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Validation of the Korean version of the Metacognitions Questionnaire-Insomnia (MCQ-I) scale and development of shortened versions using the random forest approach

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A B S T R A C T

We aimed to validate a Korean version of the Metacognitions Questionnaire-Insomnia (MCQ-I) and develop two shortened versions of the MCQ-I by applying the Random Forest (RF) algorithm. A total of 310 participants responded through an online survey, during April 3–6, 2021, which included rating scales such as the Insomnia Severity Index (ISI), Pittsburgh Sleep Quality Index (PSQI), Patient Health Questionnaire-9 (PHQ-9), and the Hospital Anxiety and Depression Scale (HADS), as well as the MCQ-I. After validating the scale, we developed two shortened versions by applying the RF. Finally, we explored the psychometric properties of the shortened versions. The Korean version of the MCQ-I showed good internal consistency based on a Cronbach's alpha of 0.96. Factor analyses showed good model fits for the single structure of the MCQ-I. From the results of the RF, 6 of the 60 items of the MCQ-I were sufficient to distinguish between people with MCQ-I scores above the cut-off value and the rest with high accuracy (AUC>0.97), leading to the 6-item (MCQI-6) version of the MCQ-I. Furthermore, we have also developed a 14-item (MCQI-14) version of the MCQ-I with higher accuracy (AUC>0.98). Both versions were reliable based on their internal consistency (alpha = 0.843 and 0.912), and confirmatory factor analysis showed good model fits for both shortened versions. In addition, good convergent validity of both shortened versions with insomnia, sleep quality, depression, and anxiety were observed. The Korean version of the MCQ-I and two shortened versions (MCQI-6, and MCQI-14) were useful, reliable, and valid tools to evaluate the role of metacognitive beliefs in sleep problems among the Korean population.

1. Introduction

Insomnia disorder involves difficulty initiating and/or maintaining sleep despite the adequate opportunity. Insomnia has an impact on personal, professional, and social functioning, with fatigue, cognitive impairments, and poor motivation. The annual prevalence of insomnia is estimated to be 30%–40% in the United States and is increasing day by day. In South Korea, according to

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statistics from the National Health Insurance Corporation, the number of patients with symptoms of insomnia increased by 34% between 2012 and 2016 [1].

Clinical guidelines for the treatment of insomnia recommended that Cognitive-Behavioral Therapy for insomnia (CBT-I) be applied first-line to treat insomnia symptoms prior to prescribing sleeping pills [2–4]. CBT-I focuses on hyperarousal, and conventional behavioral treatments included muscle relaxation, biofeedback, and sleep restriction. The second wave of cognitive behavioral therapy for insomnia attempts to break the link between distorted cognition, inappropriate habits, and hyperarousal. Recently, a metacognitive approach is emerging as a treatment principle [5]. Developing areas of interest are cognitive mechanisms that are intrusive and uncontrollable thoughts associated with worrisome and negative affect [6].

1.1. Metacognition and insomnia

Metacognition is defined as the psychological process of controlling, modifying, and interpreting a thought itself. Metacognition, known as awareness of one's own thought, is understood as a process of thinking rather than the content of thought, and contributes to anxiety disorder, depression, obsessive compulsive disorder, and psychosis. Research is underway on the role of metacognition in primary insomnia. When you feel the gap between your self-aware state and your ideal situation, you are triggered, and eventually your body state, cognitive state, and external information are intruded into your thoughts. “Intrusion” refers to thoughts that occur naturally and involuntarily. It is one of the critical factors that impact actual sleep problems. Intrusion creates negative emotions and makes it difficult to control thoughts [7]. There is widespread acceptance that intrusive thinking at bedtime characterizes primary insomnia. Primary insomnia patients describe their pre-sleep thoughts as intrusive, uncontrollable, and negative, and attribute sleeping difficulties to intrusions [8,9]. Two metacognitive belief types should operate in response to such intrusions: (i) beliefs concerning the meaning of the intrusions (e.g. thinking in bed prevents me from getting to sleep) and (ii) plans that guide and shape the form that cognition takes (e.g. before I fall asleep, I should try to switch off my thoughts) [10].

Several lines of evidence support the view that cognitive activity and associated action plans have effects on primary insomnia. What is well known to us so far has to do with dysfunctional beliefs in sleep. “Dysfunctional beliefs” refers to maladaptive beliefs, attentional bias, and excess worry about sleep that impact actual sleep problems [8]. For instance, some insomniac people have inflexible and firm expectations about their sleep needs and are preoccupied excessively when such unrealistic needs are not met. Others fear the potential consequences of insomnia for their daytime functioning and health, like dementia. In turn, such faulty beliefs and excessive worry produce emotional distress, heightening arousal and feeding into the vicious cycle of insomnia [11].

Metacognition is an important factor in the maintenance of psychological disorders. The metacognitive questionnaire (MCQ) was developed with 65 items [12] to evaluate several dimensions of metacognitive thought believed to be relevant to psychopathology following a conceptual analysis offered by Well’s Self-Regulatory Executive Function (S-REF theory) [10,13]. When there is a threatening discrepancy between one’s perceived self-state and the ideal state, the Self-Regulatory Executive Function is switched on; for example, during wakefulness when the desired goal is sleep, cognitive and external information intrudes into one’s mind, and one is disturbed.

Despite this evidence, theoretical explanations for why intrusive pre-sleep thinking characterizes primary insomnia remain lacking. Metacognition has received very little attention in the insomnia literature. Patients with primary insomnia often experience intrusive, worrisome cognitive activity in the pre-sleep period. Metacognitive beliefs may explain this; yet, no valid reliable scale exists. The Metacognitions Questionnaire–Insomnia (MCQ-I) was developed as a more specialized questionnaire for primary insomnia based on the 60-question Metacognitions Questionnaire (MCQ), which evaluates a measure of individual belief in thinking [7].

1.2. Developing the shortened version of the MCQ-I scale using Random Forest

Unlike the existing MCQ, the MCQ-I has not been verified in various population groups or diverse cultures, so it is limited to use in the evaluation of insomnia. The 60 items of the MCQ-I may help examine the patient's wide range of cognitive beliefs about sleep, but it is not easily applied in clinical practice. Especially, there is a lot of pressure to repeatedly measure responses or progressive courses of patients. We are interested in developing a briefer instrument to be used as part of a battery of scales or for screening purposes. Depending on the objectives of clinicians, a longer or shorter version could be chosen.

In this situation, we tried to develop a shortened version of the MCQ-I using Random Forest (RF). RF is a non-parametric machine learning algorithm for regression and classification [14], which has been widely used to analyze complex medical data and predict diagnoses of various diseases, including mild cognitive impairment, attention-deficit hyperactivity disorder, autism, and obstructive sleep apnea [15–18]. RF gathers multiple decision trees via bagging and random selection of features to decorrelate the decision trees and thus decrease the variance in prediction. Then, the classification results of the decorrelated decision trees are collected and the majority vote of the classification result is used as the final prediction of the RF. Importantly, during the construction of RF, the importance of each item of the MCQ-I for the prediction is automatically calculated [19,20]. Collecting the top-ranking questions allowed us to develop the shortened version of the MCQ-I.

