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To cite this article: Clara Sancho-Domingo M.A., José Luis Carballo PhD, Ainhoa Coloma-Carmona PhD, Carlos van-der Hofstadt Román PhD & Santos Asensio Sánchez M.D and PhD (2022): Psychometric Validity of the Minnesota Tobacco Withdrawal Scale in Smokers Attempting to Quit: Longitudinal Invariance across Smokers and Abstainers, Journal of Psychoactive Drugs, DOI: [10.1080/02791072.2022.2113483](https://doi.org/10.1080/02791072.2022.2113483)

To link to this article: <https://doi.org/10.1080/02791072.2022.2113483>



Published online: 25 Aug 2022.



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## Psychometric Validity of the Minnesota Tobacco Withdrawal Scale in Smokers Attempting to Quit: Longitudinal Invariance across Smokers and Abstainers

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### ABSTRACT

Tobacco withdrawal symptoms vary during smoking cessation increasing relapse risk; therefore, a longitudinal invariant measure seems necessary to validly assess withdrawal changes. This study aimed to examine the psychometric properties of the 7-item Minnesota Tobacco Withdrawal Scale (MTWS) during cessation, and to analyze longitudinal invariance across smokers and abstainers. We conducted a longitudinal study with 309 Spanish smokers (56.2 ± 9.9 years; 52.4% women). We assessed withdrawal at three occasions: pre-treatment (T1), week-12 (T2), and week-24 (T3). Reliability, validity, and invariance analyses were performed. MTWS reliability remained adequate over time ( $\omega_{T1} = 0.78$ ;  $\omega_{T2} = 0.68$ ;  $\omega_{T3} = 0.80$ ) in both smokers and abstainers, with satisfactory temporal stability (ICC = 0.73). MTWS correlations with anxiety, depression, and nicotine dependence ( $r_s > 0.3$ ) supported convergent and concurrent validity. MTWS showed no correlation with craving at T2 ( $r_s < 0.24$ ), suggesting discriminant validity. Unifactorial structure proved partial scalar invariance across time ( $\chi^2 = 246.009$ ; CFI = 0.91; IFI = 0.91; SRMR = 0.09), yet longitudinal invariance between abstainers and smokers was not supported. Across groups, partial scalar invariance was only achieved at T2. Noninvariance at T3 was mainly due to item irritability ( $d_{MACS} = 0.93$ ). The MTWS is reliable and valid measure to assess withdrawal changes during cessation. Long-term MTWS comparisons between smokers and abstainers should be taken with caution since different withdrawal patterns may exist.

### ARTICLE HISTORY

Received 18 February 2022  
Revised 20 May 2022  
Accepted 3 June 2022

### KEYWORDS

Nicotine withdrawal;  
longitudinal invariance;  
psychometric evaluation;  
Minnesota Tobacco  
Withdrawal Scale; tobacco  
cessation

### Introduction

Tobacco discontinuation results in unpleasant withdrawal symptoms that represent a relapse risk, and therefore, a central matter to tackle within smoking treatments (Piper 2015).

According to the Diagnostic and Statistical Manual of Mental Disorders, fifth edition (DSM-5; American Psychiatric Association 2013) nicotine withdrawal symptoms compile irritability, anxiety, depressed mood, increase of appetite, restlessness, sleep problems, and difficulty concentrating. Experience at least four of these symptoms causing significant distress or impairment implies the presence of tobacco withdrawal syndrome (American Psychiatric Association 2013). Although this notion assumes a similar contribution of symptoms during tobacco reduction, recent and classical studies suggest that performance of symptoms varies over time exhibiting different patterns of withdrawal (Lydon-Staley et al. 2018; Shiffman 1979). In this sense, a measure capable to accurately assess those changes of withdrawal during cessation seems crucial to

understand tobacco withdrawal syndrome and to improve interventions (Piper 2015).

