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ORIGINAL RESEARCH

Analysis of the Improvement Sequence in Insomnia Symptoms and Factors Influencing the Treatment Outcomes of Smartphone-Delivered CBT in Patients with Insomnia Disorder

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Background: The effectiveness of medication combined with smartphone-delivered cognitive behavioral therapy for insomnia (CBT-I) has been well verified, but there are few studies on the sequence of remission of insomnia symptoms. This study aims to understand the sequence of symptom improvement and the factors influencing the treatment effectiveness in patients with insomnia.

Methods: Smartphone-delivered CBT, as a form of Online CBT, allows for training through mobile devices at any time and place. We utilized the Good Sleep 365 app to conduct a survey, involving 2820 patients who met the baseline inclusion criteria. These patients were assessed using a general demographic questionnaire and the Pittsburgh Sleep Quality Index (PSQI) to evaluate general demographic information and insomnia symptoms, and subsequently underwent CBT training using the Good Sleep 365 app. A total of 1179 patients completed follow-ups at 4 weeks, 8 weeks, 16 weeks, and 24 weeks.

Results: At 4 weeks and 8 weeks, the descending order of the reduction rates of PSQI components (excluding component 6: use of sleeping medication) was: sleep latency, subjective sleep quality, sleep efficiency, sleep disturbance, sleep maintenance, and daytime dysfunction. At 16 weeks and 24 weeks, the descending order was subjective sleep quality, sleep latency, sleep efficiency, daytime dysfunction, sleep maintenance, and sleep disturbance. There were significant differences in the reduction rates of PSQI components (excluding component 6: use of sleeping medication) both at the same follow-up times and at different follow-up times (all $P<0.05$). Multivariable logistic regression analysis showed that patients older than 30 years and those with a college degree or above had better treatment outcomes, whereas those with a disease duration of more than three years had worse outcomes.

Conclusion: The sequence of symptom improvement in patients with insomnia changes over time, and age, educational level, and duration of disease are factors influencing treatment outcomes.

Keywords: insomnia, CBT-I, PSQI, influencing factors

Introduction

Insomnia is a prevalent sleep disorder affecting the general population and constitutes a global public health concern.[1] Although the reported prevalence of insomnia varies among countries due to the use of different assessment tools,[2–4] it is noteworthy that the prevalence of insomnia is showing an upward trend year by year.[5] As a chronic condition,[6] insomnia has substantial medical and psychological ramifications,[7] compromising personal health over the long term,[8] leading to a decline in productivity,[9] and imposing a significant economic burden on society.[10]

The current standards of care for the treatment of insomnia include pharmacological and non-pharmacological interventions. Among the non-pharmacological approaches, cognitive behavioral therapy for insomnia (CBT-I) is

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recommended as the first-line therapy for this condition. The action mechanisms of CBT-I involve correcting patients' misconceptions and attitudes towards sleep, changing sleep hygiene habits, enhancing sleep drive, and reducing nighttime awakenings to improve sleep quality and reduced anytime dysfunction caused by insomnia.[11,12] Due to the rapid development of mobile internet and the widespread popularity of smart phones, the treatment modality of CBT-I has gradually shifted to online. Unlike traditional CBT-I, smartphone-delivered CBT-I is not limited by the scarcity of professionals and treatment venues. Patients can receive treatment anytime and anywhere through mobile devices, which can benefit a broader population with reliable clinical efficacy.[13–16]

Ideally, non-pharmacological therapy is recommended as the first-line intervention for insomnia. However, due to the complexity of etiology and refractory nature of insomnia, pharmacotherapy is often used in combination with non-pharmacological interventions in clinical settings.[17] Previous studies have shown that CBT-I combined with medication provides more significant benefit for insomnia disorder, and the insomnia symptoms of most patients can be alleviated within weeks through systematic treatment.[18,19] However, previous studies have mainly focused on the sequence of CBT-I and drugs used in the treatment of insomnia as well as its effect on treatment efficacy.[12,15,16] A study of patients who respond to clinical treatment has found that gender, educational level, and Pittsburgh Sleep Quality Index (PSQI) score are associated with delayed treatment.[20] However, existing studies rarely provide clues about the improvement sequence of insomnia symptoms during treatment and the influencing factors that may contribute to treatment ineffectiveness.

As a real-world study, this study conducted a 6-month follow-up of patients with insomnia, aiming to explore the improvement sequence of insomnia symptoms in patients treated with smartphone-delivered CBT-I combined with medication. Based on the treatment conditions of patients during follow-up, the study also analyzed the factors influencing treatment outcomes.