In this study, we aimed to standardize and validate a Korean version of the MCQ-I scale among the general population in Korea, and to explore its clinical utility. In addition, we tried to develop shortened versions of the MCQ-I by applying Random Forest.

2. Materials and methods

2.1. Participants and procedure

We conducted this study using an on-line survey with Google Forms® (Google LLC, Mountain View, CA) during April 3–6, 2021. Through the survey system, a total of 310 participants responded through anonymous online questionnaires. This survey was administered anonymously and no personal information was gathered. The study protocol was approved by the Institutional Review Board of Sungshin Women’s University, Seoul, South Korea (SSWUIRB-2020-009). Written informed consent was waived. The survey form was developed according to the Checklist for Reporting Results of Internet e-Surveys (CHERRIES) guidelines [21] and one investigator (KK) tested its usability and technical functionality before its implementation. Through the online survey, we collected information on participants’ age, sex, job, and marital status, and their responses to rating scales. The participants voluntarily completed the survey, and a gift-coupon valued at about 3 US dollars was provided as a reward for participating.

2.2. Assessment scales

2.2.1. Metacognitions Questionnaire-Insomnia (MCQ-I)

The 60-item MCQ-I directly measures metacognitive beliefs in primary insomnia [7]. Instructions asked participants to indicate agreement on a four-point Likert scale. In the originnal study, primary insomnia patients scored significantly higher than normal sleepers on the MCQ-I. Face, concurrent, construct, and discriminant validity, scale sensitivity and specificity were all acceptable. A cut-off of 110 correctly differentiated insomnia patients from normal sleepers. The questionnaire have demonstrated good internal consistency (Cronbach's $\alpha = 0.95$). In this study, we translated the MCQ-I into Korean and back-translated it into English to check for accuracy (Supplementary Table 1).

2.2.2. Insomnia Severity Index (ISI)

The ISI is a widely used self-reporting questionnaire that comprises seven items for assessing the severity of insomnia [22]. The cut-off for insomnia with this system is a score of 15. A Korean version of the Insomnia Severity Index was used for our present study series, as it has demonstrated good validity [23].

2.2.3. Pittsburgh Sleep Quality Index (PSQI)

To evaluate subjective sleep quality, the 17-item tool of the PSQI was used. The questionnaire consists of seven subdomains: subjective sleep quality, sleep latency, sleep duration, sleep efficiency, sleep disturbance, sleep medication usage, and daytime dysfunction. Each item is scored on a four-point scale ranging from 0 to 3, and the sum of the scores ranges from 0 to 21. A score of 5 or higher with a cut-off point of 5 indicates that sleep is disturbed, and a higher score means lower quality of sleep [24]. In this study, we applied the Korean version of the PSQI [25].

2.2.4. Patient Health Questionnaire-9 items (PHQ-9)

The PHQ-9 is a reliable and valid self-administered diagnostic tool and was used to assess the severity of depressive symptoms [26]. This tool was designed to match the diagnostic criteria of major depressive disorder and comprises nine items. It measures the patient's depressive symptoms in the two weeks prior to the test. Each item is scored from 0 to 3 for a maximum score of 27 across the nine items. The cut-off point for depressive symptoms in the PHQ-9 is a score of 10 [26]. A Korean version of the PHQ-9 has been shown to have good reliability and validity [27].

2.2.5. Hospital Anxiety and Depression Scale (HADS)

The Hospital Anxiety and Depression Scale (HADS) was devised to measure anxiety and depression in a general medical population of patients [28]. The questionnaire comprises seven questions for anxiety and seven questions for depression and takes 2–5 min to complete. The validity has already been verified in Korea [29].

2.3. Statistical analysis

In this study, we used SPSS version 21.0, AMOS version 27 (SPSS, Inc, Chicago, Illinois), JASP version 0.14.1.0 software (JASP Team, Amsterdam, Netherlands), and Rstudio for statistical analysis.

In Step I, we conducted Confirmatory Factor Analysis (CFA) with a diagonally weighted least squares (DWLS) estimator to explore whether the factor structure of the Korean version of the MCQ-I scale as a 60-item version shows good fit for the model. Before conducting it, the normality assumption of each item was checked based on skewness and kurtosis for an acceptable limit of range ± 2 [30]. The Kaiser-Meyer-Olkin (KMO) value and Bartlett's test of sphericity were measured to check data suitability and sampling adequacy. In CFA, satisfactory model fit was defined by a standardized root-mean-square residual (SRMR) value ≤ 0.05, root-mean-square-error of approximation (RMSEA) value ≤ 0.10, and comparative fit index (CFI) and Tucker Lewis index (TLI) values ≥ 0.90 [31,32]. A series of multi-group CFA with configural invariance testing was run to determine whether the MCQ-I scale assessed the metacognition on insomnia across insomnia (ISI ≥ 15) and poor sleep quality (PSQI > 5). To explore the convergent validity, we performed a Pearson correlation analysis of the MCQ-I scale score with ISI and PSQI scores and sleep latency. Item-total correlation and Cronbach's alpha and McDonald's Omega coefficients were used to measure internal consistency. We conducted a Receiver Operating Characteristic (ROC) analysis to define the appropriate cut-off score of the MCQ-I, and the area under the curve (AUC), sensitivity, and specificity were calculated in accordance with clinical insomnia (ISI ≥ 15). A *t*-test has been used to compare the psychological characteristics of people with high endorsement of metacognitive beliefs and those with low endorsement. Pearson's correlation has been used to identify the association between the MCQ-I score and mood symptoms (depression and anxiety).

In Step II, we used RF to develop the shortened version of the MCQ-I. Using the optimal cut-off score of the MCQ-I in the Step I process, we divided the participants into two classes: "High" for participants with MCQ-I score higher or equal to the cut-off score, and "Low" for participants with MCQ-I score lower than the cut-off score. Then, we built a RF that predicts the participants' class based on their answers for each MCQ-I item. For this, we chose the value of a hyperparameter, mtry, the number of the subset of features needed to construct a single decision tree [16]. Specifically, to find the optimal mtry value, we first split the entire data set into 10 stratified folds, where each fold consisted of 10% of both the "High" and the "Low" classes. We used these folds to conduct a 10-fold cross-validation, where the model was trained using nine folds and tested on the remaining fold. A hyperparameter value that maximizes the average accuracy of three different 10-fold cross-validations was selected. In this research, we used 4,000 trees to guarantee that all data was used. After the optimal model was constructed, we measured feature importance using the mean decrease of accuracy, indicating the improvement in accuracy of the model via each feature.