The Minnesota Tobacco Withdrawal Scale (MTWS; Hughes and Hatsukami 1986) is one of the most used measures to assess severity of tobacco withdrawal (Acquadro et al. 2018) and was developed from an initial battery of symptoms based on literature review (Hatsukami, Hughes, and Pickens 1985). Under different names (e.g., Minnesota Nicotine Withdrawal Scale) and lengths (e.g., 15-items) the scale has demonstrated adequate internal consistency ( $\alpha = 0.77-0.91$ ), and validity for one- and two-factor structure (Al-Mrayat et al. 2020; Blebil et al. 2014; Cappelleri et al. 2005; Kim et al. 2007; Svicher et al. 2017; Toll et al. 2007; Yu et al. 2010). The latest revisions of the MTWS settle a version of seven items that conforms the DMS-5 criteria to assess intensity of withdrawal symptoms of past 7 days (Al-Mrayat et al. 2020; Hughes and Hatsukami 1986; Piñeiro et al. 2014). Although the MTWS has become a reference measure in the research of nicotine dependence, there is a lack of longitudinal validation studies

that analyze MTWS validity over time (Acquadro et al. 2018). Prospective validation studies have focus on early stages of withdrawal where symptoms are more prominent (Toll et al. 2007), however, little attention has been paid on long-term stages where the assessment of withdrawal is common (e.g., after treatment implementation) (Guliyev, İnce-Guliyev, and Ögel 2021; Piñeiro et al. 2014; Robinson et al. 2019).

Therefore, the aim of this study was to examine the psychometric properties of the MTWS during tobacco cessation in smokers willing to quit, and to test longitudinal invariance across smokers and abstainers to ensure that changes in MTWS symptoms over time and between groups attribute to actual changes in withdrawal rather than measurement bias.

## Methods

### Procedure

We conducted a longitudinal observational study evaluating smokers who intended to quit and sought for treatment in the public Healthcare System of Alicante region. Through a convenience sampling, we recruited participants after treatment referral and informed them about the characteristics of this study and the confidentiality of provided data. Those who were interested gave their informed consent and completed a brief interview (approximately 20 minutes) carried out by a psychologist. During the interview, the psychologist assessed participants' tobacco use (average number of cigarettes per day), abstinence days (24 hours), nicotine dependence, and severity of withdrawal symptoms (MTWS) before initiating treatment, and after 12 and 24 weeks from first assessment. The two follow-ups at weeks 12, and 24 were conducted through a brief phone interview (approximately 10 minutes).

Participants did not receive any compensation nor reimbursement for their collaboration. This study was approved by the Clinical Research Ethics Committee of the General University Hospital of Alicante.

### Participants

The minimum sample size required for this study was established according to a 10:1 ratio recommendation (Kline 1998) for 22 MTWS parameters of variance, covariance, and regression coefficients. Considering a dropout rate of approximately 30% during follow-ups (Robinson et al. 2019) we intended to reach at least 286 individuals.

A total of 328 Spanish tobacco smokers participated in this study, of which 5.8% ( $n = 19$ ) were excluded for

using other drugs (cannabis, cocaine, or alcohol abuse) that could interfere in tobacco withdrawal assessment. The final sample included 309 smokers with an average age of 56.2 years ( $SD = 9.9$ ; range = 21–83), of which 52.4% ( $n = 162$ ) were women. Most participants were married or in a stable relationship (64.1%;  $n = 198$ ), employed (43%;  $n = 133$ ), and with non-university education (63.1%;  $n = 195$ ).

All participants were referred to a smoking treatment: 45% ( $n = 139$ ) to varenicline, 6.1% ( $n = 19$ ) to brief therapy, 35.3% ( $n = 109$ ) to varenicline combined with brief therapy, and 13.6% ( $n = 42$ ) to a combined treatment with Nicotine Replacement Therapy (NRT). Non-significant differences ( $p > .05$ ) were found between treatment groups regarding MTWS scores or tobacco use. Among sociodemographic variables, we only found significant MTWS score differences ( $Z = 3.79$ ;  $p = .001$ ) between women ( $M = 6.4$ ;  $SD = 4.2$ ) and men ( $M = 4.7$ ;  $SD = 3.9$ ).

### Measures

We used a semi-structured interview to gather information about age, sex, marital status, education level and employment.

