Can adding personalized rule-based feedback improve the therapeutic effect of self-help digital cognitive behavioral therapy for insomnia in young adults?

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ABSTRACT

Introduction: Cognitive-behavioral therapy for insomnia (CBT-I) is recommended as the first-line treatment for insomnia, but low accessibility and relatively high cost limits the dissemination of the treatment. Several forms of digital CBT-I have been developed to increase the accessibility and shown to be effective; however, the treatment effect may be restricted by the lack of interaction within the treatment. The current study examines whether the therapeutic effects of self-help digital CBT-I could be enhanced by adding simple rule-based personalized feedback.

Method: Ninety-two young adults with self-reported insomnia were randomly assigned to three groups: a self-help group (SH, n = 31), who received an eight-session email-delivered CBT-I program; a feedback group (FB, n = 31), who went through the same CBT-I program with personalized feedback; and a waitlist group (WL, n = 30). The Insomnia Severity Index (ISI) was used as the primary outcome measure, and the 16-item version of the Dysfunctional Beliefs and Attitudes about Sleep Scale (DBAS-16), Sleep Hygiene Practice Scale (SHPS), and sleep diary were used as the secondary outcome measures. Treatment satisfaction and adherence were also compared between the treatment groups.

Results: Both the SH and FB groups showed significantly more improvements in insomnia severity, sleep-related beliefs, and sleep hygiene behaviors than the WL group. Sleep onset latency and sleep efficiency in the sleep diary were also significantly improved after treatment. None of these effects significantly differed between the two treatment groups. Nonetheless, participants in the FB group reported higher treatment satisfaction than those in the SH group.

Conclusion: This study supports the effectiveness of email-delivered self-help CBT-I for young adults with insomnia. Furthermore, while adding simple personalized feedback may not have an additional effect on sleep per se, it can enhance treatment satisfaction. This simple intervention shows promise in addressing sleep disturbance in young adults.

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1. Introduction

Insomnia is one of the most prevalent health-related problems that affects not only nighttime sleep but also daytime functioning and quality of life [1—3]. It is also shown to be a risk factor of various cardiovascular, metabolic, and mental disorders [4—7]. According to

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the Diagnostic and Statistical Manual of Mental Disorders, fifth edition (DSM-5) [8], and the International Classification of Sleep Disorders, third edition (ICSD-3) [9], insomnia disorder is defined by self-reported symptoms of difficulty initiating sleep, difficulty maintaining sleep, and early morning awakening. These symptoms must cause clinically significant functional distress or impairment, be present for at least 3 nights per week for at least 3 months, and not be caused by other sleep, medical, or mental disorders.

Cognitive behavioral therapy for insomnia (CBT-I) is recommended as the first-line treatment for insomnia in adults [10–12]; however, owing to the limited availability of trained therapists and the high costs of face-to-face therapy, its accessibility remains a challenge in clinical settings [13,14]. Different forms of digital CBT-I have been developed to increase accessibility of CBT-I. They were shown to have comparable or non-inferior therapeutic effects compared with face-to-face CBT-I in several meta-analyses [15–19]. Also, internet-delivered self-help intervention has been shown to be a preferred modality of mental health intervention—particularly in young individuals—owing to avoid stigma associated with mental health [20].

Digital CBT-I programs can be delivered via various platforms or media, such as web pages, apps, social media and email, with different levels of sophistication and costs. Among them, one the most low-cost ways is to deliver self-help materials through email or other forms of social media. For example, an 8-week email-delivered CBT-I intervention, called REFRESH, was shown to be effective in improving sleep and depressive mood among college students in the US [21], and was subsequently modified and translated into other languages and was shown to improve insomnia symptoms compared to wait-list control group in college and high-school students in Japan and Hong Kong [22,23].

However, self-help digital CBT-I has been shown to be less effective than in-person CBT-I or guided CBT-I. For example, REFRESH program was found to be less effective than group CBT-I on some outcome measures [23] and had a dropout rate as high as 57% [24]. Adding weekly telephone support to self-help CBT-I was found to lead to additional improvements in sleep onset latency and sleep quality in previous studies [25–27]. Meta-analyses also showed that self-help CBT-I guided by a practitioner or with additional telephone consultation had higher effect sizes than that administered by oneself [28,29]. One recent study comparing different forms of digital CBT-I with network meta-analysis further showed that internet-based CBT-I with the support and feedback of a real or virtual therapist could be more efficacious than face-to-face CBT-I on some outcome measures [30].

Thus, the therapeutic effect of self-help digital CBT-I could possibly be improved by providing personalized guidance or feedback from a trained professional. However, this would increase the financial and labor costs and would again limit the accessibility of the treatment to some individuals. One possible solution to this dilemma is to establish a set of rules for providing personalized feedback and guidance that could be easily administered by trained staff or even by automatic systems.

We therefore constructed a set of rules for providing feedback based on the patients' sleep diary that can be administered in conjunction with a self-help CBT-I (REFRESH) program. The aim of the current study was to examine whether providing rule-based personalized feedback could generate additional therapeutic effects for the self-help digital CBT-I. It was hypothesized that participants receiving an email-delivered CBT-I would show reduced insomnia compared with participants in a wait-list control group. Moreover, participants receiving additional personalized feedback would have more improvement in sleep, as well as more satisfaction and adherence to the treatment, and a lower dropout rate than those receiving self-help CBT-I alone.

