 6 sub-dimensions with 28 items were drawn in the AMOS 23 program, CFA was applied and the indexes of the models were calculated. The path diagrams of the 6 sub-dimensions (last) model is given in Figure 1.

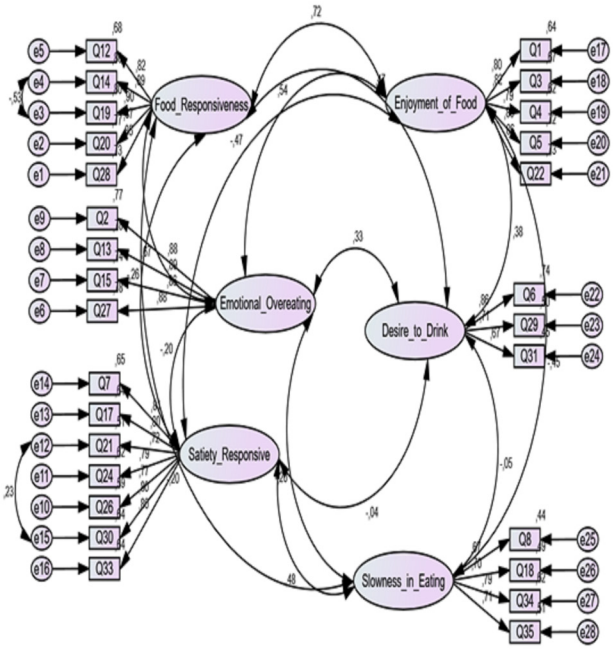

Figure 1. CNBS CFA path diagrams (6 sub-dimensions)

Rectangles in the model represent scale items (observed variables), ellipses represent sub-dimensions (latent variables), one-way arrows represent one-way effect, two-way arrows represent covariance values between variables, and ellipses drawn between e1-e35 represent error terms.

Multivariate Normal Distribution

In order to evaluate the coefficients and indices obtained after CFA, it was first checked whether the models provided the assumption of multivariate normal distribution. In order to control the multivariate normal distribution, the "Observations farthest from the centroid (Mahalonobis Distance)" value in the AMOS program menus was used. As a result of the analysis, the skewness values were calculated as 4.800 in 8 sub-dimensional models, 5.569 in 7 sub-dimensional models and 6.126 in 6 sub-dimensional models (c.r. ≤ 8). “Maximum Likelihood Estimator” was used because of the multiple normal distribution [18].

The number of samples needed to calculate appropriately accurate findings using the Maximum Likelihood Estimator with the multivariate normal distribution is anticipated to be between 150 and 200 [19].

Model Goodness of Fit Indices

For the models, general model fit, comparative model fit, absolute fit, model comparison fit indices were calculated separately. The goodness of fit indices calculated for the models and their explanations are given in Table 3.

The $\chi 2/df$ value was calculated as 1.417 in the 8-dimensional model, 1.462 in the 7-dimensional model and 1.545 in the 6-dimensional model, and the RMSEA value was calculated as 0.045 in the 8-dimensional model, 0.048 in the 7-dimensional model and 0.052 in the 6-dimensional model (Table 3). AIC values were calculated as 1014.77 in the 8-dimensional model, 987.72 in the 7-dimensional model, and 715.43 in the 6-dimensional model (Table 3). When the models were examined, it was seen that the model with the best fit was the 6-dimensional model. The sub-dimensions of the model were determined as enjoyment of food, emotional overeating, sesire to drink, satiety responsive, slowness in eating, and emotional under-eating. Food fussiness and emotional under-eating sub-dimensions were removed from the scale according to the explained variance percentages.

Discussion

A significant number of studies in the literature have examined the role of CFA. But the number of studies on CFA and competing models is negligible. Our study is the first model in the literature to use CFA competing models on a scale. The most striking result emerging from the data is that short forms of scales with CFA competing models can be prepared to facilitate data collection for researchers. It is a well-known the fact that CFA is used for scale modeling.

In the study, the Children's Eating Behavior Scale, which was answered by parents, was used to determine the eating habits of children with ASD. For the scale, 204 parents were included in the study. With the multivariate normal distribution, it is expected that the number of samples to be used to calculate adequately accurate results with the Maximum Likelihood Estimator is expected to be between 150-200 [19]. If the variables used in the study do not have a normal distribution and the kurtosis skewness coefficient is high, the number of samples to be used should be at least 10 times the number of variables [20]. The minimum error

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to be obtained in the established models is provided by adapting the data set to the multivariate distribution [21].

According to the KMO coefficient, the sample size was found to be at a very good level for the study [22]. When applying principal components analysis, one of the factor rotation methods Varimax was used for analysis. The varimax method, also known as maximum variability, prioritizes the columns in the factor loadings matrix. The rotation process is performed to ensure that factor variances are maximized [23]. The structure of the Children's Eating Behavior Scale was modeled using EFA. Eight sub-dimensions and a 35-question model were obtained in accordance with the original scale structure [16].