We evaluate the psychometric properties of the 7-item MTWS (Hughes and Hatsukami 1986). The MTWS assesses the intensity of irritability, anxiety, difficulty concentrating, restlessness, appetite, sleep problems, and depressed mood using a 4-point Likert scale (from 0 *none*, to 3 *severe*). The global score ranges between 0 and 21, where higher scores indicate greater severity of withdrawal during the past 7 days. The MTWS has demonstrated adequate reliability ( $\alpha > 0.8$ ), temporal stability, and validity among smokers willing to quit (Blebil et al. 2014; Svicher et al. 2017; Toll et al. 2007). The craving MTWS item (*desire or urges to smoke*) was used to analyze MTWS discriminant validity since craving performs differently than withdrawal symptoms during tobacco cessation (Al-Mrayat et al. 2020; Piñeiro et al. 2014).

The Short Nicotine Dependence Syndrome Scale (NDSS-S; Becoña et al. 2011) and the Hospital Anxiety and Depression Scale (HADS; Zigmond and Snaith 1983) were used to analyze concurrent and convergent MTWS validity. The 6-item NDSS-S has demonstrated to reliably ( $\alpha = 0.79$ ) assess nicotine dependence while addressing nicotine withdrawal (Becoña et al. 2011). On the other hand, the 7-item HADS subscales have proved to adequately evaluate anxiety (HADS-A:  $\alpha = 0.85$ ) and depression (HADS-D:  $\alpha = 0.84$ ), two predominant symptoms of tobacco withdrawal (Conti et al. 2020; Herrero et al. 2003).

We also used the TimeLine Follow-Back (TLFB; Sobell and Sobell 1992) to assess the average number of cigarettes per day, and 24-hours abstinence at the point of assessment. This measure uses a calendar to measure retrospectively substance use up to 12 months prior to interview (Robinson et al. 2014). In this study, we assessed daily tobacco use of past 7 days prior to interview.

### Data analysis

We analyzed sample characteristics (means, standard deviations, and frequencies) using the statistical software SPSS v.28. The MTWS psychometric properties were examined using SPSS and R software. Results were interpreted based on a 95% confidence level.

Reliability of MTWS was analyzed estimating McDonalds' omega ( $\omega$ ; McDonald 1999) at Time 1 (pre-treatment), Time 2 (week 12) and Time 3 (week 24) for the whole sample, and between smokers and abstainers. Likewise, we estimated standardized factor loadings ( $\beta$ ) for each MTWS item, where  $\beta$  values  $\geq 0.3$  indicate adequate contribution to the scale (Peterson 2000). These analyses were calculated using the macro OMEGA for SPSS (Hayes and Coutts 2020).

Temporal stability was examined by calculating the Intraclass Correlation Coefficient (ICC) across the three time points (Time 1, Time 2, and Time 3). ICC was interpreted based on the thresholds  $< 0.5$  for poor stability,  $\leq 0.75$  for moderate,  $\leq 0.9$  for good, and  $> 0.9$  for excellent (Koo and Li 2016). Since changes in MTWS are expected during tobacco cessation, we hypothesize to have consistent MTWS scores ( $ICC \geq 0.5$ ) within sustained smokers and sustained abstainers, but low score correlations among participants who relapsed ( $ICC < 0.5$ ).

Concurrent and convergent validity was estimated with Spearman's rho correlation,  $r_s$  (Fieller, Hartley, and Pearson 1957), between MTWS, HADS-A, HADS-D, and NDSS. Values of  $r_s \leq \pm 0.3$  indicate weak association between measures,  $\leq \pm 0.6$  moderate, and  $\geq \pm 0.7$  strong. Correlations between MTWS and craving were also tested to analyze discriminant validity across time.

We performed a Confirmatory Factor Analysis (CFA) for one-factor structure, since MTWS unidimensional structure has demonstrated superior data fit (Al-Mrayat et al. 2020). The CFA was analyzed across the three time points, and between smokers and abstainers using *lavaan* package for R software (Rosseel 2012). Models were estimated using Robust Maximum Likelihood (MLR) based on scaled chi-square test ( $\chi^2$ ), which provides more accurate parameter estimates with minimal samples and ordinal data (Li 2016). Because  $\chi^2$  is sensitive to sample size, we also relayed on the Comparative

Fit Index (CFI; Bentler 1990) the Incremental Fit Index (IFI; Bollen 1989) and the Standardized Root Mean Square Residual (SRMR; Chen 2007) CFI and IFI values  $\geq 0.95$  and SRMR values  $< 0.05$  were considered optimal for model fit (Hu and Bentler 1999).