2. Methods

2.1. Participants

One hundred and thirty-six participants were recruited in Taiwan and China through internet social medias (Facebook and WeChat) and were screened via a package of online questionnaires. The potential participants were then contacted through phone by a trained graduate student in clinical psychology to confirm the eligibility to participate in the study. The inclusion criteria were as follows: 1) aged 18–30 years old, 2) subjectively reported insomnia symptoms and total score on the Insomnia Severity Index (ISI) ≥ 8, and 3) subjectively reported daytime dysfunction associated with sleep difficulties. The exclusion criteria were as follows: 1) current or past history of substance use disorder or major psychiatric disorders, 2) major medical conditions, 3) sleep disorders other than insomnia, and 4) shift worker. Ninety-two of the initially recruited participants were found eligible. All participants provided their informed consent to participate. The study procedure was approved by the research ethics committee of the National Chengchi University, Taiwan.

2.2. Measurements

Insomnia Severity Index (ISI). The ISI is a 7-item Likert-type self-rating scale designed to assess the nature, severity, and impact of insomnia [31]. Each item is rated on a 5-point Likert scale, with 0 indicating no problem and 4 indicating a very severe problem. The total score ranges from 0 to 28. It was found to have good internal consistency, and was shown to be a valid and sensitive outcome measure for the treatment of insomnia [32,33]. The original interpretation of the ISI total score is as follows: 1–7 was considered to be absence of insomnia, 8–14 was sub-threshold insomnia, 15–21 moderate insomnia, and 22–28 to have severe insomnia [31]. A cut-off score of 10 was later reported to be optimal in detecting insomnia cases in community sample (sensitivity = 86.1%; specificity = 87.7%), while the cut-off score of 8 was found to have good sensitivity (95.8%) but fair specificity (78.3%) [32]. Since the current study is aiming to improve the sleep disturbances in young adults that are not necessarily meeting the diagnostic criteria of insomnia disorder, a lower cut-off point of 8 was used to include the individuals with sub-threshold insomnia in the study. The ISI total score was also used as the primary outcome measure in the current study.

Dysfunctional Beliefs and Attitudes About Sleep Scale, 16-item version (DBAS-16). The original DBAS is a 30-item questionnaire used to measure faulty sleep-related beliefs and cognitions with 100-mm visual analogue scales [31]. A 16-item version with 10-point Likert-type scale, with 1 indicating "strongly disagree" and 10 denoting "strongly agree", was developed and shown to have good validity and reliability [34]. The factor structure was similar to the original version, with four factors emerging and reflecting: 1) perceived consequences of insomnia, 2) worry/helplessness about insomnia, 3) sleep expectations, and 4) medication. The DBAS-16 was used in the current study as a secondary outcome measure.

Sleep Hygiene Practice Scale (SHPS). The SHPS is a 30-item inventory designed to measure the frequency of maladaptive sleep hygiene in daily practice on a 6-point Likert scale ranging from "1-never" to "6-always" [35]. It consists of the following four subscales: 1) Sleep Schedule consists of items related to the behaviors that may interfere with homeostatic and/or circadian sleep regulation (eg. Sleeping-in during weekends), 2) Arousal-Related Behaviors consists of items of daytime and pre-bedtime behaviors that might increase level of arousal (e.g. Doing sleep-irrelevant

activities in bed), 3) Eating/Drinking are eating and drinking habits that may interfere with sleep (eg. Excessive coffee drinking, and 4) Sleep Environment consists of items describing environmental factors that might disrupt sleep (e.g. Sleep environment is too bright or too dark). Higher scores indicated more maladaptive sleep hygiene practices. The SHPS was used in the current study as a secondary outcome measure.

Modified Treatment Satisfaction Scale (TSS). The TSS was originally developed to evaluate the level of satisfaction of psychotherapy [36]. It was adapted to evaluate the satisfaction of insomnia treatment programs [37]. The modified TSS consists of 8 items about satisfaction with various aspects of insomnia treatment, including insomnia, energy level, work productivity, coping, life enjoyment, hope-fulness, self-esteem, and mood. For each item, participants are asked to rate the degree of improvement on a 4-point Likert scale. The lower the score, the higher the improvement perceived and the higher the treatment satisfaction. In the present study, the scale was administered at post-test and the average score was used as an indicator of treatment satisfaction.

Treatment Components Adherence Scale (TCAS). The TCAS is a self-rating scale constructed to assess adherence to CBTI guidelines [37]. The degree of adherence to each therapeutic element was rated on a 4-point Likert scale, ranging from 0 (not at all) to 3 (always). The ratings for all therapeutic elements were grouped into a Behavioral Component (prescribed bedtime, getting out of bed when unable to sleep, using the bed only for sleep, and restricting time in bed) and a Cognitive Component (changing expectation and thinking about sleep). The total score was used in the current study to examine the treatment adherence.

