Rasch Analysis of Cannabis Use Disorder in an Adult Inpatient Sample

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ABSTRACT

Objective: The Diagnostic and Statistical Manual of Mental Disorders version 5 (DSM-5) defines cannabis use disorder as a polythetic unidimensional diagnosis (>2 symptoms from up to 11), but few studies have empirically evaluated the latent structure of CUD. Rasch analysis is a psychometric technique that has previously been used to validate unidimensional scales, like DSM-5 CUD. **Method:** In this study, the Rasch model was used to evaluate the DSM-5 CUD criteria in a clinical sample of adults receiving inpatient treatment for substance use disorder (n = 249) reporting active cannabis use at admission. The unidimensionality of the criteria was evaluated using the Martin-Löf test and the nonparametric $-T_2$ test of Ponocny. Model fit was assessed using the χ^2 goodness of fit test for individual items. **Results:** Results supported the unidimensional structure of the criteria. Symptom # 3 was the least endorsed, highest severity item. Conversely, symptom #9 was the most endorsed and had the lowest severity estimate. Overall, the data fit the Rasch model well, although misfit was observed for symptom # 8. **Conclusions:** Rasch's analysis of CUD symptoms in an inpatient sample broadly supports the DSM-5 CUD syndrome. Further examination is needed to determine if removing or revising the hazardous use symptom criterion in future DSM revisions would improve diagnostic measurement.

Key words: = cannabis; RASCH; CUD; addiction; psychometric analysis

Cannabis is the third most-used psychoactive drug globally after alcohol and tobacco (Connor et al., 2021). Cannabis use directly affects vital areas of the brain, especially those responsible for memory, learning, emotion, decision-making, attention, coordination, and reaction time (Filbey et al., 2014). There is also a risk of developing psychosis and bronchitis with continuous use (Mattick, 2017; Meier et al., 2012). Approximately 3 in 10 people who use cannabis regularly will develop a cannabis use disorder (CUD; Hasin et al., 2015), the clinical diagnosis for clinically significant cannabis misuse. Globally, 22.1 million people met the diagnostic criteria for CUD in 2016 (Degenhardt et al., 2018).

According to the most recent version of the Diagnostic and Statistical Manual of Mental Disorders, version 5 (i.e., DSM-5), CUD is diagnosed when a person endorses at least 2 out of the 11 symptoms (Hasin et al., 2013; Lago et al., 2016). In other words, DSM-5 defines CUD as a polythetic unidimensional diagnosis (>2

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symptoms from up to 11; Bartolucci et al., 2015). In addition, the severity of the disorder is based on the number of endorsed criteria: 2–3 = mild, 4–5 = moderate, ⩾ 6 = severe condition (Murphy & Hallahan, 2016).

The fifth edition of the DSM addressed issues concerning substance use disorder (SUD) diagnostic criteria (including CUD) that were identified with prior versions to enhance diagnostic specificity and increase clinical utility (Murphy & Hallahan, 2016). The main differences from the previous version were combining abuse and dependence into a single diagnosis, adding withdrawal and craving criteria, and removing the legal criterion (Fink et al., 2022). Several studies have suggested that the abuse and dependence criteria do not consistently capture the mildest or most severe use conditions and instead represent a single continuum of severity rather than two separate disorders (Saha et al., 2006; Sellman et al., 2014). Sophisticated statistical techniques, such as item response theory modeling, have been used to guide decisions about which criteria to include and exclude in new DSM versions (Saha et al., 2012). Further, due to insufficient evidence, cannabis withdrawal was not included in earlier DSM versions; it was added in DSM-5 based on studies conducted after the publication of DSM-IV (Budney et al., 2004). The continuous evaluation of the latent structure of CUD or SUDs, in general, can help refine the criteria that are used for diagnosis and classification for better accuracy and improved estimates of the sensitivity and specificity of each diagnostic sign or symptom (Ruscio & Ruscio, 2008). For instance, the psychometric properties of cannabis abuse and dependence (DSM-IV) have been explored before using NESARC data (Lynskey & Agrawal, 2007). Results from this research suggested the inclusion of a severity spectrum to describe CUD. Regression analyses also validated CUD criteria and severity in the DSM-5 (Fink et al., 2022). Further, factor analysis was used to assess dimensionality, and the results showed unidimensionality of the 11 criteria of DSM-5 (Shmulewitz et al., 2023). Nevertheless, the Rasch model has not been used before to evaluate the latent structure of the 11 criteria of DSM- 5 CUD.