Measurement Invariance (MI) was analyzed by increasing MTWS invariance stringency across time points (Time 1 & Time 2 & Time 3), and across time points by groups (longitudinal invariance across smokers & abstainers). To test MTWS longitudinal MI we only considered the assessments completed at follow-ups. We firstly examined MTWS configural invariance in which the structure, or the model form, is the same across groups/time points. Then, metric invariance was tested by constraining MTWS item loadings to be the same across groups/time points. And lastly, we examined scalar invariance by fixing item's loadings and intercepts to be equal across groups/time points. Configural, metric and scalar invariance was calculated based on models' fit statistics (CFI, IFI, SRMR) and by sequentially comparing models' differences in  $\chi^2$  test ( $\Delta \chi^2$ ), CFI ( $\Delta CFI$ ), IFI ( $\Delta IFI$ ) and SRMR ( $\Delta SRMR$ ). Non-Significant  $\chi^2$  differences, values of  $\Delta CFI$  and  $\Delta IFI \leq 0.01$ , and values of  $\Delta SRMR \leq 0.03$  were considered favored to maintain the most stringent model (Chen 2007).

Partial invariance was tested examining modification indices and achieved if less than 20% of model parameters were freed from the model (Dimitrov 2010). Additionally, effect size  $d_{MACS}$  of item non-equivalence across groups was also estimated. Values of  $d_{MACS} < 0.5$  were considered small,  $< 0.8$  medium, and  $\geq 0.8$  large (Nye and Drasgow, 2011). For MI analyses we used *semTools* package for R software (Jorgensen et al. 2018).

## Results

### Reliability over time

Reliability of the MWTS was adequate across the three time points, with high omega's values at Time 1 ( $\omega = 0.78$ ) and Time 3 ( $\omega = 0.8$ ), and acceptable at Time 2 ( $\omega = 0.68$ ). As observed in Table 1, most of the items contribute to MWTS internal consistency with adequate standardized loadings for the scale over time ( $\beta \geq 0.3$ ) except for Item 5 appetite ( $\beta$  range = 0.12–0.22). Results indicated that deletion of Item 5 would help increase MTWS omega, majorly during follow-ups (Time 2  $\omega = 0.72$ ; Time 3  $\omega = 0.85$ ). Similarly, deletion of Item 6 (sleep problems) also showed a slight improvement of omega at Time 2 ( $\omega = 0.7$ ) and at Time 3 ( $\omega = 0.81$ ), but since the item had adequate standardized loadings ( $\beta$  range = 0.31–0.42), its maintenance in the MTWS scale appears adequate (see Table 1).

**Table 1.** MTWS reliability ( $\omega$ ) and items' standardized loadings over time and between smokers and abstainers.

Time points	Scale reliability if item deleted ( $\omega$ )						Items' standardized loadings							
	T1		T2		T3		T1		T2		T3			
	Total (309)	Total (144)	Abs. (84)	Smk. (60)	Total (85)	Abs. (49)	Smk. (36)	Total (309)	Total (144)	Abs. (84)	Smk. (60)	Total (85)	Abs. (49)	Smk. (36)
1.Irritability	.74	.63	.6	.64	.76	.75	.76	.54	.39	.46	.31	.53	<b>.24</b>	.81
2.Anxiety	.72	.57	.59	.56	.71	.69	.72	.70	.65	.59	.68	.84	.74	.97
3.Concentration	.75	.66	.66	.64	.76	.72	.78	.48	.30	<b>.29</b>	.31	.50	.49	.54
4.Restlessness	.71	.60	.62	.56	.73	.66	.79	.73	.55	.47	.64	.73	.76	.70
5.Appetite	<b>.79</b>	<b>.72</b>	<b>.71</b>	<b>.72</b>	<b>.85</b>	<b>.82</b>	<b>.87</b>	<b>.22</b>	<b>.14</b>	<b>.21</b>	<b>.15</b>	<b>.12</b>	<b>.13</b>	<b>.16</b>
6.Sleep problems	<b>.79</b>	<b>.70</b>	<b>.70</b>	<b>.73</b>	<b>.81</b>	<b>.78</b>	<b>.83</b>	.42	.31	<b>.24</b>	.36	.38	<b>.25</b>	.50
7.Depression	.75	.61	.62	.58	.74	.71	.78	.54	.50	.43	.57	.68	.63	.72
MTWS reliability ( $\omega$ )	.78	.68	.68	.67	.80	.77	.82							