Sleep diary. Participants were asked to fill in an on-line sleep diary daily via a WeChat App throughout the study period. The items were taken from the Core Consensus Sleep Diary [38] and modified to be presented through an App. The questions asked about including: 1) the time of getting into bed, 2) sleep onset latency, 3) number of awakenings, 4) duration of awakenings, 5) time of final awakening, 6) final rise time, and 7) perceived sleep quality. Sleep parameters, including sleep onset latency (SOL), duration of waking after sleep onset (WASO), numbers of WASO, sleep efficiency (SE), and subjective sleep quality (SQ) were derived from the data for analyses.

2.3. Procedures

The study was a three-arm, parallel-group, randomized controlled study. The participants were randomly assigned to one of three groups: a self-help group (SH; n = 31), a feedback group (FB; n = 31), and a wait-list control group (WL; n = 30; see Fig. 1). The randomization procedure was conducted with a computer-generated random table by the research team. It was blinded for the participants but not for the researchers. Participants in all groups were assessed before the treatment period using online questionnaires, including the ISI to assess the severity and impact of insomnia; the DBAS-16 to measure faulty sleep-related beliefs and cognitions; and the SHPS to measure maladaptive sleep hygiene in daily practice.

After the baseline assessment, participants in the SH and FB groups started an eight-week email-delivered self-help CBT-I, the REFRESH program, without and with feedback, respectively. The participants were also required to maintain an online daily sleep diary. Participants in the FB group received additional weekly feedback emails with supportive comments and reminders for homework assignments. The contents of the feedback were derived from a set of standard rules (see Table 1) conducted by a trained graduate student in a clinical psychology program. Participants in the WL group were asked to wait eight weeks before starting treatment. At the end of the eight-week period, all participants were asked to complete a set of questionnaires that was the same as the baseline assessment. In addition, the modified TSS and TCAS were administered to evaluate the level of satisfaction with insomnia treatment programs and to assess adherence to the CBT-I guidelines, respectively (see Fig. 1 for the study procedure).

2.4. Intervention

The REFRESH program is an email-based CBT-I developed at Stanford University designed to improve sleep in college students. As mentioned above, it was shown to be effective in improving sleep and depressive mood among college students in the US [21]. The program was subsequently translated and modified into different languages (Korean, Chinese, and Japanese) and was shown to be effective for college and high-school students with RCTs [22–24]. The Chinese version of the REFRESH was used in the current study.

The intervention materials were sent to the participants via email with an attached PDF file weekly for eight subsequent weeks. The material contents covered 1) sleep architecture and the sleep cycle, 2) homeostatic and circadian processes of sleep regulation, 3) sleep restrictions, 4) relaxation exercises, 5) mindfulness meditation, 6) sleep hygiene education, 7) sleep-related cognition, and 8) sleep preservation. A quiz link consisting of four multiple-choice questions regarding the material was sent after each session to ensure that participants read and understood the materials. New session materials were delivered only when the participants' responses to the quizzes were received and their sleep diary for the week was completed.

In addition to these reminders, participants in the FB group also received a personalized weekly feedback message generated by a trained graduate student based on a set of simple rules (see Table 1). The rules were constructed by the research team including a certified expert in behavioral sleep medicine (CMY) and certified physician in sleep medicine (HCL). The feedback message included two parts: the first part was to highlight the improvements achieved and to offer compliments for their efforts; the second part was to provide specific instructions for the behavioral changes needed, as well as to guide the participants to read the REFRESH materials relevant to the behavior instructions. The feedback messages were constructed in the format as a message delivered through social media. For example, for a participant who have cut down time-in-bed but still have longer naps during the weekend may receive a feedback message such as "Congratulations! Your sleep efficiency has improved from 78% to 85%. You have been doing very well in maintaining your time-in-bed of around 7.0 h. You however got up late during weekend on [giving the dates]. As this may lower your homeostatic drive at bedtime and disrupt the regularity of your biological clock as we described in the REFRESH material [giving the section and page numbers], we recommend to try to avoid a nap longer than 30 min" The sentences used for the feedback messages were standardized but the numbers were personalized based on the participants' data.