The models were decided by using the competitive models objective and the percentages of variance explained in the selected models. A model variance percentage of at least 60.0% (95) is desired. For this reason, while the first model was established with eight sub-dimensions, the sub-dimensions of food fussiness (5.126%) and emotional under-eating (5.49%) were removed from the model, respectively, so seven and six-dimensional CFA models were established.

In models established with EFA, all items are released in the model and distribution into sub-dimensions is expected as a result of the analysis. However, in models established with CFA, applications are made by knowing which sub-dimension (latent variable) the scale items belong to [24-25]. Establishing the structure in EFA also tests the accuracy of the structure identified with CFA [6]. While it is not known how many latent variables will be obtained as a result of EFA, the number of latent variables was determined before the model was established with CFA [26-27]. While EFA takes into account the factors explaining the variance of the data, CFA now considers the variance-based fit [7]. While model significance cannot be tested as a result of EFA, model compatibility can be checked as a result of fit indices obtained with CFA [2]. In addition, one of the most important advantages of CFA analysis is that the covariance structures are presented to researchers visually [4].

For the three models established, firstly, multivariate normal distribution control was provided, the estimation method to be used was determined and the goodness of fit indices were calculated. Due to the multivariate normal distribution in the data in the models of the study, the "Maximum Likelihood Estimator" was used for estimation [21]. Many indices with different numbers and features are used in order to evaluate the compatibility between the model defined by the researchers and the basic model [18].

When the indices of the six-dimensional model are examined, the RMSEA value of 0.051 indicates that the sample size is sufficient for the model. The $\chi 2/df$ value of 1.545, which is one of the most important criteria showing the significance of the model, shows that the model fit is very suitable for the data structure. Other fit indices of the model were also found to be in the desired range ($\chi 2/df < 3$, IFI>0.90, CFI>0.90, RMSEA<0.80). When the AIC and ECVI values were examined, the lowest coefficient was obtained in the 6-dimensional model. Therefore, the 6-dimensional model was found to be the best model both in terms of fit and in comparison to other models [5, 9, 18].

Goodness of fit indexes are calculated in order to analyze the accuracy of the models obtained by CFA. The results are given by controlling the statistical significance of the model by giving more than one index instead of using only one of the indexes calculated at the end of the model. [8, 24-25, 29].

CEBS is a scale that was first developed by Wardle et al. in 2001. In 2008, Viana and Sinde made the Portuguese adaptation. In their study conducted in the Netherlands in late 2008, Sleddens and Kremers revealed a 7-sub-dimension structure of the scale by combining the emotional overeating and food responsiveness sub-dimensions into the overeating sub-dimension. With the prepared seven sub-dimensions, an increase in the internal consistency coefficient of the scale was achieved. However, the narrow age range used in the study limited the generalizability of the study [17].

CEBS, which was adapted into Turkish by Yılmaz et al. in 2011, was modeled in its original structure [17]. In 2012, questions were asked in the revised scale, but the dimension reduction method was not used [30]. In this study conducted in 2012, the relationship between the CEBS and the parental feeding style scale was additionally examined with canonical correlation, but no size reduction was made [30]. In 2014, Özer et al. examined the relationship between children's eating behaviors and obesity using CEBS [31]. In all studies using CEBS, a 35-item model with eight sub-dimensions was used. In our study, eight-, seven- and six- dimensional models were examined separately.

In this study, it was found that the CEBS applied to the parents of children diagnosed with ASD could measure food responsiveness, emotional overeating, enjoyment of food, desire to drink, satiety responsive, slowness in eating sub-dimensions and nutritional behaviors. The calculated indices and values showed that the sample size for the study was sufficient.

Considering the issue addressed the study, bringing competing models to the literature will provide a new perspective in scale validity and reliability studies. In our study, it has been shown that the long structures of the scales have explanatory and sufficient measuring power in short. The loss of time experienced while collecting data in scales with CFA competing models, the desire not to participate in the studies due to the long sample units, the difficulties experienced in data entry, and the financial budget allocated for the studies will be minimized.

Conclusion

Our study is the first to use competing models in confirmatory factor analysis to reduce scale dimensions. The CEBS consists of 35 items and a model consisting of eight sub-dimensions: emotional overeating, food responsiveness, desire to drink, Food responsiveness, Slowness in eating, emotional under-

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eating, and food fussiness. However, the two sub-dimensions, food fussiness and emotional under-eating, which explained the lowest percentage of variance estimated by EFA, were separately removed and the scale was restructured. The application of different evaluation methods can be used in future studies to increase the level of information obtained, depending on the sample size and the change in structure.

The CFA used in our study is presented with competing models, where the scale to be used in a study is not long, but it is sufficient to give sufficient and correct information.

Conflict of interests
The authors declare that there is no conflict of interest in the study.

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Ethical approval
Approval was obtained from Inonu University Health Sciences Non-Interventional Clinical Research Ethics Committee and with the protocol code 2018/9-21.

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