The Rasch model is a statistical technique that is well-suited for evaluating unidimensional latent diagnoses. Introduced by Georg Rasch (Rasch, 1960), it is a one-parameter logistic item response model in which both the item difficulty and the person's ability are scaled independently along an underlying latent continuum using an equal interval log odds scale (Kahler & Strong, 2006) the Rasch model uses the logit of the probability of a person endorsing an item to model the difference between a person's CUD severity level and the item's severity level. If the item severity level is greater than the person's severity level, the probability of endorsement will be low. Like the deterministic Guttmann scaling method (Stouffer et al., 1950), the Rasch model assumes that endorsing a severe item means that the person also endorsed all less severe items in the index; the only difference is that the Rasch model allows for probabilistic ordering of item severities (Kahler & Strong, 2006). Thus, the Rasch model can be used to find the most likely pattern of responses for each possible total score, evaluate the relative severity of each item, and compare sub-groups through item severity estimates from independent analyses (as the estimation of item characteristics does not depend on the distribution of the latent construct; Strong et al., 2003).

The Rasch model has been used in prior research to validate measures of psychiatric disorders, including motivation for treatment of drug disorders (Martinez-Gonzalez et al., 2020), nicotine dependence symptoms (Strong et al., 2003), gambling problems (Strong & Kahler, 2007), food addiction (Saffari et al., 2022), internet addiction (Lu et al., 2022), and DSM-5 items for alcohol use disorder (AUD; Ingesson et al., 2022). However, the Rasch model has not been previously used to evaluate DSM-5 CUD criteria.

The present study extends previous psychometric evaluations of the DSM-5 by evaluating CUD criteria using Rasch analysis in a clinical sample of adults receiving inpatient treatment for SUD. More specifically, we aimed to (1) assess the fit of the criteria to the Rasch model and (2) examine the severity and range of the criteria. We hypothesized that the DSM 5 criteria would be a good fit for the Rasch model. Moreover, If the current data fit the model well, the probability of endorsing a particular criterion will increase as the individual's CUD severity exceeds the severity expressed by the criterion (Bond & Fox, 2007; Kahler & Strong, 2006). This means that those with more severe CUD are more likely

to endorse all symptoms, and less severe items are more likely to be endorsed by all subjects (Bond & Fox, 2007). More broadly, support for a unidimensional construct of CUD would support the contemporary DSM-5 conceptualization.

METHODS

Participants and Procedure

Participants in this study were adults who voluntarily entered a large inpatient SUD treatment program located in Guelph, Ontario, between April 26, 2018, and February 28, 2020. The program consisted of 35 – 42 days of abstinence-based treatment for adults aged 19+ with various SUDs. Data was collected using electronic, self-administered assessments as part of routine clinical assessment upon admission to the program. The assessment consisted of psychometrically validated scales that measured a variety of clinically relevant domains, including the DSM-5 SUD symptom checklist for each endorsed substance (e.g., cannabis, alcohol, cocaine, etc.). This research protocol received ethical approval from the Regional Centre for Excellence, Research Ethics Board in Guelph, Ontario, Canada (protocol #19-8).

During the study, 1639 patients entered the treatment program and completed the clinical assessment. The responses from the first treatment episode were retained for those patients who were admitted more than once over the study period (n = 83). The principal eligibility criteria were: 1) cannabis use, 2) no missing responses for the DSM-5 CUD checklist items, 3) positive for CUD (i.e., endorsed at least two symptoms from the DSM-5 checklist), 4) reported only recreational cannabis use, and 5) were discharged from the addiction program, leaving a final sample of 249 patients for the analysis. Among these 249 patients, 90.4% endorsed alcohol use, and 65.1% endorsed multiple substance use (cocaine, alcohol, and cannabis) By examining the severity of each endorsed substance, cannabis was showed the highest severity of use by 18.5%. The average age of the sample was 33.9 years; 78.3% self-reported as male, 70.7 % as employed, and 89.6 % as white (see Table 1).