2.5. Statistical analyses

R 4.2.3 version was used for Linear Mixed Model analyses. All the other statistical analyses were performed using SPSS Statistics version 21 (IBM). Since the Intention-To-Treat (ITT) approach is recommended for randomized controlled study, and Linear Mixed Models (LMM) were suggested to be a better method for ITT analyses of a randomized control study with missing data, LMM was used for the analyses of the outcome measures [39,40]. The missing data were estimated using maximum likelihood in the LMM
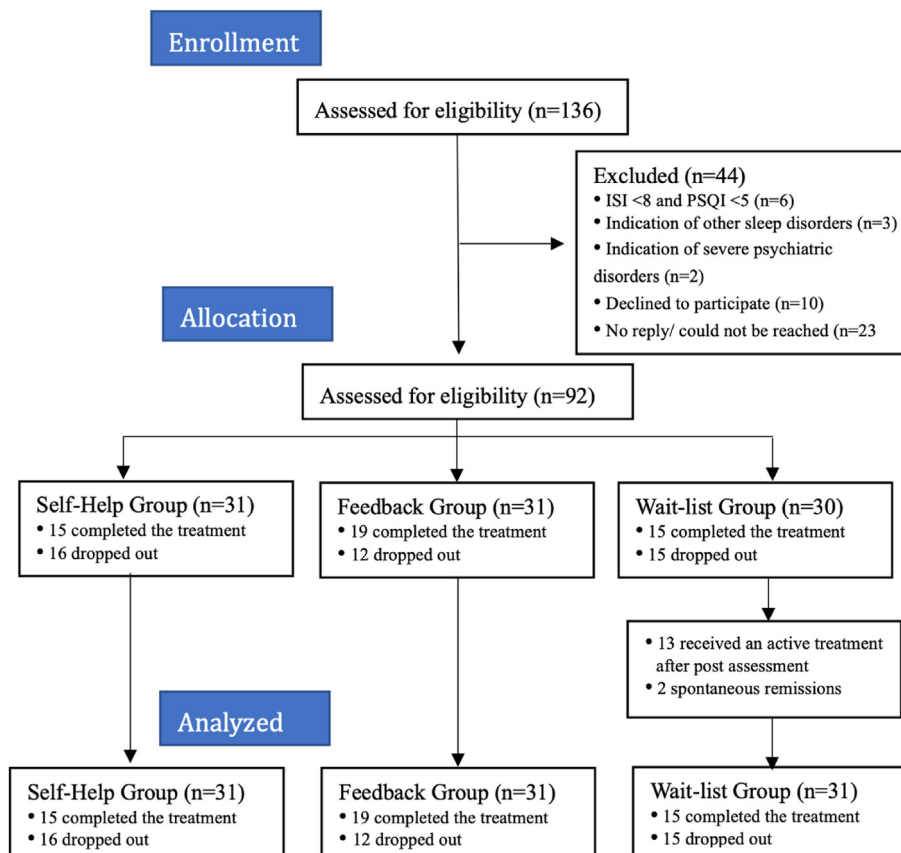
Fig. 1. The CONSORT diagram for the study procedures.

Table 1
A summary of the rules for personalized feedback.

Process	Criteria	Feedback
Homeostatic Process	Sleep efficiency <85%	Apply sleep restriction based on REFRESH section 2 and provide recommended bedtime and wake-up time
	Time in bed >9 h for more than three nights	Recommend reduced time in bed
	Nap within the 6 h prior to bedtime	Advise to eliminate or advance nap time
	Napping longer than 30 min	Recommend to cut down nap time
	All the above conditions	A brief explanation about the association between bedtime/naptime and homeostatic process
Circadian Process	Light exposure after waking up < 3 times/week	Encourage to expose to sunlight after waking up every day
	Differences between bedtimes or wake-up times >2 h	Remind to follow a regular sleep/wake schedule
Arousal System and Sleep Hygiene	Having caffeinated drink after 3:00pm	Provide information regarding caffeine metabolization and recommend to finishing drinking caffeinated drink by 3:00pm
	Performing exercise within 2 h before bedtime	Recommend to advance the timing to do exercise
	Having a meal 2 h before bedtime	Recommend to advance the timing to have a meal
	Relaxation exercise <3 times/week	Encourage to do relaxation exercise everyday
	Score of 8 or more on any item of the DBAS scale	Provide some alternative beliefs to replace dysfunctional beliefs

analyses. Two LMM analyses were conducted to compare the variables over time among the three groups (SH vs FB vs WL), one using WL as the reference group and the other using FB as the reference group in order to obtain the contrast comparisons among all the three groups. Since treatment satisfaction, adherence, and daily sleep diary were obtained in the participants completed the FB or SH program only, t-tests were conducted to compare the TSS and TCAS scores between the two treatment groups, and a 2 (time)

x 2 (group) mixed-designed ANOVAs were utilized to compare the parameters from sleep diary. Simple main effects were examined by paired-sample t-tests with Bonferroni corrections. The participants who discontinued to participate in the study before the completion were all considered as dropouts. Chi-square tests were applied to compare the dropout rate between the two treatment groups.

3. Results

3.1. Background information

The mean age of the 92 participants were 22.4 ± 2.5 years. There were 25 males and 67 females. The mean ages and gender distributions of the three groups were as follows: mean age = 22.6 ± 3.0 years and male:female = 9:22 for the FB group; mean age = 22.6 ± 2.7 years and male:female = 8:23 for the SH group; mean age = 22.0 ± 1.6 years and male:female = 8:22 for the WL group.

3.2. Primary treatment outcome measure

The mean and SDs of all the measures are presented in Table 2. The ISI mean scores for the FB, SH, and WL groups were 15.32 ± 3.52, 16.32 ± 3.18, and 15.90 ± 3.43, respectively (see Table 2). Both the FB and SH groups showed significantly more improvements in ISI scores than WL group (FB vs WL: EB = −5.40, $t = −3.73, p < .001$; SH vs WL: EB = −4.16, $t = −2.77, p = .01$). FB and SH groups showed no significant difference in the treatment effect (EB = 1.24, $t = 0.86, p = .39$) (see Fig. 2) (see Table 3).

3.3. Secondary treatment outcome measures

On DBAS-16 total score, FB group showed significantly more improvements than WL group (EB = −32.94, $t = −3.18, p = .002$) and SH showed a nonsignificant trend to improve more than WL group (EB = −20.27, $t = −1.89, p = .061$). There were no significant difference between the two treatment groups (EB = 12.66, $t = 1.23, p = .22$). When the subscales were analyzed separately, FB group had more reductions in all the subscale scores but Medication subscale. SH group showed significantly more improvement on the Perceived Consequences and Sleep Expectations scale and near significant improvement on Worry/Helplessness subscale than WL group, but had no difference on Medication subscale. The improvement on none of the subscales were different significantly between the FB and SH groups (see Table 4 for the LMM results).