In Step III, the psychometric properties of the two shortened versions (MCQI-6 and MCQI-14) were assessed. We ran item analysis (corrected item-total correlation, internal consistency reliability, etc.), CFA, a graded response model (an IRT model for polytomous items), and Rasch analysis to estimate the item discrimination, difficulties, and factor structure. We also ran multigroup CFAs and differential item functioning (DIF) biases of both short versions across having insomnia symptoms (ISI ≥ 15) and having poor sleep (PSQI > 5). A Pearson product-moment correlation coefficient was run to assess the association of the short versions' scores with ISI, PHQ-9, HADS-anxiety scale, and PSQI scores.

3. Data availability

The computational code for predicting the classification via RF based on either the MCQI-6 or the MCQI-14 can be obtained from the following database: a GitHub link will be provided upon acceptance of the manuscript.

4. Results

All 310 participants among the general population participated in this online survey (Table 1). The mean age was 39.0 $\pm$ 11.8 years (mean $\pm$ SD); they were evenly distributed from the 20s to the 60s.

Table 1
Socio-demographic characteristics of participants (N = 310).

Variables	Mean ± SD, N (%)
Sex (male)	151 (48.7%)
Job	
None or housewives	55 (17.7%)
University students	35 (11.3%)
Work of regular schedule	192 (61.9%)
Shift-worker	15 (4.8%)
Others	13 (4.2%)
Age	39.0 ± 11.8
18 - 29	78 (25.2%)
30 - 39	81 (26.1%)
40 - 49	80 (25.8%)
50 - 73	71 (22.9%)
Marital status	
Single	106 (34.2%)
Married	195 (62.9%)
Other	8 (2.6%)
Rating scales	
Insomnia Severity Scale	11.7 ± 5.8
Insomnia Severity Scale ≥ 15	100 (32.0%)
Pittsburgh Sleep Quality Index	6.1 ± 3.1
Pittsburgh Sleep Quality Index > 5	157 (51.1%)
Patient Health Questionnaire-9 items	3.7 ± 4.1
Patient Health Questionnaire-9 items ≥ 10	22 (7.1%)
Hospital Anxiety and Depression Scale - Anxiety	6.0 ± 4.1
Hospital Anxiety and Depression Scale - Anxiety ≥ 8	107 (34.5%)

Of the participants, 48.7% were male and 62.9% were married. The largest proportion of the study subjects had jobs that were worked during regular hours (61.9%), followed by unemployed or housewives (17.7%), college students (11.3%), and shift-workers (4.8%).

4.1. Validity and reliability of the Korean version of the MCQ-I scale

The normality assumption for the 60 items was checked with the skewness and kurtosis with an acceptable limit of range ± 2; the distribution of all 60 items was within the normal limit (Supplementary Table 2). The KMO measure (0.937) and Bartlett's test of sphericity (< 0.001) showed that the sampling was adequate and the data was suitable for factor analysis. A CFA was conducted to explore the factor model of the Korean MCQ-I as a single model, and we observed that the single factor model of the MCQ-I showed a good fit for the model (CFI = 0.981, TLI = 0.980, RMSEA = 0.049, RSMR = 0.053). A multigroup CFA revealed that the MCQ-I can measure one's metacognition on sleep in the same way across having insomnia (ISI ≥ 15, CFI = 0.957, TLI = 0.956, RMSEA = 0.027, RSMR = 0.087) or having poor sleep (PSQI > 5, CFI = 0.970, TLI = 0.969, RMSEA = 0.046, RSMR = 0.096).

The Korean version of the MCQ-I showed good internal consistency based on a Cronbach's alpha of 0.962 and McDonald' omega of 0.963. The Cronbach's alpha when items were deleted ranged from 0.961–0.963. The item-rest correlation was from 0.267–0.729. The MCQ-I score was significantly higher among participants with clinical insomnia [ISI ≥ 15, t(308) = 10.726, $p < 0.001$] compared to those without, and also higher among those with poor sleep quality [PSQI > 5, t(305) = 8.403, $p < 0.00$) than those without. The MCQ-I score was positively correlated with scores on the ISI (r = 0.63, $p < 0.01$) and PSQI (r = 0.54, $p < 0.01$), and with sleep onset latency (r = 0.38, $p < 0.01$), which suggests adequate convergent validity. The MCQ-I score was also significantly correlated with depression (PHQ-9 score, r = 0.41, $p < 0.01$) and anxiety (HADS-A total score, r = 0.49, $p < 0.01$). The ROC analysis revealed an optimal cut-off score of the MCQ-I as 140, in accordance with clinical insomnia (ISI ≥ 15, 76% of sensitivity and 74% of specificity).

4.2. Development of the shortened version of the MCQ-I using Random Forest

4.2.1. Analysis of the result of the RF

We constructed the RF classifying participants into "High" (MCQ-I total score ≥ 140, n = 133) and "Low" (MCQ-I total score < 140, n = 177) classes based on their responses to the MCQ-I. This allows us to rank items according to their importance for the classification (Fig. 1). Items 51 and 60 were the most important for the classification, while items 3 and 5 did not contribute much. This indicates that considering several top-rank items is sufficient for the classification. To search for the optimal number of items used, we calculated how accurate the classification could be depending on the number of items used for the prediction using AUC (Fig. 2). Indeed, even with a few important items, accurate and precise predictions can be made. Specifically, when the top six important items (i.e., items 51, 60, 28, 58, 23, and 39; Table 2 and Fig. 3) were used, the AUC was higher than 0.97. Also, using the top 14 important items (i.e., items 51, 60, 28, 58, 23, 39, 42, 47, 18, 50, 54, 31, 33, and 12; Table 3 and Fig. 4) led to an AUC higher than 0.98 (Fig. 2).

4.2.2. Validity and reliability of the six-item MCQ-I (MCQI-6)

The shortened, six-item version of the MCQ-I (MCQI-6) showed a good fit for the single-factor model ($\chi2$/df = 0.911, CFI = 1.000, TLI = 1.00, RMSEA = 0.000, RSMR = 0.038) (Table 4). A multigroup CFA revealed that the MCQI-6 can measure one's metacognition on sleep in the same way across having insomnia (ISI ≥ 15, CFI = 1.000, TLI = 1.013, RMSEA = 0.000, RSMR = 0.062) or having poor sleep (PSQI > 5, CFI = 1.000, TLI = 1.010, RMSEA = 0.000, RSMR = 0.064). The Cronbach's alpha was 0.843 and the McDonald' omega was 0.846. The Cronbach's alpha when items were deleted ranged from 0.80–0.85. The corrected item-total correlation ranged from 0.48–0.69.