Table 1. *Socio-Demographic and Clinical Characteristics*

Demographics % or Mean (SD)	N = 249
Sex (%)	
Males	78.3 %
Age Mean (SD)	
years	33.9 (9.9)
Education (%)	
Some college/ university	54.6%
Employment (%)	
Employed	70.7%
Marital Status (%)	
Married or partnered	31.3%
Race (%)	
Caucasians	89.6%
First Nation, Inuit, or Metis	2.4%
Asian	0.8%
African, Caribbean, Black	1.2%
Latin American	0.4%
Multiple or mixed	4.4%

Measures

Symptoms of CUD. Symptoms of CUD were assessed using the 11 items of the DSM-5 SUD checklist (Hasin et al., 2013). Response options were dichotomous (yes or no), indicating whether the individual had experienced each symptom over the past 90 days. Items are presented in Table 2, ordered by their endorsement frequency. Based on the DSM-5 guidelines, individuals who endorsed two or more symptoms would meet the criteria for diagnosis of CUD.

Data Analysis

The measurement properties of the 11 items of the DSM-5 CUD checklist were examined by evaluating the fit of the data to the Rasch model. The primary assumption of the Rasch model is unidimensionality (i.e., that the DSM-5 CUD items measure only a single construct). An exploratory common factor analysis of the inter-item tetrachoric correlations was performed to test this assumption. Both eigenvalues and factor loadings were examined. It was concluded that the measure was unidimensional if a single factor accounted for a large proportion of the variance in responses and if all items loaded strongly (> .30) on the single factor (Ponocny, 2001). To assess unidimensionality, the following tests were applied: the Martin-Löf test that uses the likelihood ratio test (Christensen et al., 2002) and the nonparametric - T_2 test of Ponocny (Ponocny,

2001) that checks for multidimensionality within model-deviating subscales via decreased dispersion (variance was used) of subscale person raw scores (Mair et al., 2022).

Another assumption of the Rasch model is local independence (i.e., the item responses are independent of one another). To test this, the standardized residual correlations of the items after fitting the Rasch model were first examined. A principal components analysis (PCA) of the residuals was also conducted. The assumption was considered violated if an inter-item residual correlation was more than 0.2 greater than the average correlation (Christensen et al., 2017) and/or if components extracted from the PCA accounted for greater than 1.5 units of variance (Linacre, 1998).

The item parameters of the Rasch model were computed using conditional maximum likelihood (CML) estimation with the sum of the item parameters fixed to zero. Item and person severity estimates are expressed in equal interval log odds units (logits). The Rasch model fit was assessed using the infit (inlier-sensitive or information-weighted fit) and outfit (outlier-sensitive fit) statistics based on the mean-square residuals. The acceptable range for model fit is 0.6 to 1.4 (Wright & Linacre, 1994). Lower values indicate an overfit to the model (i.e., responses are too predictable), whereas higher values indicate an underfit to the model (i.e., data are too noisy; Kahler & Strong, 2006). The χ^2 goodness of fit test for individual symptoms (Tennant & Conaghan, 2007) is a significant test that indicates an item misfit with the model. Finally, the symptom-total correlations were computed, the point biserial correlations between a given item, and the sum of the remaining items. More significant correlations indicate that the item has a stronger association with the latent construct and is more efficient in predicting responses (Kahler & Strong, 2006). The person separation reliability, which indicates the measure's ability to reliably order persons along the latent continuum and discriminate the sample into levels, was also estimated. The person separation reliability is similar in interpretation to Cronbanch's α. However, it is more conservative and less misleading as it adjusts for the fact that data are never a perfect fit to the Rasch model (Linacre, 1997). All analyses were performed using R version 4.2.0 (R Core Team, 2022).