On SHPS total score, both FB and SH groups showed significantly more improvements than WL group (FB vs WL: EB = −19.97, $t = −3.44, p = .00$; SH vs WL: EB = −14.33, $t = −2.38, p = .02$), but the difference between the two treatment groups was not significant (EB = 5.64, $t = 0.97, p = .33$). Further examination of the subscale showed that FB group improved significantly more on the Sleep Schedule and Arousal Behavior subscales but not on the Drinking/Eating and Sleep Environment subscales; SH group showed significantly more improvement on the Arousal Behavior subscale but not on the rest of the subscales. No significant interaction effects were found between the FB and SH groups on any of the subscales (see Table 5 for the LMM results).

3.4. Other comparisons between FB and SH groups

Treatment satisfaction measured by TSS showed significantly higher satisfaction (lower score) for the FB group (mean = 12.79, SD = 4.54) than for the SH group (mean = 16.93, SD = 5.51; t [32] = 2.41, $p = .022$). Treatment adherence measured by TCAS showed no significant difference between FB group (mean = 39.95, SD = 12.55) and SH group (mean = 32.73, SD = 12.15; $t[32] = 1.69$, $p = .101$).

Sleep log showed significant Time main effects for all variables except TST. WASO duration showed a significant Group main effect and Group × Time interaction ($F = 5.85, p = .021$; see Table 6). A simple main effect analysis showed that the differences between pre- and post-treatment WASO were statistically significant for the SH group ($t[14] = -2.655, p = .019$), but not for the FB group ($t [18] = -1.598, p = .128$), when Bonferroni's correction was applied.

Of the 92 participants, 44 (47.8%) dropped out before the study's completion. Among them, 12 (38.7%) were in the FB group, 16 (51.6%) in the SH group, and 15 (50.0%) in the WL group. Chi-square test indicated no significant difference in dropout between the three group ($\chi^2[2] = 0.612$, df = 2, n.s.).

4. Discussion

The current randomized controlled study examined the treatment effect of an email-delivered CBT-I for sleep disturbance among young adults and investigated the additional benefit of adding personalized rule-based feedback. Our results regarding treatment outcomes are consistent with those of previous studies conducted in Hong Kong and Japan. The improvements in insomnia symptoms as measured using the ISI were within the range of 4.4−6.6 points [21,22]. Dysfunctional sleep cognition and maladaptive sleep hygiene practices were also significantly reduced.

The second purpose of our study was to test whether adding simple personalized weekly feedback could generate additional therapeutic effects to self-help digital CBT-I. The results did not support our hypothesis and showed no enhanced treatment effect on insomnia symptoms. However, the feedback group did report better satisfaction with treatment. In addition, while the dropout

Table 2
The means and standard deviations (SD) of the scores on the insomnia severity index (ISI), the dysfunctional beliefs and attitudes about sleep scale (DBAS-16), and the sleep hygiene practice scale (SHPS) at pre- and post-treatment.

Measures	Mean (SD)					
	Feedback		Self-Help		Wait-List	
	Pre (N = 31)	Post (N = 19)	Pre (N = 31)	Post (N = 15)	Pre (N = 30)	Post (N = 15)
ISI Total Score	15.32 (3.51)	8.90 (2.94)	16.32 (3.18)	11.13 (3.56)	15.9 (3.43)	14.87 (3.54)
DBAS-16						
Consequences	29.71 (9.39)	18.06 (7.39)	33.62 (10.47)	25.6 (9.42)	30.84 (7.96)	30.8 (6.34)
Worry	39.04 (10.98)	24.79 (8.56)	41.17 (11.68)	32.07 (9.67)	35.94 (9.07)	35.4 (10.57)
Expectations	13.59 (4.68)	8.53 (4.48)	15.26 (4.14)	10.27 (3.94)	14.94 (3.49)	15.27 (3.06)
Medication	11.62 (6.38)	8.27 (5.03)	10.75 (7.17)	11.2 (5.61)	9.67 (6.11)	8.54 (4.87)
Total Score	93.94 (25.85)	59.64 (21.18)	100.78 (27.91)	79.14 (20.08)	91.37 (22.53)	90 (21.2)
SHPS						
Sleep Schedule	26.65 (7.18)	17.95 (4.95)	26.75 (6.16)	21.47 (4.72)	25.7 (6.69)	24.87 (4.92)
Arousal Behavior	30.68 (6.01)	20.06 (3.74)	31.07 (6.64)	23 (4.08)	30.7 (6.93)	30.74 [6]
Eating/Drinking	9.07 (3.44)	7.58 (3.17)	10.75 (4.15)	8.6 (3.55)	10.17 (3.82)	10.8 (3.39)
Environment	17.97 (7.25)	16.48 (6.75)	19.65 (7.08)	18.47 (6.65)	20.97 (6.29)	18.8 (5.29)
Total Score	84.36 (14.25)	62.06 (13.51)	88.2 (16.15)	71.54 (11.75)	87.54 (11.32)	85.2 (11.41)

Table 3
Results of linear mixed model analysis for differences in change estimates on the insomnia severity index (ISI) score among the treatment groups from pre-treatment to post-treatment.