T1: pre-treatment; T2: 12 weeks after first assessment; T3: 24 weeks after first assessment; Abs.: Abstainers; Smk.: Smokers;  $\omega$ : McDonald's omega; r: Spearman's r. Bold typing indicates reliability improvement if item deleted and poor standardized loadings (<.3).

Regarding differences between smokers and abstainers in MTWS reliability, some items performed differently over time. As seen in Table 1, loadings of Item 3 (concentration) and 6 (sleep problems) at Time 2, and Items 1 (irritability) and 6 at Time 3 were under the acceptable threshold of  $\beta = 0.3$  in the abstainers' group, which indicates that these symptoms might have lower contribution in nonsmokers' withdrawal. The largest difference between groups was observed in Item 1 (irritability), where the standardized loadings in abstainers ( $\beta = 0.21$ ) and smokers ( $\beta = 0.81$ ) suggested a different pattern in the MTWS construct. This concurs with a lower reliability in abstainers at Time 3 ( $\omega = 0.77$ ) compared with smokers ( $\omega = 0.82$ ), and the similar omega values across groups when irritability item was deleted ( $\omega = 0.75$  and  $0.76$ ) (see Table 1).

### Temporal stability

ICC of MWTS over the three time points was satisfactory (ICC = 0.73; 95%CI = 0.61–0.82). As expected, ICC was good in sustained smokers (ICC = 0.87;  $p < .05$ ), moderate in sustained abstainers (ICC = 0.72;  $p < .05$ ) and poor in those who relapsed (ICC = 0.32;  $p > .05$ ) suggesting adequate temporal stability discriminating subgroups during tobacco cessation.

### Concurrent, convergent, and discriminant validity

As observed in Table 2, MTWS correlations with the HADS-A and the HADS-D showed moderate to strong significant associations over the three time points in both groups ( $r_s = 0.35$ – $0.68$ ;  $p < .05$ ). Similarly, correlation between MTWS and NDSS indicated a moderate positive association ( $r_s = 0.31$ – $0.49$ ;  $p < .05$ ). These results indicate that higher scores in MTWS were associated with higher scores in anxiety, depression, and

**Table 2.** CFA over time for MTWS one-factor structure, and MTWS Spearman's r correlations with anxiety (Hads-A), depression (Hads-D), nicotine dependence (NDSS), and craving.

	One-factor CFA				$r_s$ correlations			
	$\chi^2$	CFI	IFI	SRMR	HADS-A	HADS-D	NDSS	Craving
Time 1	22.497	.98	.98	.03	.68**	.51**	.35**	.32**
Time 2	15.114	.99	.99	.04	.61**	.39**	-	.14
abstainers	14.610	.99	.99	.05	.53**	.35**	-	.05
smokers	18.100	.96	.96	.08	.68**	.44**	.31*	.24
Time 3	17.869	.98	.98	.04	.62**	.57**	-	.40**
abstainers	20.734	.93	.93	.07	.52**	.61**	-	.30*
smokers	33.208**	.86	.85	.09	.62**	.54**	.49**	.53**

$\chi^2$  = scaled chi-squared; CFI = Comparative Fit Index; IFI = Incremental Fit Index; SRMR = Standardized Root Mean Square Residual;  $r_s$ : Spearman's r correlations. \* $p < .05$ ; \*\* $p < .01$ .

nicotine dependence during tobacco cessation, which supports MTWS concurrent and convergent validity across time and between smokers and abstainers.

On the other hand, MTWS and craving were positively associated ( $r_s = 0.30$ – $0.53$ ;  $p < .05$ ) at Time 1 and 3 in both groups, but non-correlated at Time 2 ( $r_s = 0.05$ – $0.24$ ;  $p > .05$ ) (see Table 2). These results support MTWS concurrent and convergent validity for specific time points, as well as discriminant validity due to different trends during tobacco cessation between craving and withdrawal.