RESULTS

Unidimensionality and Local Independence

The principal iterated common factor analysis of the tetrachoric correlations supported a one-factor solution. The first eigenvalue of the common factor solution was 4.91, which was almost six times larger than the second eigenvalue of 0.81. Loadings on the first factor ranged from 0.41 to 0.81, except for "Recurrent cannabis use in physically unsafe environments (symptom 8)" (0.29), and the first factor accounted for 45% of the common variance among the CUD items. The Martin-Löf test (with the mean as the subgroup criteria) failed to reject the null hypothesis of unidimensionality (LR = 29.22, p = 0.454), and the nonparametric T_2 test suggested no evidence of multidimensionality (p = 1). Overall, for the single factor solution, all the item loadings were > .30, with one exception (symptom 8, "recurrent cannabis use in physically unsafe environments," which was .29 ~ .30), and both the Martin-Löf test and nonparametric T_2 test supported unidimensionality, it was concluded that the syndrome was unidimensional.

All inter-item (symptom) standardized residual correlations after fitting the Rasch model were less than 0.2 larger than the absolute value of the average correlation (0.09), except for the correlation between symptom 6 (Continued cannabis use despite it causing significant social or interpersonal problems) and item 10 (Tolerance: Individual requires increasingly higher doses of the substance to achieve the desired effect, or the usual dose has a reduced effect; -0.34). Since symptom responses should not influence one another after accounting for the underlying construct (Wright & Linacre, 1994), this suggests that the local independence assumption was violated for that pair of symptoms. Principal components analysis of the standardized residuals further supported the unidimensionality of the items. However, it also indicated that the local independence assumption was violated as the eigenvalue of the first contrast was 1.84 (which is above the suggested cutoff value of 1.50 but still <2). Symptom 4 (Experiencing craving, a pressing desire to use cannabis, 0.49), symptom 5 (Cannabis use impairs the ability to fulfill major obligations at work,

school, or home, -0.48), item 6 (Continued use of the substance despite it causing significant social or interpersonal problems, -0.71), symptom 7 (Reduction or discontinuation of recreational, social, or occupational activities because of substance use, -0.45), item 10 (Tolerance, 0.53), and item 11 (Withdrawal, 0.46) all had high loadings (>0.4) on the first component.

There was not enough evidence of local independence of symptom item responses. Local dependency always exists in empirical data, but it only affects the spacing, not the ordering of measures.

Model Fit

Table 2 presents each item's percentage endorsement, difficulty estimates with standard errors, item-total correlations, and infit and outfit statistics. The range of infit values was 0.749 to 1.290, and the range of outfit values was 0.719 to 1.632. The infit values for all the 11 items were within the acceptable range of 0.6 to 1.4. For (symptom 8) "Recurrent cannabis use in physically unsafe environments," the outfit value was above the acceptable range and can be considered to have relatively less predictable responses. The symptom-level chi-square goodness of fit tests indicated that two symptoms, (symptom 2), "Persistent desire to cut down or regulate use. The individual may have unsuccessfully attempted to stop in the past" (p = 0.001) and (symptom 8; p < 0.001), had a suboptimal model fit (see Table 3). The range of the total correlations between the symptoms was 0.196 (symptom 8) to 0.593 (symptom 1: Consuming the substance in larger amounts and for a longer amount of time than intended). Finally, the estimated person separation reliability was 0.660, which suggests that the symptoms did not reliably order participants in the sample. A misfit was observed for symptom # 8, "Recurrent cannabis use in physically unsafe environments".

Table 2. *Items, Endorsement, and the Rasch Model Estimates*

Criteria	Symptom	% Endorsed	Item Total Correlation	Item difficulty Parameter	SE	Infit	Outfit
1	Consuming cannabis in larger amounts and for a longer amount of time than intended	53.4	0.59	-0.27	0.14	0.75	0.72
2	Persistent desire to cut down or regulate use	49.4	0.28	-0.05	0.14	1.27	1.33
3	Spending a great deal of time obtaining, using, or recovering from the effects of Cannabis	28.9	0.56	1.26	0.17	0.90	0.81
4	Experiencing craving, a pressing desire to use cannabis	51.4	0.55	-0.16	0.14	0.83	0.78
5	Cannabis use impairs the ability to fulfill major obligations at work, school, or home	32.1	0.53	1.02	0.16	0.94	0.87
6	Continued use of cannabis despite it causing significant social or interpersonal problems	36.9	0.51	0.69	0.15	0.96	0.88
7	Reduction or discontinuation of recreational, social, or occupational activities because of cannabis use	37.8	0.59	0.64	0.15	0.84	0.81
8	Recurrent cannabis use in physically unsafe environments	60.2	0.19	-0.63	0.14	1.29	1.63