Materials and Methods

Ethics Approval

This research is a retrospective study utilizing data from patients who visited the Sleep Disorder Clinic of Hangzhou Seventh People's Hospital in the past. A waiver for informed consent was requested and granted by the Ethics Committee of Hangzhou Seventh People's Hospital (Ethics Approval Number: 2024–044). The waiver was granted due to the study's retrospective nature. All patient information used in this study will be anonymized and securely stored, with access limited to authorized personnel only. This study complies with the Declaration of Helsinki, guaranteeing that all research practices uphold the ethical principles of respect for human subjects and their rights.

Study Subjects

Patients who visited the Sleep Disorder Clinic of Hangzhou Seventh People's Hospital between November 1, 2017, and October 22, 2023, and completed smartphone-delivered CBT-I via the "Good Sleep 365" platform (Hangzhou Silpu Diagnosis Co., Ltd., version 4.8.0) were selected. "Good Sleep 365" is an application (APP) designed for the diagnosis, treatment, and rehabilitation of insomnia, allowing patients to engage in cognitive-behavioral training, sleep assessment, and music relaxation, and also offering regular professional rehabilitation video pushes and doctor consultations via online calls.

Sample Size, Inclusion and Exclusion Criteria

This study determined the sample size by considering the research question, statistical power, and practical feasibility. Initially, a power analysis was performed to identify the sample size required to detect a clinically significant difference between groups. We used G*power 3.1.9.7 for this analysis, setting parameters for *t*-tests with a two-tailed test, an effect size of 0.5, alpha of 0.05, and power of 0.80, which indicated a required sample size of 1179. Inclusion criteria: (1) Patients meeting the diagnostic criteria of International Classification of Diseases 10th Revision (ICD-10) for insomnia; (2) aged between 18 to 64 years; (3) capable to use the "Good Sleep 365"APP; (4) PSQI baseline score ≥5, receiving smartphone-delivered CBT-I, and completing follow-ups at 4 weeks, 8 weeks, 16 weeks, and 24 weeks. A total of 1179 patients met these criteria.

Exclusion Criteria: (1) Insomnia caused by various psychiatric diseases (secondary or comorbid insomnia); (2) insomnia caused by psychoactive substances or physical illness; (3) pregnant or lactating women.

Study Design

This study adopted self-report questionnaires. Patients were required to complete general information and baseline assessments, as well as monthly PSQI, Patient Health Questionnaire (PHQ-9), and Generalized Anxiety Disorder (GAD-7) evaluations via mobile phone. The "Good Sleep 365" software was used for smartphone-delivered CBT-I.

The smartphone-delivered CBT-I provided by "Good Sleep 365" platform included sleep restriction, stimulus control, cognitive restructuring, sleep hygiene education, and relaxation training. These contents were pushed to patients daily in the form of videos or audio, comprising 62 videos and 4 audio clips, each lasting 1–4 minutes. The platform also send daily sleep diaries for patients to record. The back-end system pushed the content based on patient assessment results. Patients could review the content what they learned but could not select new videos or audio clips.

Assessment Tools

A self-designed questionnaire was used to survey the general information of the study subjects, including gender, age, disease duration, family history, and educational level.

PSQI: consisting of self-rated and sleep partner rated items. Only self-rated items were scored, including 19 items across 7 components. The total score was 21, with 0–4 indicating no insomnia, 5–9 mild insomnia, 10–14 moderate insomnia, and 15–21 severe insomnia.[21]

Efficacy Evaluation

The efficacy was evaluated based on the PSQI scores collected at baseline, 4 weeks, 8 weeks, 16 weeks, and 24 weeks. The rate of reduction in PSQI was used as a measure of clinical efficacy, calculated as (Score before treatment - Score after treatment) / Score before treatment * 100%. Effective: reduction rate ≥25%; Ineffective: reduction rate <25%.[22]

Statistical Analysis

Data were analyzed and visualized using SPSS 21.0 and GraphPad Prism 9.5.1 software. Repeated measures analysis of variance (ANOVA) was used to compare the differences in the reduction rates of PSQI components at different follow-up times, while one-way ANOVA was used to compare the differences in the reduction rates of PSQI components within the same follow-up period. Given the increased risk of Type I errors due to multiple ANOVA tests, the Bonferroni correction method was implemented to adjust for multiple comparisons. Multivariable logistic regression analysis, adjusted for age, gender, disease duration, educational level and family history, was conducted to identify factors influencing insomnia treatment outcomes, with risk factors presented as odds ratio (OR) and 95% confidence interval (CI). The level of significance was set at $\alpha=0.05$ (two-tailed), with $P<0.05$ considered statistically significant.