### Confirmatory factor analysis

The cross-sectional CFA revealed optimal fit for one-factor MTWS structure at Time 1 ( $\chi^2 = 22.497$ ;  $df = 14$ ;  $p > .05$ ; CFI = 0.98; IFI = 0.98; SRMR = 0.034), Time 2 ( $\chi^2 = 15.114$ ;  $df = 14$ ;  $p > .05$ ; CFI = 0.99; IFI = 0.99; SRMR = 0.014), and Time 3 ( $\chi^2 = 17.869$ ;  $df = 14$ ;  $p > .05$ ; CFI = 0.98; IFI = 0.98; SRMR = 0.046). The model's goodness of fit decreased gradually over time particularly among the group of smokers, where CFA showed unsatisfactory fit statistics at Time 3 ( $\chi^2 = 33.208$ ;  $df = 14$ ;  $p < .05$ ; CFI = 0.86; IFI = 0.85; SRMR = 0.085).

**Table 3.** MTWS longitudinal measurement invariance across smokers and abstainers.

	$\chi^2$	CFI	IFI	SRMR	$\Delta\chi^2$	$\Delta$ CFI	$\Delta$ IFI	$\Delta$ SRMR
<i>Across time points (T1&amp;T2&amp;T3)</i>								
Configural	226.139**	.908	.907	.095				
Metric	230.225**	.917	.917	.089	7.889	.009	.010	-.006
Scalar	257.417**	.894	.892	.097	27.878**	-.023	-.025	.008
Partial scalar	246.009**	.908	.907	.092	15.881	-.009	-.010	.003
<i>Across time points by group</i>								
Configural	698.218**	.674	.666	.140				
<i>Across groups (T2)</i>								
Configural	32.721	.975	.976	.063				
Metric	50.877*	.910	.911	.096	17.831**	-.065	-.065	.033
Partial metric	37.904	.974	.974	.077	5.226	-.001	.002	.014
Scalar	58.196*	.898	.896	.102	21.157**	-.076	-.078	.025
Partial scalar	43.981	.968	.968	.084	6.1149	-.005	-.006	.007
<i>Across groups (T3)</i>								
Configural	53.382**	.892	.882	.075				

T1: pre-treatment (N = 309); T2: week 12 (n = 144); T3: week 24 (n = 85);  $\chi^2$  = scaled chi-squared; CFI = Comparative Fit Index; IFI = Incremental Fit Index; SRMR = Standardized Root Mean Square Residual;  $r_s$ : Spearman's r correlations. \*p < .05; \*\*p < .01.

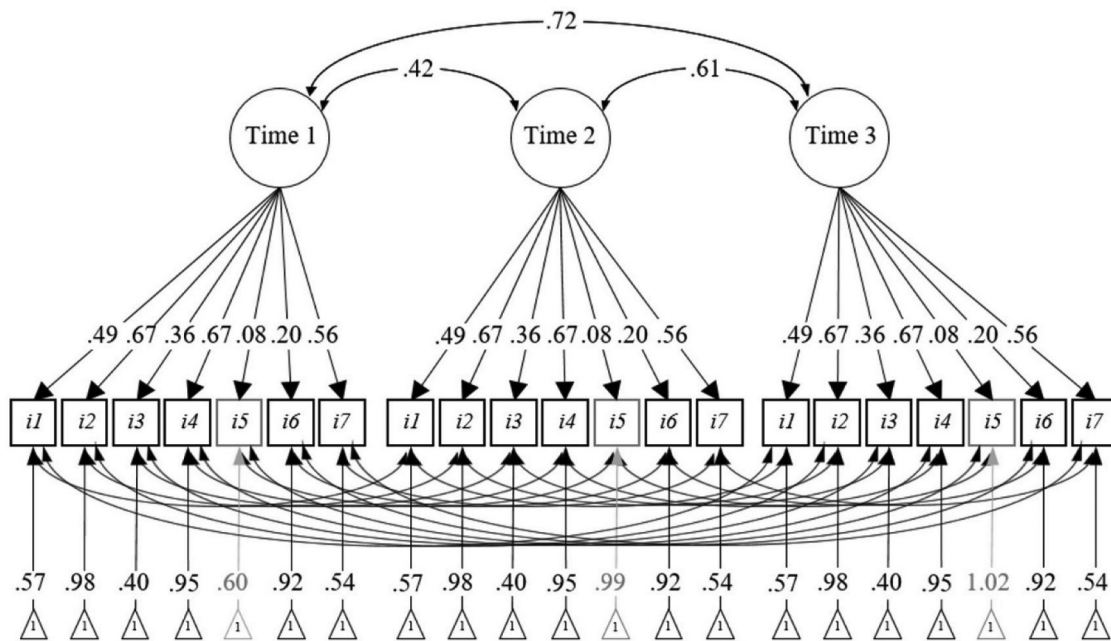
**Measurement invariance across time points and groups**