9	Persistent cannabis use despite knowledge that it may cause or exacerbate physical or psychological	81.1	0.23	-1.82	0.16	0.97	0.94
10	Tolerance: individual requires increasingly higher doses of cannabis to achieve the desired effect, or the usual dose has a reduced effect	74.3	0.29	-1.39	0.15	0.95	0.94
11	Withdrawal: A collection of signs and symptoms that occurs when blood and tissue levels of the substance decrease. Individuals are likely to seek the substance to relieve symptoms.	36.9	0.586	0.69	0.15	0.85	0.79

Table 3. *A Chi-Square Test for Individual CUD Criteria: A Significant Test Indicates an Item Misfit to the Model*

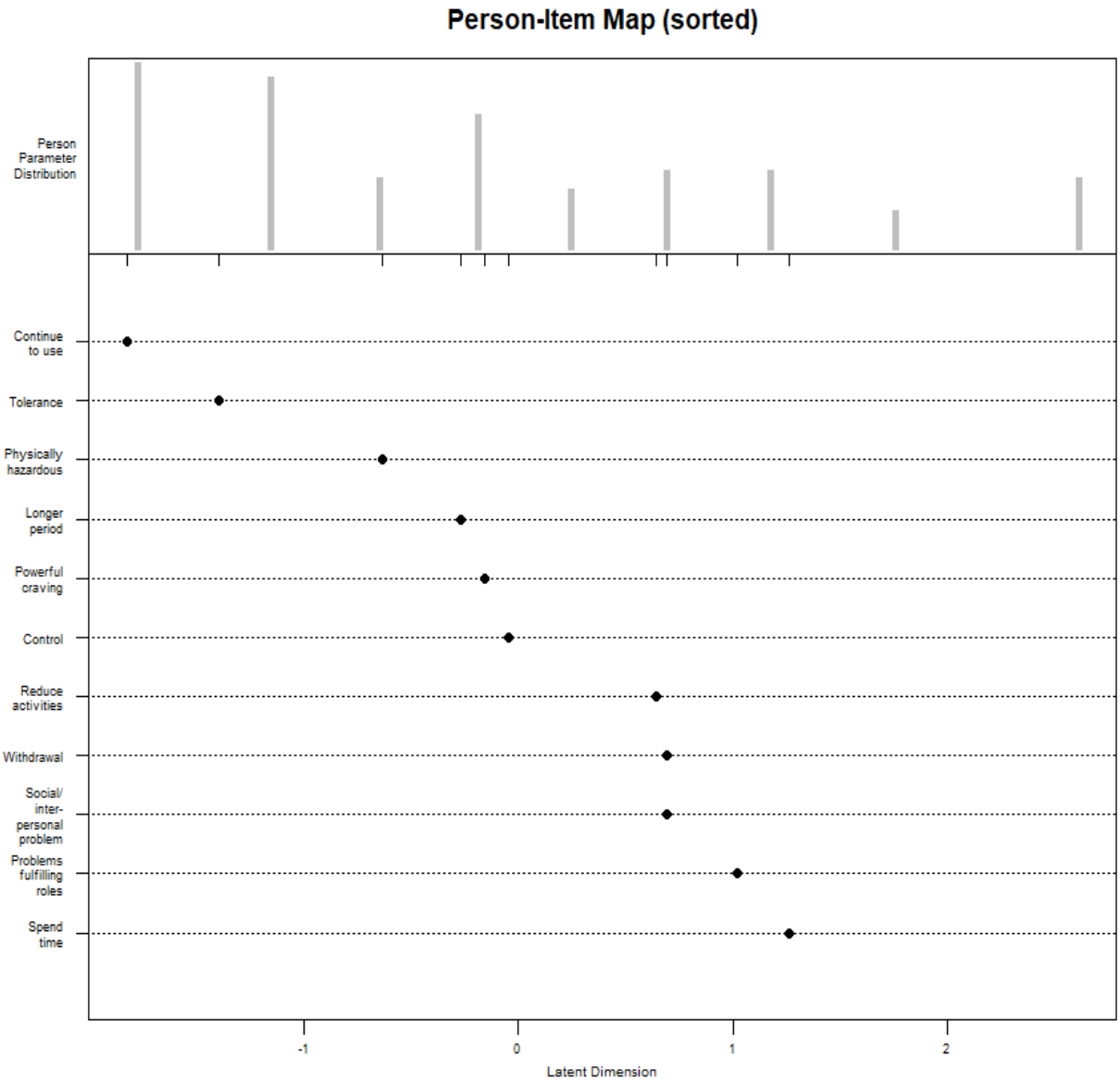
Number	Symptom	χ^2	*p* - value
1	Consuming cannabis in larger amounts and for a longer amount of time than intended	164.64	.99
2	Persistent desire to cut down or regulate use	304.43	.001
3	Spending a great deal of time obtaining, using, or recovering from the effects of Cannabis	185.78	.98
4	Experiencing craving, a pressing desire to use cannabis	177.97	.99
5	Cannabis use impairs the ability to fulfill major obligations at work, school, or home	199.27	.91
6	Continued use of cannabis despite it causing significant social or interpersonal problems	202.61	.89
7	Reduction or discontinuation of recreational, social, or occupational activities because of cannabis use	186.63	.98
8	Recurrent cannabis use in physically unsafe environments	373.71	< .001
9	Persistent cannabis use despite knowledge that it may cause or exacerbate physical or psychological problems	216.51	.69
10	Tolerance: An individual requires increasingly higher doses of cannabis to achieve the desired effect, or the usual dose has a reduced effect	214.44	.73
11	Withdrawal: A collection of signs and symptoms that occurs when blood and tissue levels of the substance decrease. Individuals are likely to seek the substance to relieve symptoms. . Individuals are likely to seek cannabis to relieve the symptoms	181.74	.99