Results

General Information

A total of 1179 patients were enrolled in this study (Figure 1), including 297 males (25.19%) and 882 females (74.81%), with an average age of 46.32±10.63 years. Taking the reduction rate in the total score of PSQI≥25% as the criterion for effective clinical treatment, 760 cases achieved effective treatment at 8 weeks, while 419 cases deemed ineffective, resulting in a total effective rate of 64.46%. At 16 weeks, effective treatment was observed in 843 cases, while 336 cases had ineffective treatment, yielding an effective rate of 71.50%. At 24 weeks, 854 cases yielded effective treatment and 325 were ineffective treatment, resulting in an effective rate of 72.43%.

Reduction Rate of PSQI Score for Each Component Over Time

A one-way ANOVA was used to compare the differences in the reduction rate of PSQI score for each component (except for component 6: use of sleeping medication) at the same follow-up period with two-way comparisons. The results, as

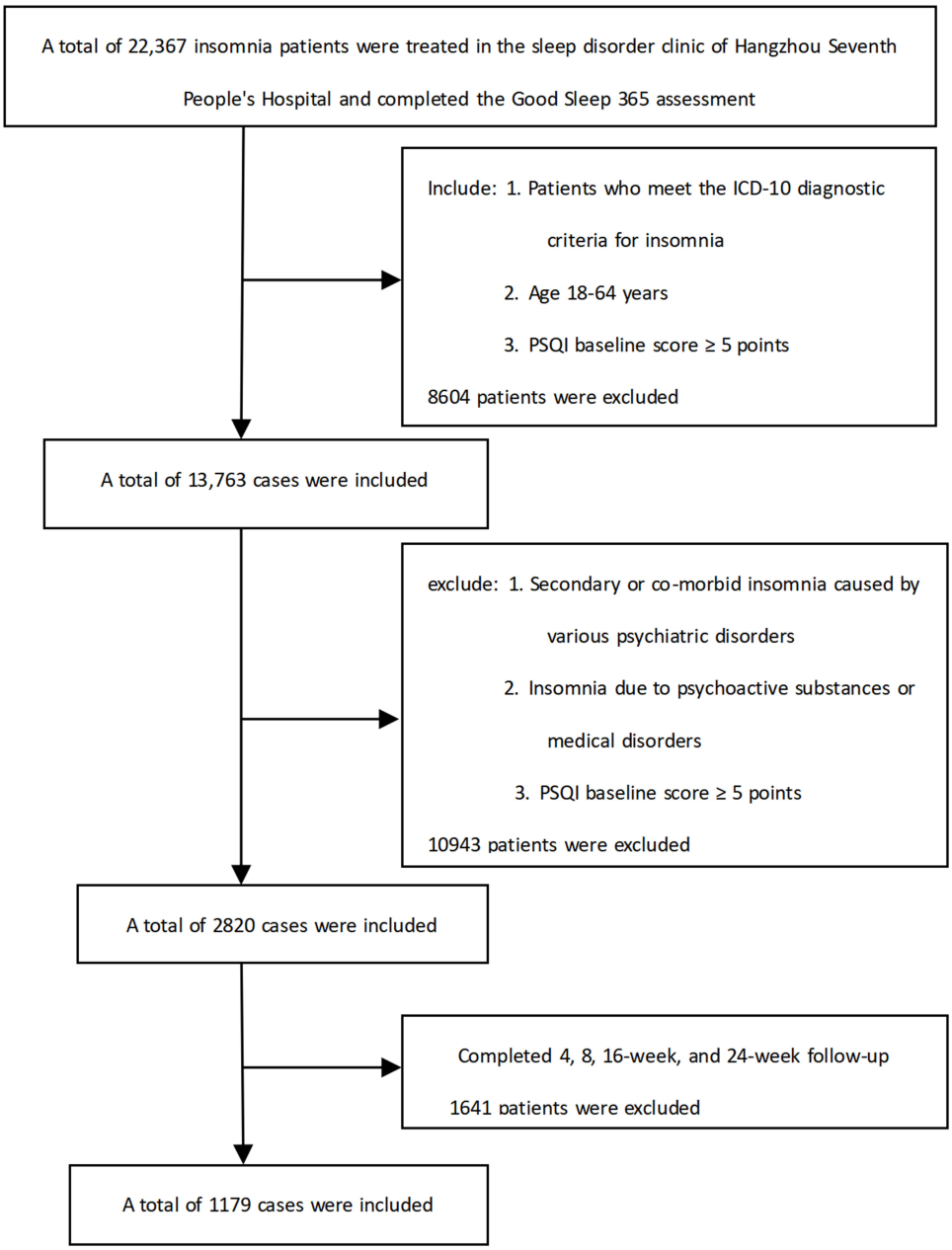

Figure 1 STROBE flowchart describing patient selection.