Graded response model (an IRT model) outputs are presented in Supplementary Table 3. All items' fit values are non-significant at p = 0.01. These non-significant model fits suggest that these items belong to the MCQI-6. Regarding slope parameters (α), item 39 has a moderate slope and the rest of the items have very high slopes. Item 39 provides the least information and item 28 provides the most. All of the items except item 39 are very highly efficient in discriminating among individuals assessed by the MCQI-6. Threshold coefficients (b) in Supplementary Table 3 suggest that higher latent trait or theta is required to endorse Likert-type response options – from 'agree moderately' to 'agree very much'. The scale information curve (Supplementary Fig. 1) suggests that the MCQI-6 will be efficient in assessing insomnia among individuals with theta levels between −1.5 and 2.75.

Supplementary Table 5 shows the Rasch analysis outputs (infit and outfit mean squares [MnSq]) of the MCQI-6. Both infit and outfit MnSqs are ranged between 0.80 and 1.42, and 0.84 and 1.40, respectively. These MnSqs suggest a good model fit. Item difficulty values are ranged between −0.33 and 0.35. Item 58 is the least difficult item and item 39 is the most difficult item in MCQI-6. Table 4 shows that the MCQI-6 has acceptable item and person reliability (0.880 and 0.819, respectively), and item and person separation index (2.704 and 2.126, respectively). Additionally, the MCQI-6 has good IRT reliability (0.862). Differential Item Functioning (DIF) bias results (non-significant p-values) in Supplementary Table 6 and 7 show the absence of DIF bias among items of the MCQI-6 across having insomnia (ISI ≥ 15) and having poor sleep (PSQI > 5).

The total score of the MCQI-6 was significantly correlated with the ISI (r = 0.59, $p < 0.01$), PSQI (r = 0.51, $p < 0.01$), PHQ-9 (r = 0.36, $p < 0.01$), and the HADS-anxiety scale (r = 0.44, $p < 0.01$). Total scores on the MCQI-6 were significantly higher among participants

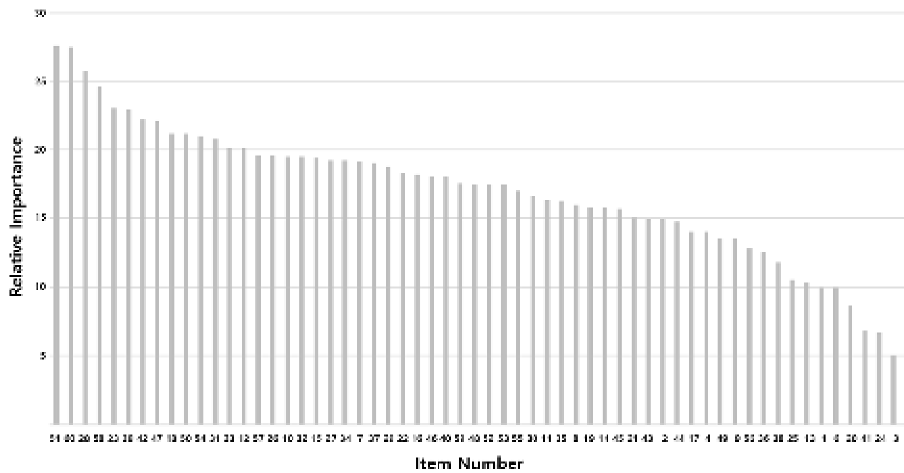

Fig. 1. The relative importance of 60 items of the Korean version MCQ-I by the RF (n = 310). The importance for each item was computed as the difference between the out-of-bag (OOB) prediction accuracy of the model trained on given data and the model trained on the data where the input features are randomly permuted.

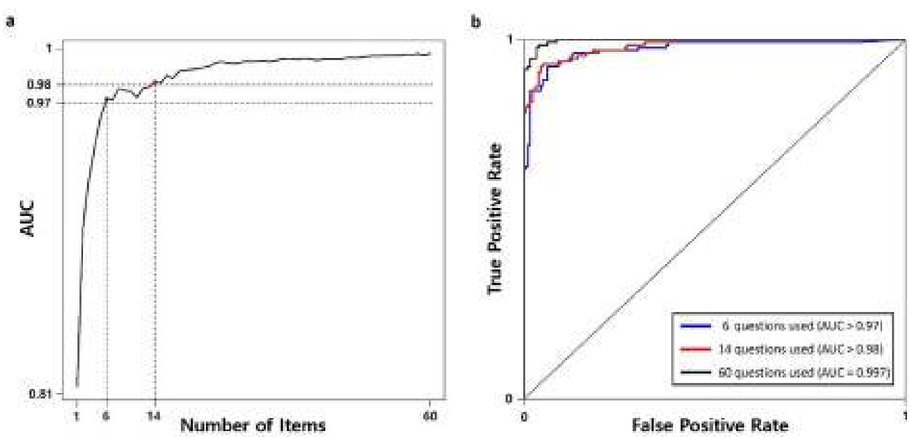

Fig. 2. Prediction performance of the RF with different numbers of items. (a) AUC value when different numbers of items were used to predict the class of participants. Using the top 6 items and 14 items in Figure 1 leads to AUC higher than 0.97 and 0.98, respectively. (b) ROC curve for the model using 6, 14, and 60 items.

Table 2
Item properties of the six-item, Korean version of the MCQ-I (MCQI-6).

Items		Response scale (%)				CITC	CID	Factor loading (95% CI)
		1	2	3	4			
Item 23	Before I fall asleep, I should try and stop physical sensations in my body.	25.5	34.5	32.6	7.4	0.62	0.82	0.685 (0.595, 0.775)
Item 28	Before I fall asleep, I should try as many ways as I can to control my thoughts.	29.7	42.3	23.2	4.8	0.68	0.81	0.756 (0.658, 0.854)
Item 39	When frustrated in bed, I should tell myself not to be so silly.	34.2	34.2	26.1	5.5	0.48	0.85	0.513 (0.433, 0.592)
Item 51	Before I fall asleep, I should try and switch off my thoughts.	28.1	34.8	29.7	7.4	0.69	0.80	0.768 (0.672, 0.863)
Item 58	Being awake in bed means I have lost control of my sleep.	18.1	40.0	33.5	8.4	0.59	0.82	0.636 (0.546, 0.727)
Item 60	At lights out, I should try and control my sleep.	24.2	31.0	34.8	10.0	0.59	0.80	0.771 (0.677, 0.866)

1 = Do not agree, 2 = Agree slightly, 3 = Agree moderately, 4 = Agree very much, M, mean; SD, standard deviation; CITC, corrected item-total correlation.
CID, Cronbach's alpha if item deleted; CI, confidence interval.

with insomnia (ISI $\geq$ 15, t(308) = 10.40, $p < 0.001$), poor sleep quality (PSQI > 5, t(305) = 8.23, $p < 0.001$), depression [PHQ-9 $\geq$ 10, t(308) = 3.29, $p < 0.01$] and anxiety [HADS-A $\geq$ 8, t(308) = 6.29, $p < 0.01$].