Item (Symptom) Difficulty Estimates and Person-Item Map

The item severity, [the symptoms that are least likely (severe) or more likely (easy) to be endorsed], estimates ranged from -1.822 to 1.260, related to the endorsement percentage (Table 2). Symptom 3, "Spending a great deal of time obtaining, using, or recovering from the effects of cannabis use," was the most difficult (severe) symptom with the lowest endorsement (28.9%), and symptom 9 (Persistent use despite the knowledge that it may cause or exacerbate physical or psychological problems) was the least difficult symptom with the highest endorsement (81.1%). The distance between the easiest item (symptom 9) and the next easiest item, "Tolerance" (symptom 10), was 0.429 logits. The distance between the most difficult item (symptom 3) and the next most difficult (symptom 5), "Cannabis use impairs the ability to fulfill major obligations at work, school, or home", was 0.237 logits.

Figure 1 presents the person-item map where the symptoms are sorted in increasing order according to their location on the latent CUD severity dimension. All person and symptom locations are expressed in logits. From the upper panel, the person parameter distribution is slightly positively skewed. Patients with the lowest severity estimates answered 'no' to almost every symptom, and those with the highest severity estimates answered 'yes' to almost every symptom. From the lower panel of the person-item map (symptom 9), "Persistent use despite the knowledge that it may cause or exacerbate physical or psychological problems." was the least severe symptom (i.e., easiest) and (symptom 3), "Spending a great deal of time obtaining, using, or recovering from the effects of cannabis," was the most severe symptom (i.e., hardest); as symptoms fall higher on the latent continuum they are less likely to be endorsed. The following symptoms: [(symptom 7), "Reduction or discontinuation of recreational, social, or occupational activities because of cannabis use," (symptom 11), "experiencing withdrawal symptoms, which can be relieved by taking more cannabis," and (symptom 6), "Continued use of cannabis despite it causing significant social or interpersonal problems"], exhibited very similar levels of severity.

Figure 1. *Person-Item Map Sorting CUD Symptoms by Latent Severity Dimension**



Note. *All person and item locations are expressed in logits. Patients with the lowest severity estimates answered 'no' to almost every CUD symptom, and those with the highest severity estimates answered 'yes' to almost every symptom.