Table 3 displays MI results across time points and across smokers and abstainers. MTWS proved metric invariance across the three time points ( $\Delta\chi^2 = 7.889$ ;  $p > .05$ ;  $\Delta$ CFI = 0.009;  $\Delta$ IFI = 0.01;  $\Delta$ SRMR = -0.006). However, the comparison between the scalar and the metric model showed a substantial change of model fit ( $\Delta\chi^2 = 27.878$ ;  $p < .01$ ;  $\Delta$ CFI = -0.023;  $\Delta$ IFI = -0.025;  $\Delta$ SRMR = 0.008). To test partial scalar invariance, we examined modification indices of items' intercepts. Intercepts of Item 5 (appetite) showed the largest indices and were released from the model. As illustrated in

Figure 1, partial scalar invariance demonstrated similar fit to the metric model, supporting adequate MTWS scores comparisons during tobacco cessation ( $\chi^2 = 246.009$ ;  $p < .05$ ; CFI = 0.91; IFI = 0.91; SRMR = 0.09).

By contrast, longitudinal MI by group showed poor fit of the configural model ( $\chi^2 = 698.218$ ;  $p < .01$ ; CFI = 0.67; IFI = 0.66; SRMR = 0.14), indicating noninvariance of model form across time between the two groups. To explore measurement differences between smokers and abstainers, we analyzed MI across groups at Time 2 and Time 3 separately.

At Time 2, the fit of the metric model was significantly different from the configural model ( $\Delta\chi^2 = 17.831$ ;  $p < .01$ ;



**Figure 1.** MTWS partial strong invariance across time points with intercepts of item 5 released from the model. Note. i1: irritability; i2: anxiety; i3: difficulty concentrating; i4: restlessness; i5: increase of appetite; i6: sleep problems; i7: depressed mood.

$\Delta CFI = -0.065$ ;  $\Delta IFI = -0.065$ ;  $\Delta SRMR = 0.033$ ), suggesting variant loadings between groups. Loadings of Item 1 (irritability) showed the largest modification indices and were freed from the model. As seen in Table 3, partial metric invariance was satisfactorily achieved ( $\chi^2 = 37.904$ ;  $p > .05$ ;  $CFI = 0.97$ ;  $IFI = 0.97$ ;  $SRMR = 0.077$ ), however its comparison with the scalar model showed a substantial decrease of model fit ( $\Delta\chi^2 = 21.157$ ;  $p < .01$ ;  $\Delta CFI = -0.076$ ;  $\Delta IFI = -0.078$ ;  $\Delta SRMR = 0.025$ ). In this case, modification indices showed that releasing intercepts of Item 5 (appetite) across groups would increase goodness of fit. This way, partial scalar invariance was achieved at Time 2 (average of  $57.8 \pm 26.4$  days of abstinence), since less than 20% of parameters were released from the model (Dimitrov 2010).

At Time 3, inadequate fit statistics of the configural model suggested MTWS noninvariance across abstainers and smokers ( $\chi^2 = 53.382$ ;  $p < .01$ ;  $CFI = 0.89$ ;  $IFI = 0.88$ ;  $SRMR = 0.075$ ). We estimated MI effect sizes to identify which items differed between groups in the MTWS pattern. Item 1 (irritability) yielded the largest effect size of  $d_{MACS} = 0.93$ , indicating that its impact in MTWS structure differs between smokers and abstainers in long-term comparisons (an average of  $140.4 \pm 44$  days of abstinence).