shown in Table 1, illustrated that there were significant differences in the reduction rates of PSQI components (excluding component 6: use of sleeping medication) at the same follow-up period (all $P<0.05$). At 4 weeks and 8 weeks, the reduction rates from high to low were: sleep latency, subjective sleep quality, sleep efficiency, sleep disturbance, sleep maintenance, and daytime dysfunction. At 16 weeks and 24 weeks, the order was subjective sleep quality, sleep latency, sleep efficiency, daytime dysfunction, sleep maintenance, and sleep disturbance. During the four time points, the rate of improvement in sleep maintenance and reduction in sleep disorders was significantly lower than the improvement in subjective sleep quality and reduction in sleep latency, and this difference was statistically significant. The decrease in sleep efficiency at 4 weeks and 8 weeks was significantly lower than the improvements in subjective sleep quality and sleep latency. The reduction in daytime dysfunction at 4 weeks, 8 weeks, and 16 weeks was significantly lower than the improvements in subjective sleep quality and sleep latency, and this difference was statistically significant. We compared the differences in the rates of improvement in various factors of the PSQI (except factor 6: use of sleeping medication) at

Table 1 The Percentage Reduction Rate of Each PQSI Factor Over Time

PSQI	Number	Follow-Up Time				*F*	*P*
		4W	8w	16w	24w		
Subjective sleep quality	1146	42.18±1.14	49.22±1.10*	53.25±1.05*#	51.23±1.12*	38.970	0.000
Sleep latency	1139	43.70±1.33	49.22±1.10*	52.76±1.15*	49.70±1.19*&	22.593	0.000
Sleep maintenance	1043	21.84±1.20ab	27.97±1.23ab*	32.85±1.21ab*#	31.95±1.20ab*#	43.234	0.000
Sleep efficiency	1038	32.21±1.65ab	41.47±1.62ab*	49.09±1.43*#	46.80±1.56*#	45.906	0.000
Sleep disorders	1142	22.10±1.19ab	28.19±1.22ab*	29.50±1.23ab*	29.87±1.27ab*	16.593	0.000
Daytime function	1117	12.93±1.70ab	27.79±1.59ab*	37.06±1.53ab*#	46.26±1.48*#&	172.702	0.000
F		80.807	67.847	69.296	50.803		
p		0.000	0.000	0.000	0.000		

Notes: Same follow-up time, a P < 0.05 compared with sleep onset latency, b P < 0.05 compared with subjective sleep quality. Same factor group, compared with 4 w, *P < 0.05; compared with 8 w, #P < 0.05, compared with 16 w, and P < 0.05.

the four follow-up time points using one-way repeated measures ANOVA, and we used the Bonferroni method for pairwise comparison.

As shown in Table 1, there were significant differences in the reduction rates of PSQI components (excluding component 6: use of sleeping medication) at 4 weeks, 8 weeks, 16 weeks, and 24 weeks (all $P<0.05$). The reduction rates of PSQI components at 8 weeks, 16 weeks, and 24 weeks were all lower than those at 4 weeks, with statistically significant differences. The reduction rates in subjective sleep quality, sleep maintenance, sleep efficiency, and daytime dysfunction factors at 16 weeks were significantly reduced compared to those at 8 weeks, with statistically significant differences. The reduction rates for sleep latency and daytime dysfunction at 24 weeks were notably decreased compared to those at 16 weeks, with statistically significant differences. The changes in the reduction rates of PSQI components over time are presented in Table 1, and the graphical representation is shown in Figure 2.

The Curve of the Percentage of Hypnotic Drug Use Over Time

As shown in Figure 3, the percentage of patients who used hypnotic drugs 3 times or more per week increased before 4 weeks and gradually decreased at the beginning of the 4th week; the percentage of patients who did not use hypnotic drugs declined before 4 weeks and gradually increased in the 4th week; the percentage of patients who used hypnotic drugs less than once a week and 1–2 times a week declined before 4 weeks and basically stabilized at the beginning of the 8th week, and the percentage of patients who used hypnotic drugs 1–2 times a week was gradually higher than that of patients who used hypnotic drugs less than once a week.