DISCUSSION

The present study evaluated the DSM-5 CUD criteria using Rasch analysis in a sample of patients receiving inpatient treatment for SUD. Previous research has debated whether SUDs are a unidimensional or a multidimensional diagnostic phenomenon and whether the importance of criteria differs by severity (Boness et al., 2021), broadly supporting the unidimensionality of the 11 DSM-5 SUD criteria (Kervran et al., 2020), but few studies have examined the construct validity of the DSM-5-CUD diagnosis. The present study's findings extend this previous work by showing that Rasch's analysis supports the DSM-5 conceptualization of CUD as a polythetic unidimensional syndrome.

Our results showed that the data fit the Rasch model well in terms of the overall model fit. However, misfit was observed for symptom # 8, "Recurrent cannabis use in physically unsafe environments," where the outfit value was above the acceptable range and had a significant χ^2 test. A high outfit mean square value indicates that this symptom may be more sensitive to extreme

responses. This is consistent with a previous study assessing the properties of the DSM-5 CUD criteria in a sample of individuals in addiction treatment (Kervran et al., 2020). In that study, the results of a factor analysis indicated that the hazardous use criterion had the lowest factor loading of all the criteria. Another study applying a 2-parameter IRM to the DSM-5-AUD criteria also found that symptom # 8 had the lowest discrimination parameter of all the criteria, which could explain its poor fit to the Rasch model, which assumes equal discrimination across symptoms (Saha et al., 2020).

On the other hand, a large study of a nationally representative sample of adult Australians identifying use disorders among people who use cannabis or alcohol found an excellent fit for a unifactorial model for DSM-5 (Lago et al., 2016). However, there are few CUD studies, making contextualizing these findings regarding CUD criteria difficult. The short form of the CUD Identification Test-Revised (CUDIT-R), based on DSM-5-CUD criteria, has been evaluated using Rasch analysis, characteristic test curve, logistic regression, and discriminant function analysis in two community samples of cannabis users from two countries. The four-item (symptom)-selection methods were implemented to identify the optimal three-item shortened version. Results from the Rasch analysis revealed that items 4 (fail to do what was usually expected because of cannabis), 5 (spending more time getting, using, or recovering from cannabis), and 6 (problem with your memory or concentration after using cannabis) were the best-fitting items that also differentiated between participants with different levels of cannabis use problems in both samples (Bonn-Miller et al., 2016).

Regarding item severity, which indicates how difficult it is to endorse each of the CUD criteria, symptom # 3 (Spending a great deal of time obtaining, using, or recovering from the effects of substance use) was the most severe symptom and the least endorsed. Conversely, symptom # 9 (Persistent substance use despite the knowledge that it may cause or exacerbate physical or psychological problems) had the lowest severity estimate and was the most endorsed item. On the other hand, previous studies on DSM-5-AUD criteria found that symptom 8 is the most severe item (Hallgren et al., 2022). Further investigations are necessary to reassess which symptoms are most likely to be endorsed and which are less likely to be endorsed in order to provide improved recommendations for future versions of the DSM.

Strengths and Limitations

The present study's findings should be interpreted considering certain strengths and limitations. However, a limitation of the study is that all data were collected from a single addiction treatment program where the patients were predominantly males, Caucasian, educated, and employed. As a result, the sample may only partially represent the diverse characteristics found in many other treatment settings and may not represent patients in primary care or the general population. Further, the lack of demographic variability limited our ability to test for differential symptoms functioning across subgroups. Future research should replicate these findings across various treatment settings and with a more demographically diverse sample. Finally, as with all patient-reported information, responses are vulnerable to self-report bias that could have affected the results.

Conclusion

The present study extends previous evaluations of the DSM-5 e CUD syndrome using Rasch analysis in a clinical sample of adults receiving inpatient treatment for SUD (Dawson et al., 2010; Hagman & Cohn, 2011; Hasin & Beseler, 2009) supporting its unidimensionality. However, the item-level results suggest that the consideration of symptom 8 in future studies and DSM revisions could possibly improve the diagnostic construct. A fulsome evaluation of the current psychiatric nosology is essential for optimizing future iterations.

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