4.2.3. Validity and reliability of the fourteen-item MCQ-I (MCQI-14)

The shortened fourteen-item version of the MCQ-I (MCQI-14) showed also good fit for the single factor model ($\chi 2$/df = 1.001, CFI = 1.000, TLI = 1.000, RMSEA = 0.000, RSMR = 0.051) (Table 4). Multigroup CFA revealed that the MCQI-14 also can measure one's metacognition on sleep in a same way across having insomnia (ISI $\geq$ 15, CFI = 1.000, TLI = 1.002, RMSEA = 0.000, RSMR = 0.076) or having poor sleep (PSQI > 5, CFI = 1.000, TLI = 1.001, RMSEA = 0.000, RSMR = 0.034). Cronbach's alpha of 0.912 and McDonald' omega of 0.913. The Cronbach's alpha if item deleted ranged from 0.90–0.91. The corrected item-total correlation ranged from 0.51–0.75.

Graded response model output in Supplementary Table 4 shows that all items' fit values are non-significant at $p = 0.05$. These non-significant model fits suggested that these items belong to the

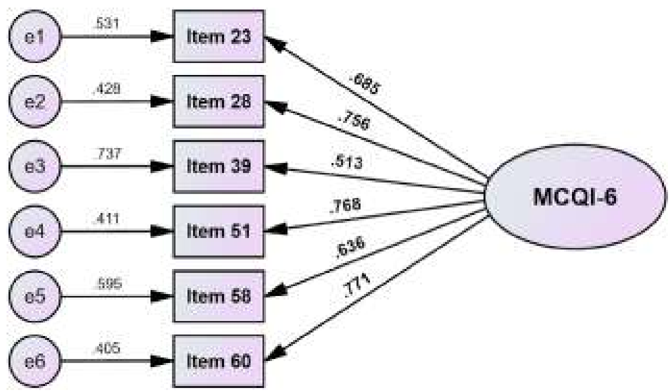

Fig. 3. Factor structure of the MCQI-6.

MCQI-14. About slope parameters (α), items 23, 47, and 50 have a moderate slope, items 31 and 54 have a high slope, and the rest of items have a very high slope. Item 50 provides lowest information and item 28 provides highest information. All the items are efficient in discriminating among individuals assessed by MCQI-14. Threshold coefficients (b) in Supplementary Table 4 shows that items 39, 42, 47, and 50 are less difficult items compared to the rest of the items of the MCQI-14. In these four items, a higher latent trait or theta is required to endorse the highest Likert-type response option ('agree very much'). Scale information curve (Supplementary Fig. 1) suggests that the MCQI-6 will be efficient to assess insomnia among individuals between −2.0 and 3.0 theta levels.

Both infit and outfit MnSqs (Supplementary Table 5) are ranged between 0.74 and 1.35, and 0.73 and 1.40, respectively. These MnSqs suggested good model fit. Item difficulty values are ranged between −1.27 and 1.05. Item 50 is the lowest difficult item and item 58 is the highest difficult item in MCQI-14. Table 4 shows that the MCQI-14 has acceptable item and person reliability (0.975 and 0.905, respectively), and item and person separation index (6.283 and 3.077, respectively). Besides, the MCQI-6 has good IRT reliability (0.923). Differential Item Functioning (DIF) bias results (non-significant p-values) in Supplementary Table 6 and 7 shows the absence of DIF bias among items of the MCQI-14 across having insomnia (ISI ≥ 15) and having poor sleep (PSQI > 5).

The total score of the MCQI-14 was significantly correlated with ISI ($r = 0.63$, $p < 0.01$), PSQI ($r = 0.55$, $p < 0.01$), PHQ-9 ($r = 0.41$, $p < 0.01$), and HADS-anxiety scale ($r = 0.47$, $p < 0.01$). The total score MCQI-14 was significantly higher among participants with insomnia (ISI ≥ 15, $t(308) = 10.95$, $p < 0.001$), poor sleep quality (PSQI > 5, $t(305) = 8.72$, $p < 0.001$), depression [PHQ-9 ≥ 10, $t(308) = 3.94$, $p < 0.01$] and anxiety [HADS-A ≥ 8, $t(308) = 6.85$, $p < 0.01$].

5. Discussion

In this study, we observed that the Korean version of the MCQ-I scale was a valid and reliable rating scale that can measure one's metacognition on their insomnia. However, it is not easy to apply all sixty items of the MCQ-I scale in clinical practice, and we tried to develop a shortened version of the MCQ-I scale. We applied the RF and developed two shortened versions of the MCQ-I, MCQI-6, and MCQI-14. Those shortened versions were reliable and valid rating scales that can measure one's metacognition on insomnia.

5.1. The Korean version of MCQ-I

The MCQ-I was a valid and reliable tool for measuring metacognition on insomnia as a single factor model. Though it does not directly measure the degree of insomnia, it provides an opportunity to identify the dysfunctional metacognitive beliefs that act as aggravating factors for persistent insomnia and suggest appropriate cognitive therapy for restructuring the belief and attention bias. Significant associations were observed between the MCQ-I, the severity of insomnia (ISI), quality of sleep (PSQI) and sleep onset latency. The MCQ-I proves promising psychometric properties for assessing sleep problems as well as accompanying mood problems. Also, the short version of MCQ-I showed a profile similar to that of MCQ-I. The evaluation was made easier by significantly reducing the number of items from 60 to 6. Too long evaluation exhausts the patient as well as the doctor.

5.2. Two shortened versions of MCQ-I; MCQI-6 and MCQI-14: application of the RF

The two shortened versions of MCQ-I (MCQI-6 and MCQI-14) are also valid and reliable brief multidimensional measures of metacognitions about insomnia that are more economical to use than the original MCQ-I. The present results show that the instrument and its subscales have good internal consistency and a factor structure consistently with that of the original scale. Our results support that the worry experienced immediately before bedtime appears to be especially important.

Table 3
Item properties of the fourteen-item, Korean version of the MCQ-I (MCQI-14).