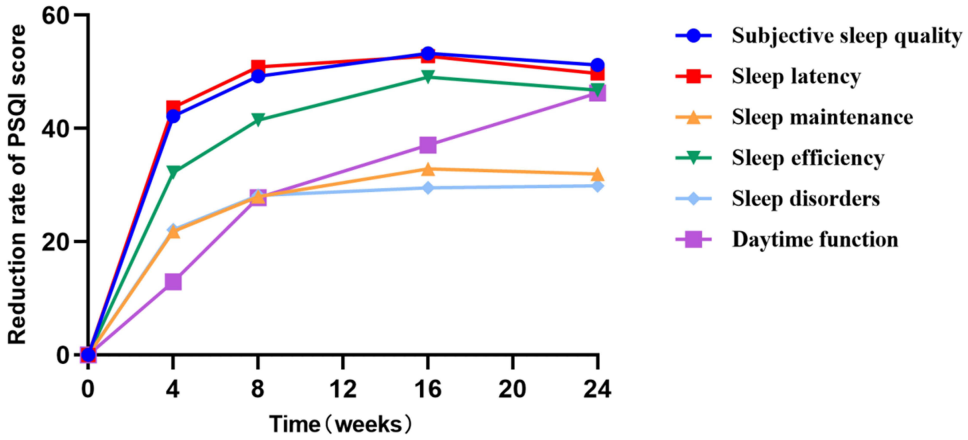

Figure 2 Plot of PSQI score reduction rates for each component (except component 6: use of sleeping medication) over time.
Abbreviation: PSOI, Pittsburgh Sleep Quality Index.

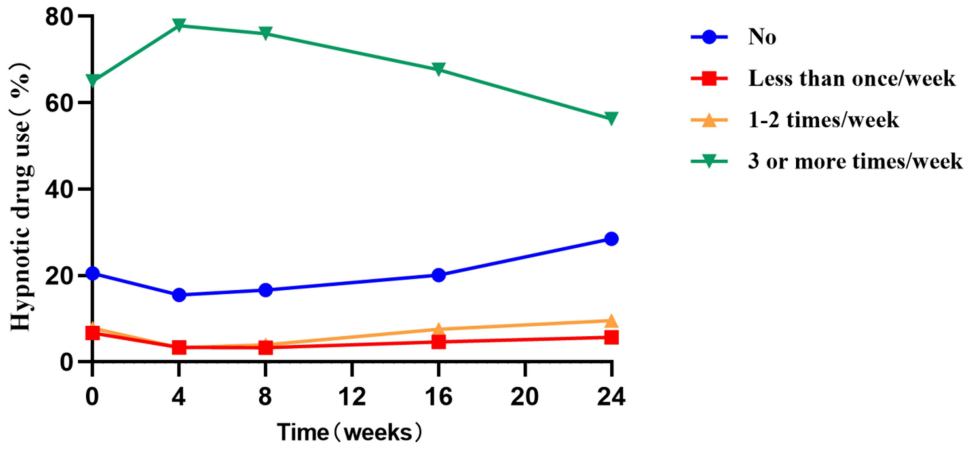

Figure 3 Plot of percentage of hypnotic drug use factor over time.

Multivariable Logistic Regression Analysis of Factors Affecting Efficacy at 8-Week Follow-Up

The multivariable logistic regression analysis at the 8-week follow-up revealed that a disease duration of more than 3 years (OR=0.746, 95% CI: 0.584–0.954, *P*=0.020) was associated with poorer treatment outcomes. The results are shown in Table 2.

Multivariable Logistic Regression Analysis of Factors Affecting Efficacy at 16-Week Follow-Up

The multivariable logistic regression analysis at the 16-week follow-up indicated that patients aged 30 years or older (OR=2.308, 95% CI: 1.491–3.574, *P*<0.01) and those with college degree or higher (OR=1.678, 95% CI: 1.120–2.513, *P*=0.012) exhibited better treatment outcomes. Conversely, a disease duration exceeding 3 years (OR=0.695, 95% CI: 0.535–0.904, *P*=0.007) was associated with less favorable therapeutic results. The results are shown in Table 3.

Multivariable Logistic Regression Analysis of Factors Affecting Efficacy at 24-Week Follow-Up

The multivariable logistic regression analysis at the 24-week follow-up showed that patients aged 30 years or older (OR=1.918, 95% CI: 1.272–3.085, *P*=0.002) and those with college degree or higher (OR=1.695, 95% CI: 1.131–2.539,

Table 2 Logistic Regression Analysis of Factors Affecting 8-Week Efficacy

	B	SE	Wald χ^2	P	OR	95% CI	
Age	0.314	0.219	2.045	0.153	1.368	0.890	2.103
Gender	−0.095	0.143	0.442	0.506	0.909	0.686	1.204
Education							
Middle/high school	0.077	0.180	0.185	0.667	1.080	0.759	1.537
Bachelor degree or above	0.341	0.195	3.070	0.080	1.407	0.960	2.060
Duration of illness	−0.293	0.125	5.442	0.020	0.746	0.584	0.954
Family	0.012	0.150	0.006	0.937	1.012	0.755	1.357
Constant	0.302	0.270	1.250	0.263	1.352		

Notes: For reference categories in the logistic regression analysis: Age was referenced by those under 30 years old; Gender was referenced by females; Education level was referenced by those who completed primary school; Family history was referenced by those with a negative history; Disease duration was referenced by those with a duration of 3 years or less.