	Term	Estimate β	SE β	df	t-value	p
Model 1 (Wait-List as reference)	Intercept	15.90	3.42	0.00	4.65	1.00
	Self-Help	0.42	0.86	135.00	0.49	0.62
	Feedback	−0.58	0.86	135.00	−0.67	0.50
	Group X Time interaction	−1.03	4.88	0.00	−0.21	1.00
	Self-Help	−4.16	1.50	135.00	−2.77	0.01
	Feedback	−5.40	1.45	135.00	−3.73	0.00
Model 2 (Feedback as reference)	Intercept	15.32	3.42	0.00	4.48	1.00
	Self-Help	1.00	0.85	135.00	1.17	0.24
	Wait-List	0.58	0.86	135.00	0.67	0.50
	Group X Time interaction	−6.43	4.86	0.00	−1.32	1.00
	Self-Help	1.24	1.44	135.00	0.86	0.39
	Wait-List	5.40	1.45	135.00	3.73	0.00
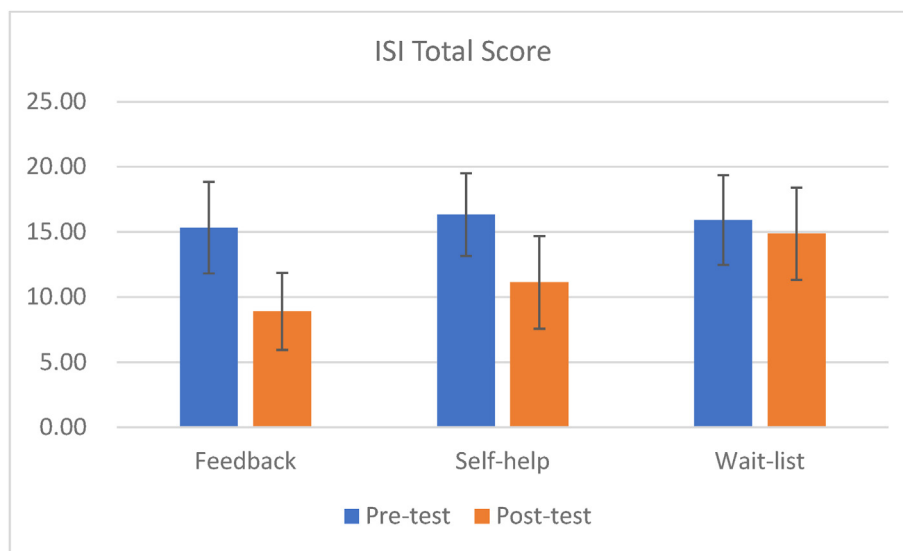
Fig. 2. The total scores of insomnia severity index (ISI) before and after treatment of the three groups.

rate for the SH group (51.6%) and control group (50.0%) were similar to what was reported in Korean and Hong Kong [18], the drop-out rate for the FB group was slightly lower (38.7%). However, the difference was not statistically significant. In addition, FB group was shown to improve dysfunctional sleep cognitions more than WL control group, while SH group demonstrated a near-significant trend in improving dysfunctional sleep cognitions comparing to the control group; also, FB group was shown to decrease maladaptive sleep schedule more than WL control group, while SH group did not have this effect. The above findings suggest that simple personalized feedback, although not enhancing the treatment effect on sleep-related outcomes, could lead to a feeling of more psychological support, and might be helpful in reducing maladaptive sleep cognitions and behaviors.

One unexpected finding was that the decrease in WASO duration was higher in the SH group than in the FB group. This might be due to the higher WASO in the SH group (mean = 24.66 min) than in the FB group (mean = 3.74 min) at baseline. There were only two participants with a WASO above 20 min at baseline for the FB group, compared with seven participants for the SH group, and both participants in the FB group showed good improvement in their WASO (35.28−12.86 min, and 22.14 to 7.85 min) after treatment.

While the study showed promising results, some limitations should be taken into consideration when interpreting the findings.

First of all, the study has an overall dropout rate as high as 47.8%. Although high dropout rate is commonly reported in digital CBT-I studies, and Intention-to-Treat analyses with LMM was used to estimate the missing data, it still could bias the results and threaten the validity of the study. Secondly, the sample size of the study is relatively small, which may limit the statistical power of the study. This could particularly have an impact on the comparisons of the treatment effects between the FB and SH groups. While the average improvement scores on most of the outcome variables were larger for FB group than SH group, the differences were not significant statistically. Some of the differences might become significant with a larger sample size. Furthermore, the study used an ISI cut-off score of 8 as an inclusion criterion for participation in the study. This low cut-off was applied with the intention to include young adults with milder insomnia into the study because the treatment could be a mean to prevent their insomnia to become more severe. The cut-off score of 8 has been reported to have good sensitivity (95.8%) but fair specificity (78.3%) in detecting insomnia disorder in community sample [33]. Therefore, some of the participants might not fulfill the diagnostic criteria of insomnia disorder. The findings may not be generalized to clinical patient populations. Also, participants with milder insomnia may not have great distress associated with their sleep disturbances, which may have contributed to the high dropout rate and limited the range of improvements that could be achieved by the interventions. Lastly, the sleep logs

Table 4
Results of linear mixed model analysis for differences in change estimates of subscale and total scores on the dysfunctional beliefs and attitudes about sleep scale (DBAS-16) among the treatment groups from pre-treatment to post-treatment.