Items		Response scale (%)				CITC	CID	Factor loading (95% CI)
		1	2	3	4			
Item 12	Before I fall asleep, I should replace stressful thoughts with less stressful ones.	16.5	32.6	36.8	14.2	0.58	0.91	0.614 (0.553, 0.676)
Item 18	Before I fall asleep, I must try to have a restful mind.	16.5	29.7	41.9	11.9	0.63	0.91	0.663 (0.598, 0.727)
Item 23	Before I fall asleep, I should try and stop physical sensations in my body.	25.5	34.5	32.6	7.4	0.66	0.90	0.695 (0.630, 0.761)
Item 28	Before I fall asleep, I should try as many ways as I can to control my thoughts.	29.7	42.3	23.2	4.8	0.67	0.90	0.706 (0.637, 0.776)
Item 31	The slightest noise means my chance of sleep will be jeopardized.	30.3	37.4	20.6	11.6	0.54	0.91	0.560 (0.499, 0.620)
Item 33	At lights out, I should search for a comfortable position.	10.3	20.6	45.5	23.5	0.51	0.91	0.527 (0.467, 0.587)
Item 39	When frustrated in bed, I should tell myself not to be so silly.	34.2	34.2	26.1	5.5	0.51	0.91	0.535 (0.476, 0.593)
Item 42	When feeling tired in bed, I must still try hard to sleep.	31.9	39.4	21.6	7.1	0.66	0.90	0.694 (0.625, 0.763)
Item 47	Any body sensation in bed means my sleep may be compromised.	31.9	41.3	23.9	2.9	0.58	0.91	0.598 (0.535, 0.661)
Item 50	At lights out, I must force myself not to look at the clock.	48.4	32.6	15.2	3.9	0.57	0.91	0.596 (0.528, 0.665)
Item 51	Before I fall asleep, I should try and switch off my thoughts.	28.1	34.8	29.7	7.4	0.74	0.90	0.787 (0.718, 0.857)
Item 54	Before I fall asleep, I should push anxious feelings away.	25.8	29.7	35.2	9.4	0.70	0.90	0.734 (0.670, 0.798)
Item 58	Being awake in bed means I have lost control of my sleep.	18.1	40.0	33.5	8.4	0.60	0.91	0.623 (0.558, 0.688)
Item 60	At lights out, I should try and control my sleep.	24.2	31.0	34.8	10.0	0.75	0.90	0.792 (0.724, 0.860)

1 = Do not agree, 2 = Agree slightly, 3 = Agree moderately, 4 = Agree very much, M, mean; SD, standard deviation; CITC, corrected item-total correlation.
CID, Cronbach's alpha if item deleted; CI, confidence interval.

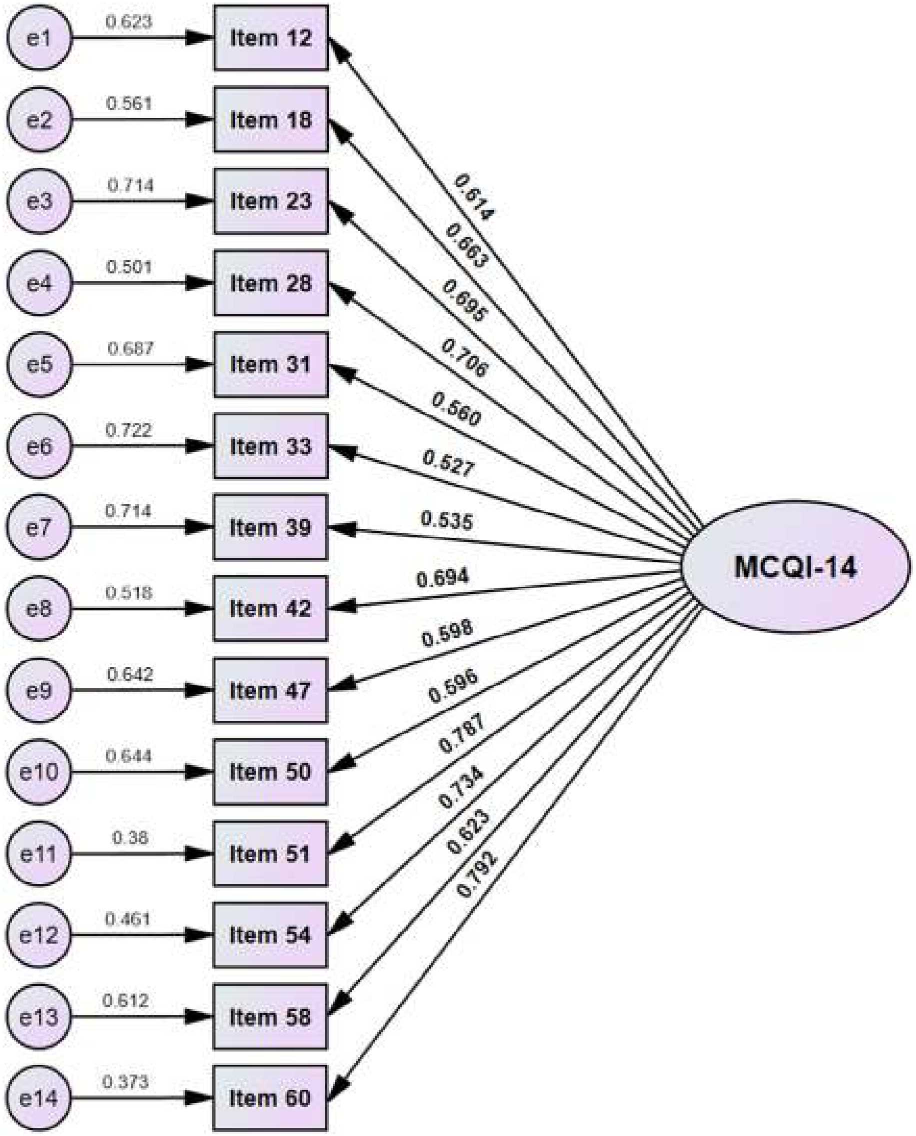

Fig. 4. Factor structure of the MCQI-14.

Table 4
Scale level psychometric properties of the MCQI-6 and MCQI-14.

Psychometric properties	MCQI-6	MCQI-14	Suggested cut-off
Floor effect	5.2%	0.3%	15%
Ceiling effect	1%	0%	15%
Mean inter-item correlation	0.472	0.425	Between .15 and .50
Cronbach's alpha	0.843	0.912	≥ .7
McDonald's Omega	0.846	0.913	≥ .7
Split-half reliability (odd-even)	0.819	0.927	≥ .7
Standard error of measurement	1.605	2.567	Smaller than SD/2
Ferguson delta	0.978	0.987	≥ .9
***Rho* coefficient**	0.845	0.910	≥ .7
IRT reliability	0.862	0.923	≥ .7
Item reliability	0.880	0.975	≥ .7
Person reliability	0.819	0.905	≥ .7
Item separation index	2.704	6.283	≥ 2
Person separation index	2.126	3.077	≥ 2
Model fits of confirmatory factor analysis			
χ^2 (df, *p* value), χ^2/df	8.20 (9, 0.514), 0.911	77.05 (77, 0.477), 1.001	Nonsignificant, < 5
CFI	1.000	1.000	>.95
TLI	1.001	1.000	>.95
RMSEA [90% CI value] (*p* value)	0.000 [0.000, 0.060], 0.893	0.001 [0.000, 0.032], 1.00	<.08
SRMR	0.038	0.051	<.08

RF performed with high accuracy (AUC > 0.97) while utilizing only six items, representing a 90% reduction in the number of items of the MCQ-I questionnaire. We observed that both shortened versions are valid and reliable rating scales. However, there are some issues about feature importance obtained by the RF. In this research, we used the mean decrease of accuracy, the most advanced variable importance measure in RF [33], to capture the feature importance for classification as done in [17]. Using different measures such as Gini importance [19,20], the rank of items might vary. Moreover, due to the 'randomness' of the RF, calculated feature importance can vary each time we apply the RF. To dismiss this issue, we constructed 500 different RFs and averaged the result to calculate the feature importance.