Table 3 Logistic Regression Analysis of Factors Affecting 16-Week Efficacy

	B	SE	Wald χ^2	P	OR	95% CI	
Age	0.837	0.223	14.067	0.000	2.308	1.491	3.574
Gender	−0.020	0.154	0.017	0.896	0.980	0.724	1.326
Education							
Middle/high school	0.218	0.188	1.342	0.247	1.243	0.860	1.797
Bachelor degree or above	0.517	0.206	6.302	0.012	1.678	1.120	2.513
Duration of illness	−0.363	0.134	7.363	0.007	0.695	0.535	0.904
Family	−0.094	0.158	0.355	0.551	0.910	0.668	1.240
Constant	0.069	0.276	0.063	0.802	1.072		

Notes: For reference categories in the logistic regression analysis: Age was referenced by those under 30 years old; Gender was referenced by females; Education level was referenced by those who completed primary school; Family history was referenced by those with a negative history; Disease duration was referenced by those with a duration of 3 years or less.

Table 4 Logistic Regression Analysis of Factors Affecting 24-Week Efficacy

	B	SE	Wald χ^2	P	OR	95% CI	
Age	0.684	0.226	9.153	0.002	1.981	1.272	3.085
Gender	0.010	0.156	0.004	0.949	1.010	0.744	1.371
Education			6.794	0.033			
Middle/high school	0.268	0.188	2.027	0.155	1.307	0.904	1.891
Bachelor degree or above	0.528	0.206	6.542	0.011	1.695	1.131	2.539
Duration of illness	−0.286	0.135	4.491	0.034	0.751	0.577	0.979
Family	−0.065	0.159	0.164	0.686	0.938	0.686	1.281
Constant	0.174	0.278	0.391	0.532	1.190		

Notes: For reference categories in the logistic regression analysis: Age was referenced by those under 30 years old; Gender was referenced by females; Education level was referenced by those who completed primary school; Family history was referenced by those with a negative history; Disease duration was referenced by those with a duration of 3 years or less.

P=0.011) experienced better treatment outcomes. In contrast, a disease duration of more than 3 years (OR=0.751, 95% CI: 0.577–0.979, *P*=0.034) was associated with inferior treatment efficacy. The results are shown in Table 4.

Discussion

The predisposing factors for insomnia include demographic, biological, psychological, and sociological factors, and gender differences have been identified in sleep physiology. In the present study, 1179 patients were enrolled in 4 follow-ups, of whom 882 (74.81%) were women, confirming that women are more prone to insomnia.[23] Since insomnia is primarily a fluctuating condition, sleep improvement cannot occur uniformly or simultaneously,[24] which requires a more nuanced assessment of the priority symptoms and persistent symptoms. Prior studies seldom delve into the variations of individual components in the PSQI scale; however, our analysis revealed that during the initial 8 weeks, the most notable improvements occurred in the components including sleep latency, subjective sleep quality, sleep efficiency, sleep disturbances, and sleep maintenance, while daytime dysfunction showed the slowest recovery. This study emphasized that understanding the sequence of insomnia symptom improvement can enhance patient confidence in treatment. This not only provides guidance for clinical decision-making but also helps professionals recognize the patterns of insomnia recovery under standardized treatment.

A previous study on CBT-I plus drug therapy reported 100% improvement in sleep latency and efficiency within the first 2 weeks and 100% improvement in sleep quality in the week 3,[25] slightly diverging from our findings. Comparative studies of different cognitive-behavioral approaches and medications indicate that CBT-I effectively reduce sleep onset latency.[26] In the early treatment phase, drugs offer immediate benefits, significantly reducing sleep onset latency and

night awakenings, while enhancing sleep maintenance, efficiency, and quality within the first 8 weeks.[27–29] However, the treatment outcomes exhibit a flattening trend over time. This flattening suggests that while initial improvements were notable, subsequent reductions in PSQI scores became less pronounced. This flattening can be explained by the adaptive mechanisms in the body and brain. Initially, medication can significantly alter neurochemical processes to improve sleep, but over time, the body may develop tolerance to the medication, leading to diminished effects. This observation underscores the need for ongoing evaluation of treatment efficacy and potential adjustments to optimize long-term outcomes. Moreover, as sleep latency decreases and duration extends, sleep disturbances tied to nocturnal awakenings do not further change significantly after 8 weeks, suggesting that these issues can be addressed within this timeframe. However, some patients may experience adverse effects from medication or switching medications. Combining sleep restriction with medication may exacerbate drowsiness, negatively impacting self-perception and maintaining daytime dysfunction.