		Term	Estimate β	SE β	df	t-value	p
DBAS - Consequence	Model 1 (WL as reference)	Intercept	30.83	6.10	0.00	5.05	1.000
		Self-Help	2.78	2.26	135.00	1.23	0.222
		Feedback	−1.12	2.26	135.00	−0.50	0.620
		Group X Time interaction	−0.03	8.78	0.00	−0.00	1.000
		Self-Help	−7.98	3.94	135.00	−2.02	0.045
		Feedback	−11.62	3.80	135.00	−3.06	0.003
	Model 2 (FB as reference)	Intercept	29.71	6.10	0.00	4.87	1.000
		Self-Help	3.90	2.25	135.00	1.74	0.084
		Wait-List	1.12	2.26	135.00	0.50	0.620
		Group X Time interaction	−11.66	8.71	0.00	−1.34	1.000
		Self-Help	3.64	3.79	135.00	0.96	0.338
		Wait-List	11.62	3.80	135.00	3.06	0.003
DBAS - Worry	Model 1 (WL as reference)	Intercept	35.93	7.13	135.00	5.04	0.000
		Self-Help	5.23	2.63	135.00	1.99	0.049
		Feedback	3.10	2.63	135.00	1.18	0.241
		Group X Time interaction	−0.53	10.26	135.00	−0.05	0.959
		Self-Help	−8.56	4.59	135.00	−1.87	0.064
		Feedback	−13.71	4.42	135.00	−3.10	0.002
	Model 2 (FB as reference)	Intercept	39.03	2.09	135.00	18.66	<0.000
		Self-Help	2.13	2.61	135.00	0.82	0.416
		Wait-List	−3.10	2.63	135.00	−1.18	0.241
		Group X Time interaction	−14.24	3.30	135.00	−4.31	0.000
		Self-Help	5.15	4.41	135.00	1.17	0.245
		Wait-List	13.71	4.42	135.00	3.10	0.002
DBAS - Expectations	Model 1 (WL as reference)	Intercept	14.93	1.45	135.00	10.27	<0.000
		Self-Help	0.32	1.04	135.00	0.31	0.755
		Feedback	−1.35	1.04	135.00	−1.30	0.196
		Group X Time interaction	0.33	2.19	135.00	0.15	0.879
		Self-Help	−5.32	1.81	135.00	−2.94	0.004
		Feedback	−5.39	1.75	135.00	−3.08	0.002
	Model 2 (FB as reference)	Intercept	13.58	1.45	135.00	9.38	<0.000
		Self-Help	1.68	1.03	135.00	1.63	0.106
		Wait-List	1.35	1.04	135.00	1.30	0.196
		Group X Time interaction	−5.05	2.13	135.00	−2.38	0.019
		Self-Help	0.06	1.74	135.00	0.04	0.971
		Wait-List	5.39	1.75	135.00	3.08	0.002
DBAS- Medication	Model 1 (WL as reference)	Intercept	9.67	1.32	135.00	7.35	0.000
		Self-Help	1.08	1.57	135.00	0.69	0.494
		Feedback	1.95	1.57	135.00	1.24	0.217
		Group X Time interaction	−1.13	2.17	135.00	−0.52	0.602
		Self-Help	1.59	2.73	135.00	0.58	0.561
		Feedback	−2.22	2.63	135.00	−0.84	0.401
	Model 2 (FB as reference)	Intercept	11.61	1.30	135.00	8.94	0.000
		Self-Help	−0.87	1.56	135.00	−0.56	0.576
		Wait-List	−1.95	1.57	135.00	−1.24	0.217
		Group X Time interaction	−3.35	2.04	135.00	−1.65	0.102
		Self-Help	3.81	2.63	135.00	1.45	0.149
		Wait-List	2.22	2.63	135.00	0.84	0.401
DBAS - Total Score	Model 1 (WL as reference)	Intercept	91.37	10.39	0.00	8.79	1.000
		Self-Help	9.41	6.16	135.00	1.53	0.129
		Feedback	2.57	6.16	135.00	0.42	0.677
		Group X Time interaction	−1.37	15.34	0.00	−0.09	1.000
		Self-Help	−20.27	10.73	135.00	−1.89	0.061
		Feedback	−32.94	10.34	135.00	−3.18	0.002
	Model 2 (FB as reference)	Intercept	93.94	10.36	0.00	9.07	1.000
		Self-Help	6.84	6.11	135.00	1.12	0.265
		Wait-List	−2.57	6.16	135.00	−0.42	0.677
		Group X Time interaction	−34.30	15.05	0.00	−2.28	1.000
		Self-Help	12.66	10.31	135.00	1.23	0.222
		Wait-List	32.94	10.34	135.00	3.18	0.002

FB: feedback group; WL: wait-list group.

used in this study was modified from the Core Consensus Sleep Diary [38] to be conducted through an App. This modification has not been validated. Therefore, precautions should be taken in interpreting the results.