In terms of practicality, the value of the shortened version of the MCQ-I in this study can be highly evaluated. If there are too many test items, concentration decreases, making it difficult for respondents, especially for patients with sleep disorders who are tired and deconcentrated, a shortened test was needed. In order to evaluate the reliability and validity of the shortened MCQ-I, the internal consistency, construct validity, and factor analysis were tested. Since the number of questions is small, the distribution of the original score is narrow. It is difficult to decide the standards for relative evaluation. Therefore, in the shortened test, subjects are selected using a cut score rather than a norm. Empirical evidence on the validity of the shortened reference score is needed using a cut score [34]. In this study, statistical methods were used to determine how many items should be shortened. However, this alone cannot be determined, and a clinician's judgment is needed to understand the contents well to measure. In this study, when experts evaluate the degree of metacognition of the sleep, on-site verification was not made as to whether a shortened scale consisting of 6 or 14 items could be used. In the use of shortened scales, it is important that the baseline scores provided by developers are not iron rules, but are flexibly applied according to the purpose of using the scale to preserve the value of the test and ensure high-quality use. This can be confirmed in subsequent studies. It is necessary to continuously verify, modify, and supplement through feedback from experts and researchers.

6. Limitations

We would acknowledge several limitations in this study. First, since this study was conducted online, assessment of sleep was made by self-reports of non-clinician responses. Some participants would not meet strict research diagnostic criteria for primary insomnia disorder as below [35]; (1) difficulty initiating and/or maintaining sleep or non-restorative sleep (2) with at least one associated daytime impairment (3) for at least 1 month (4) in the absence of a sleep disruptive medical/psychiatric condition, substance abuse (5) and/or other sleep disorder. However, we tried to supplement the limitations of the online evaluation by using multi-dimensional evaluation tools for insomnia. Second, MCQ-I could not readily discriminate between primary insomnia sufferers and normal sleepers. Although the MCQ-I score and ISI score showed a positive correlation, the MCQ-I cut-off point itself did not show excellent sensitivity and specificity for detecting insomnia patients. The MCQ-I will help predict insomnia patients' inappropriate metacognition, but it is difficult to use as a diagnostic tool for insomnia. Lastly, the data are cross-sectional and all identified associations within the variables are correlational so causal interpretations cannot be drawn. The current data did not include all potential antecedents of insomnia one or more of which may account for the identified relationships between thought control strategies and insomnia.

In conclusion, we observed that the Korean version of MCQ-I, and two shortened versions (MCQI-6, and MCQI-14) clustered by RF were valid and reliable tools for measuring one's metacognition on insomnia. We found the possibility of applicability of RF to develop the shortened version of the long original scale. We consider that this study will be helpful to choose the shortened version of MCQ-I confirmed with machine learning in clinical practice.

CRediT authors contribution statement

Joohee Lee: Data curation, Writing—original draft, and Writing—review & editing. **Seokmin Ha:** Formal analysis, Methodology, Writing—original draft, and Writing—review & editing. **Oli Ahmed:** Conceptualization, Formal analysis, and Writing—review & editing. **Inn-Kyu Cho:** Data curation, Writing—original draft, and Writing—review & editing. **Dongin Lee:** Data curation, Writing—original draft, and Writing—review & editing. **Kyumin Kim:** Conceptualization, Data curation, Writing—original draft, and Writing—review & editing. **Sangha Lee:** Conceptualization, Data curation, Writing—original draft, and Writing—review & editing. **Solbi Kang:** Data curation, Writing—original draft, and Writing—review & editing. **Sooyeon Suh:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Methodology, Writing—original draft, and Writing—review & editing. **Seockhoon Chung:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Methodology, Writing—original draft, and Writing—review & editing. **Jae Kyoung Kim:** Formal analysis, Funding acquisition, Methodology, Writing—original draft, and Writing—review & editing.

Declaration of competing interest

All authors have no conflict of interest defined as any financial interests or connections.

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Abbreviations

Area under the curve (AUC)
Cognitive-Behavioral Therapy for insomnia (CBT-I)
Comparative fit index (CFI)
Confirmatory Factor Analysis (CFA)
Diagonally weighted least squares (DWLS)
Differential item functioning (DIF)
Hospital Anxiety and Depression Scale (HADS)
Insomnia Severity Index (ISI),
Metacognitions Questionnaire-Insomnia (MCQ-I)
Patient Health Questionnaire-9 (PHQ-9),
Pittsburgh Sleep Quality Index (PSQI),
Random Forest (RF)
Receiver Operating Characteristic (ROC)
Root-mean-square-error of approximation (RMSEA)
Self-Regulatory Executive Function (S-REF)
Standardized root-mean-square residual (SRMR)
Tucker Lewis index (TLI)

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.sleep.2022.06.005.