## Discussion

The aims of this study were to analyze the MTWS psychometric properties across time and to examine longitudinal invariance across smokers and abstainers. MTWS internal consistency remained adequate over time, as observed in previous studies (Svicher et al. 2017; Toll et al. 2007), but the contribution of several items to the scale was questionable, and their maintenance in the scale could be due to clinical interest. The item appetite showed a small involvement to the compilation of withdrawal symptoms (Svicher et al. 2017; Toll et al. 2007), and its potential deletion indicated improvement of MTWS reliability and longitudinal invariance. Although increase of appetite is as a reliable indicator of tobacco cessation, it might appear during cessation as a coping strategy of unpleasant withdrawal experiences (e.g., anxiety) rather than as a symptom itself, as suggested in previous works (Anker et al. 2021). Further exploration of this item contribution is needed to understand its role in tobacco withdrawal and its maintenance in the MTWS.

To a less extent, sleep problems also showed low contribution to the scale, majorly among abstainers. To experience insomnia or other sleep problems might appear in early stages of tobacco discontinuation or during unsuccessful quit attempts, which supports the variability of symptoms over time (Lydon-Staley et al. 2018). However,

the sleep item showed invariance across time and groups, which supports its maintenance to the scale.

Interestingly, the irritability item restricted comparisons of MTWS scores between smokers and long-term sustained abstainers (Time 3). This noninvariance suggested that differences between abstainers and smokers in MTWS scores could be partially due to measurement limitations rather than withdrawal. Irritability emerges during early stages of withdrawal, but diminish in non-smokers with time (Conti et al. 2020), therefore, the low impact of irritability in sustained abstainers suggests that the item should be measured differently or discarded for valid long-term comparisons.

The ICC was satisfactory and slightly higher than in previous studies (Kim et al. 2007), indicating that MTWS scores remain consistent over time within sustained smokers and abstainers, but change alongside with variations of smoking patterns (e.g., relapse). Likewise, changes in MTWS scores were positively correlated with related measures of withdrawal supporting concurrent and convergent validity, as well as discriminant validity to differentiate other unpleasant experiences during cessation, such as craving (Al-Mrayat et al. 2020; Piñeiro et al. 2014).

As in other validation studies, MTWS unifactorial structure yielded satisfactory fit indices, suggesting a unidimensional construct of tobacco withdrawal (Toll et al. 2007; Yu et al. 2010). This MTWS structure supported longitudinal partial invariance, and therefore, valid MTWS mean comparisons during the process of tobacco cessation within participants. Although longitudinal invariance across groups was not supported, essentially due to appetite and irritability items, MTWS differences between smokers and abstainers seem adequate up to 8 weeks of abstinence and biased up to 20 weeks. These results concur with previous works that suggest different patterns of withdrawal symptoms during smoking cessation (Lydon-Staley et al. 2018; Shiffman 1979), and therefore potential metric differences in withdrawal assessment. Based on our results, researchers should be cautious comparing and interpreting differences in MTWS scores between smokers and sustained abstainers.

This study counts with several limitations to take into consideration. First, abstinence was assessed with the TLFB without biochemical verification. Although biomarkers limit the assessment of abstinence duration, future validation studies should consider including this type of objective measures. Likewise, future studies should also consider analyzing MTWS psychometric properties with larger samples which could perhaps yield different metric results. On the other hand, concurrent and convergent validity were tested with related

measures of withdrawal, however analogue measures could perhaps provide more accurate information of MTWS criterion validity (Yu et al. 2010). Lastly, the impact of smoking treatments over withdrawal experiences was unexplored. Although non-significant differences were found between treatments in MTWS scores, future studies should consider if MTWS remain invariant across treatment effects.

Our research expands knowledge about the adequate use of MTWS, and demonstrates that the MTWS is a valid and reliable measure to assess withdrawal allowing to monitor changes during the process of tobacco cessation. Long-term MTWS comparisons between unsuccessful quitters and sustained abstainers are inadvisable. Future validation studies should explore longitudinal MTWS validity during early stages of withdrawal to cover treatment needs to prevent relapse (Piper 2015) and improve physical and mental health (Campbell et al. 2018).

## Disclosure statement

No potential conflict of interest was reported by the author(s).


## Funding


The author(s) reported there is no funding associated with the work featured in this article.


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