Past research posited that sleep efficiency obtained minimal further improvement after three weeks under combination therapy;[25] conversely, our study found that sleep quality had the most significant enhancement after 16 weeks, and sleep latency and efficiency still showed notable improvements. As per guidelines, hypnotic drugs were gradually reduced over follow-ups, and our results echoed this reduction. The early pharmacological advantages waned but initially motivated patients to continue behavioral therapy,[25] thereby facilitating the long-term benefits of CBT-I. Contrary to the previous claim that CBT-I offers no help for daytime functioning,[30] we observed an improvement in daytime functioning, particularly after 8 weeks, potentially due to enhanced sleep quality[29] and reduced sedation as medication doses decreased and tolerance developed,[31] leading to enhanced daytime alertness. Notably, sleep maintenance did not extend further, aligning with prior findings,[31] supporting Morin's notion that insomnia patients may need shorter sleep.[32] This underscores for clinicians that the total sleep time for patients with insomnia is generally sufficient, and no additional medication is needed to prolong the overall sleep duration beyond the week 16. Although the overall sleep time is not prolonged, the daytime functioning of patients is consistently better, and some affirmative answers for real clinical treatment can enhance the confidence of patients in treatment to some extent.

Our findings were consistent with previous prior clinical randomized trials and large-scale real-world studies,[33,34] except that our 6-month follow-up did not observe a decline in sleep quality to pre-treatment levels, which was in contrast to past studies reporting deterioration three months post-treatment. In our study, the continuous learning via mobile devices can explain this discrepancy, which allows the reinforcement of learned material and enhances its effectiveness. The treatment effectiveness rate at 8, 16, and 24 weeks was 64.46%, 71.50%, and 72.43%, respectively. The sleep quality and daytime functioning,-crucial indicators for insomnia treatment,-also recovered,[35] validating the effectiveness of medication combined with smartphone-delivered CBT-I for adult insomniacs.

Analyzing hypnotic drug use in conjunction with the evaluation of CBT-I effectiveness provides a more nuanced understanding of how combined therapies impact insomnia treatment. During the initial stage of treatment, patients may rely more on hypnotic drugs due to persistent insomnia symptoms or while adapting to the new CBT-I regimen. This is indicated by the decrease in the percentage of patients not using hypnotics at the start, suggesting that medication was used as a coping mechanism for residual symptoms despite starting CBT-I. As the treatment progresses, there is a decrease in frequent hypnotic use around the 4th week, accompanied by an increase in the percentage of non-users. This indicates that CBT-I is beginning to show its effectiveness, leading to reduced dependency on medication. By the 8th week, the stabilization of hypnotic use patterns, with the frequency of use less than once a week and 1–2 times a week leveling off, highlights the potential for CBT-I to lead to more sustainable improvements in insomnia. Moreover, the increasing proportion of patients using hypnotics 1–2 times a week over those using them less than once a week might signify a transition phase where patients are managing their symptoms better but still rely occasionally on medication. The variations in hypnotic drug use could be reflective of differences in patient populations, treatment durations, or specific CBT-I protocols. For instance, studies with shorter follow-up periods may not capture the full impact of CBT-I on medication use, whereas those with longer durations might reveal a more pronounced shift away from medication reliance.

Logistic regression analyses showed that the factor influencing the efficacy at the week 8 was disease duration, ie, patients with a disease duration of more than 3 years had poorer efficacy, and the factors influencing the efficacy at week