References

[1] Service NHI. Sleepless nights "insomnia," the number of patients steadily increases. Retrieved from, https://www.nhis.or.kr/nhis/index.do; 2018.
[2] Choi H, Youn S, Um YH, Kim TW, Ju G, Lee HJ, et al. Korean clinical practice guideline for the diagnosis and treatment of insomnia in adults. Psychiatry Investig 2020;17(11):1048–59. https://doi.org/10.30773/pi.2020.0146.
[3] Edinger JD, Arnedt JT, Bertisch SM, Carney CE, Harrington JJ, Lichstein KL, et al. Behavioral and psychological treatments for chronic insomnia disorder in adults: an American Academy of Sleep Medicine clinical practice guideline. J Clin Sleep Med 2021;17(2):255–62. https://doi.org/10.5664/jcsm.8986.
[4] Riemann D, Baglioni C, Bassetti C, Bjorvatn B, Dolenc Groselj L, Ellis JG, et al. European guideline for the diagnosis and treatment of insomnia. J Sleep Res 2017;26(6):675–700. https://doi.org/10.1111/jsr.12594.
[5] Ong JC, Ulmer CS, Manber R. Improving sleep with mindfulness and acceptance: a metacognitive model of insomnia. Behav Res Ther 2012;50(11): 651–60. https://doi.org/10.1016/j.brat.2012.08.001.
[6] Clark DA. Intrusive thoughts in clinical disorders: theory, research, and treatment. Guilford Publications; 2005.
[7] Waine J, Broomfield NM, Banham S, Espie CA. Metacognitive beliefs in primary insomnia: developing and validating the Metacognitions Questionnaire–Insomnia (MCQ-I). J Behav Ther Exp Psychiatr 2009;40(1):15–23. https://doi.org/10.1016/j.jbtep.2008.03.002.
[8] Harvey AG. A cognitive model of insomnia. Behav Res Ther 2002;40(8): 869–93. https://doi.org/10.1016/s0005-7967(01)00061-4.
[9] Kuisk LA, Bertelson AD, Walsh JK. Presleep cognitive hyperarousal and affect as factors in objective and subjective insomnia. Percept Mot Skills 1989;69(3 Pt 2):1219–25. https://doi.org/10.2466/pms.1989.69.3f.1219.
[10] Wells A. Emotional disorders and metacognition: innovative cognitive therapy. Wiley; 2002.
[11] Morin CM, Espie CA. Insomnia: a clinical guide to assessment and treatment. Springer US; 2013.
[12] Cartwright-Hatton S. Beliefs about worry and intrusions: the Meta-Cognitions Questionnaire and its correlates. J Anxiety Disord 1997;11(3):279–96. https://doi.org/10.1016/s0887-6185(97)00011-x.
[13] Wells A. Meta-cognition and worry: a cognitive model of generalized anxiety disorder. Behav Cognit Psychother 1995;23(3):301–20. https://doi.org/10.1017/S1352465800015897.
[14] Pal M. Random forest classifier for remote sensing classification. Int J Rem Sens 2005;26(1):217–22. https://doi.org/10.1080/01431160412331269698.
[15] Byeon H. Is the random forest algorithm suitable for predicting Parkinson's disease with mild cognitive impairment out of Parkinson's disease with normal cognition? Int J Environ Res Publ Health 2020;17(7). https://doi.org/10.3390/ijerph17072594.
[16] Duda M, Ma R, Haber N, Wall DP. Use of machine learning for behavioral distinction of autism and ADHD. Transl Psychiatry 2016;6(2):e732. https://doi.org/10.1038/tp.2015.221.
[17] Ma E-Y, Kim J-W, Lee Y, Cho S-W, Kim H, Kim JK. Combined unsupervised-supervised machine learning for phenotyping complex diseases with its application to obstructive sleep apnea. Sci Rep 2021;11(1):4457. https://doi.org/10.1038/s41598-021-84003-4.
[18] van der Meer D, Hoekstra PJ, van Donkelaar M, Bralten J, Oosterlaan J, Heslenfeld D, et al. Predicting attention-deficit/hyperactivity disorder severity from psychosocial stress and stress-response genes: a random forest regression approach. Transl Psychiatry 2017;7(6):e1145. https://doi.org/10.1038/tp.2017.114.
[19] Wei P, Lu Z, Song J. Variable importance analysis: a comprehensive review. Reliab Eng Syst Saf 2015;142(C):399–432. Retrieved from, https://EconPapers.repec.org/RePEc:eee:reensy:v:142:y:2015:i:c. p:399-432.
[20] Wei P, Zhenzhou L, Song J. Variable importance analysis: a comprehensive review. Reliab Eng Syst Saf 2015:142. https://doi.org/10.1016/j.ress.2015.05.018.
[21] Eysenbach G. Correction: improving the Quality of web surveys: the Checklist for Reporting results of internet E-Surveys (CHERRIES). J Med Internet Res 2012;14(1):e8.
[22] Bastien CH, Vallières A, Morin CM. Validation of the Insomnia Severity Index as an outcome measure for insomnia research. Sleep Med 2001;2(4): 297–307. https://doi.org/10.1016/s1389-9457(00)00065-4.
[23] Cho YW, Song ML, Morin CM. Validation of a Korean version of the insomnia severity index. J Clin Neurol 2014;10(3):210–5. https://doi.org/10.3988/jcn.2014.10.3.210.
[24] Aloba OO, Adewuya AO, Ola BA, Mapayi BM. Validity of the Pittsburgh sleep quality index (PSQI) among Nigerian university students. Sleep Med 2007;8(3):266–70. https://doi.org/10.1016/j.sleep.2006.08.003.
[25] Sohn SI, Kim DH, Lee MY, Cho YW. The reliability and validity of the Korean version of the Pittsburgh sleep quality index. Sleep Breath 2012;16(3): 803–12. https://doi.org/10.1007/s11325-011-0579-9.
[26] Kroenke K, Spitzer RL, Williams JB. The PHQ-9: validity of a brief depression severity measure. J Gen Intern Med 2001;16(9):606–13. https://doi.org/10.1046/j.1525-1497.2001.016009606.x.
[27] Choi HS, Choi JH, Park KH, Joo KJ, Ga H, Ko HJ, Kim SR. Standardization of the Korean version of patient health questionnaire-9 as a screening instrument for major depressive disorder. J Korean Acad Fam Med 2007;28(2):114–9. Retrieved from, http://www.kjfm.or.kr/journal/view.php?number=357.
[28] Zigmond AS, Snaith RP. The hospital anxiety and depression scale. Acta Psychiatr Scand 1983;67(6):361–70. https://doi.org/10.1111/j.1600-0447.1983.tb09716.x.
[29] Se Man Oh MD, Kyung-Jun Min MD, Doo-Byung Park MD. A study on the standardization of the hospital anxiety and depression scale for Koreans. [A study on the standardization of the hospital anxiety and depression scale for Koreans - a comparison of normal, depressed and anxious groups -]. J Korean Neuropsychiatr Assoc 1999;38(2):289–96. Retrieved from, http://scholar.dkyobobook.co.kr/searchDetail.laf?barcode=4050026370454.
[30] Gravetter F, Wallnau L. Essentials of statistics for the behavioral sciences. eighth ed. Belmont, CA: Wadsworth; 2014.
[31] Brown TA. Confirmatory factor analysis for applied research. Guilford Press; 2006.
[32] Byrne BM. Structural equation modeling with AMOS: Basic concepts, applications, and programming. Lawrence Erlbaum Associates; 2001.
[33] Strobl C, Boulesteix AL, Zeileis A, Hothorn T. Bias in random forest variable importance measures: illustrations, sources and a solution. BMC Bioinf 2007;8:25. https://doi.org/10.1186/1471-2105-8-25.
[34] Seo Dg, Lee S, Kim J-N. Psychometric methods and validation of short form for the psychological scale: based on the Korean dysfunctional depression scale. Kor. J. Psychol. 2019;38:75–102.
[35] Edinger JD, Bonnet MH, Bootzin RR, Doghramji K, Dorsey CM, Espie CA, et al. Derivation of research diagnostic criteria for insomnia: report of an American academy of sleep medicine work group. Sleep 2004;27(8):1567–96. https://doi.org/10.1093/sleep/27.8.1567.