16 and 24 were the same, including age, educational level, and duration of the disease. Specifically, older than 30 years and college degree or above were associated with better outcomes, and similarly, and disease duration of more than 3 years was a risk factor for efficacy. The longer the duration of the disease, the worse the outcome. Educational attainment has been demonstrated to be an enabling factor for psychiatric disorders,[36] as well-educated patients have a deeper knowledge of their illnesses, a greater willingness to trust specialized physicians, and a better understanding of smartphone-delivered CBT-I. The effect of age on efficacy is demonstrated by the fact that older patients show better efficacy in the treatment of insomnia, and from previous studies we know that older patients have stronger tolerance to sleep deprivation and lower self-reported insomnia rates compared to younger age groups.[37] Possibly due to the looser definition of the criteria for treatment efficacy, the self-rated scores of insomnia in older patients decline once their symptoms are relieved. However, the exact mechanism of the effect is yet to be further investigated. It is well-accepted that the longer the duration of the disease, the worse the treatment efficacy. Insomnia itself is a relieving disease easy to recur. Current treatment strategies basically follow the natural course of insomnia.[38] The longer the duration of the disease, the patients themselves may have cognitive bias towards sleep, resulting in poor compliance with cognitive-behavioral therapy and lack of confidence in treatment in the long run, which increases the difficulty of treatment. In addition, insomnia is an independent risk factor for many psychiatric disorders.[39] The longer course of the disease is prone to co-morbidize other psychiatric disorders, such as anxiety and depression, again posing a therapeutic challenge. Michael's review[40] suggests that once insomnia persists beyond an indeterminate period, the probability of remission will decrease, echoing our finding that the treatment effect is diminished for those with insomnia lasting for three years. Further investigation with diverse samples are needed to validate this threshold. In addition, there was a difference in the factors affecting the outcome of patients at 8 weeks and after 8 weeks, which may be due to the rapid effect of drugs in the early stage of treatment, and the greater impact on treatment in the later stage, as the role of CBT becomes dominant, the demographic characteristics and sociological factors that demand the outcome of CBT become increasingly prominent.

Morin CM et al have explored the trajectory of symptom changes in insomnia treatment by comparing CBT alone with CBT combined with zolpidem.[25] Their results showed that early treatment response does not reliably predict final recovery status. The current study focused on the improvement sequence of symptoms under receiving medication combined with smartphone-delivered CBT-I, whereas some symptoms may be sensitive to medication and some symptoms may be more sensitive to environmental changes. Hence, the results of the present study may only be applicable to patients receiving medication combined with smartphone-delivered CBT-I. In addition, since the back-end of the mobile phone cannot force patients to perform CBT-I training, it is difficult to ensure patient compliance. Therefore, future research should ensure that the included subjects receive similar types of drugs and same frequency of smartphone-delivered CBT-I training, as well as the comparison between individual therapy and combination therapy, so as to further compare the improvement sequence of insomnia symptoms and to provide a basis for clinical treatment decisions for insomnia in the real world.

On the basis of previous studies,[20] this study took all the patients included as the study subjects, to analysis the factors influencing the effectiveness and ineffectiveness of CBT-I combined with drug treatment for insomnia. Different from previous studies using sleep diary and PSG as observation indicators, we used the PSQI scale in clinical diagnosis and treatment as a study tool for the first time to analyze the sequence of improvement of insomnia symptoms, which is helpful for clinicians to understand the order of remission of insomnia symptoms and to recognize the factors affecting the treatment effect, thereby facilitating the implementation of standardized treatment, rather than blindly changing the treatment scheme.

This study has several limitations. Firstly, we did not collect data on specific sleep medications and other medication. Thus, any potential interaction between different medications and CBT-I treatment cannot be discussed. Secondly, we did not gather data on the frequency or duration of app usage. Additionally, the generalizability of the results could be limited by sample characteristics, and the long-term efficacy beyond 24 weeks remains uncertain. Lastly, the study's design does not fully address potential biases in self-reported data. During offline follow-ups, clinicians review the patients' training progress and emphasize the importance of mobile CBT to enhance adherence. However, the platform can only monitor training frequency and cannot enforce completion.

In summary, the improvement sequence in insomnia symptoms varies over time. Initial 8 weeks see the fastest improvements in sleep onset latency, while daytime dysfunction lingers. By 16 weeks, sleep quality shows the most significant enhancement and daytime function is notably enhanced, yet sleep duration remains unchanged. Factors influencing treatment efficacy include age over 30 years, college education, and disease duration exceeding 3 years. This study underscores the evolving nature of insomnia treatment responses and highlights the need for tailored strategies addressing individual patient characteristics and the complex interplay of factors influencing insomnia management. These findings contribute to understanding treatment dynamics but should be viewed as part of a broader context of ongoing research.

Data Sharing Statement

Due to restrictions related to participant confidentiality, the data are not publicly available. The data that support the findings of this study are available from the corresponding author upon reasonable request.

Ethics Statement

This research is a retrospective study. The data used in this study were derived from patients who visited the Sleep Disorders Clinic of Hangzhou Seventh People's Hospital in the past. This study was reviewed and approved by the Ethics Committee of Hangzhou Seventh People's Hospital, with an agreement to waive informed consent (Ethics Approval Number: 2024-044). All procedures were conducted in accordance with relevant guidelines.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Disclosure

The authors declare no competing interests.

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