5. Conclusion

The results of the current study confirm previous findings that providing sleep-related knowledge and helpful practice strategies

Table 5
Results of linear mixed model analysis for differences in change estimates of subscale and total scores on the sleep hygiene practice scale (SHPS). among the treatment groups from pre-treatment to post-treatment.

		Term	Estimate β	SE β	df	t-value	p
SHPS - Sleep Schedule	Model 1 (WL as reference)	Intercept	25.70	2.67	135.00	9.62	<0.000
		Self-Help	1.04	1.57	135.00	0.66	0.508
		Feedback	0.95	1.57	135.00	0.60	0.548
		Group X Time interaction	−0.83	3.94	135.00	−0.21	0.833
		Self-Help	−4.44	2.73	135.00	−1.63	0.106
		Feedback	−7.86	2.63	135.00	−2.99	0.003
	Model 2 (FB as reference)	Intercept	26.65	2.66	135.00	10.01	<0.000
		Self-Help	0.10	1.56	135.00	0.06	0.950
		Wait-List	−0.95	1.57	135.00	−0.60	0.548
		Group X Time interaction	−8.70	3.87	135.00	−2.25	0.026
		Self-Help	3.42	2.63	135.00	1.30	0.195
		Wait-List	7.86	2.63	135.00	2.99	0.003
SHPS - Behavior	Model 1 (WL as reference)	Intercept	30.70	5.44	135.00	5.65	0.000
		Self-Help	0.36	1.52	135.00	0.24	0.811
		Feedback	−0.02	1.52	135.00	−0.02	0.988
		Group X Time interaction	0.03	7.76	135.00	0.00	0.997
		Self-Help	−8.10	2.65	135.00	−3.05	0.003
		Feedback	−10.66	2.56	135.00	−4.17	0.000
	Model 2 (FB as reference)	Intercept	30.68	5.43	135.00	5.65	0.000
		Self-Help	0.39	1.51	135.00	0.26	0.798
		Wait-List	0.02	1.52	135.00	0.02	0.988
		Group X Time interaction	−10.62	7.73	135.00	−1.37	0.172
		Self-Help	2.56	2.55	135.00	1.00	0.317
		Wait-List	10.66	2.56	135.00	4.17	0.000
SHPS - Eating/Drinking	Model 1 (WL as reference)	Intercept	10.17	1.13	0.00	8.98	1.000
		Self-Help	0.58	0.94	135.00	0.61	0.541
		Feedback	−1.10	0.94	135.00	−1.18	0.242
		Group X Time interaction	0.63	1.74	0.00	0.37	1.000
		Self-Help	−2.78	1.63	135.00	−1.70	0.091
		Feedback	−2.12	1.57	135.00	−1.35	0.181
	Model 2 (FB as reference)	Intercept	9.07	0.84	0.00	10.80	1.000
		Self-Help	1.68	0.93	135.00	1.80	0.073
		Wait-List	1.10	0.94	135.00	1.18	0.242
		Group X Time interaction	−1.49	1.30	0.00	−1.15	1.000
		Self-Help	−0.66	1.57	135.00	−0.42	0.676
		Wait-List	2.12	1.57	135.00	1.35	0.181
SHPS - Environment	Model 1 (WL as reference)	Intercept	20.97	1.47	135.00	14.24	<0.000
		Self-Help	−1.32	1.71	135.00	−0.77	0.442
		Feedback	−3.00	1.71	135.00	−1.75	0.081
		Group X Time interaction	−2.17	2.41	135.00	−0.90	0.371
		Self-Help	0.99	2.99	135.00	0.33	0.741
		Feedback	0.67	2.88	135.00	0.23	0.816
	Model 2 (FB as reference)	Intercept	17.97	1.46	135.00	12.34	<0.000
		Self-Help	1.68	1.70	135.00	0.99	0.326
		Wait-List	3.00	1.71	135.00	1.75	0.082
		Group X Time interaction	−1.49	2.27	135.00	−0.66	0.512
		Self-Help	0.32	2.87	135.00	0.11	0.913
		Wait-List	−0.67	2.88	135.00	−0.23	0.816
SHPS - Total Score	Model 1 (WL as reference)	Intercept	87.53	2.96	135.00	29.59	<0.000
		Self-Help	0.66	3.46	135.00	0.19	0.849
		Feedback	−3.18	3.46	135.00	−0.92	0.360
		Group X Time interaction	−2.33	4.86	135.00	−0.48	0.632
		Self-Help	−14.33	6.03	135.00	−2.38	0.019
		Feedback	−19.97	5.81	135.00	−3.44	0.001
	Model 2 (FB as reference)	Intercept	84.36	2.93	135.00	28.84	<0.000
		Self-Help	3.84	3.43	135.00	1.12	0.265
		Wait-List	3.18	3.46	135.00	0.92	0.360
		Group X Time interaction	−22.30	4.56	135.00	−4.89	0.000
		Self-Help	5.64	5.80	135.00	0.97	0.332
		Wait-List	19.97	5.81	135.00	3.44	0.001

FB: feedback group; WL: wait-list group.

based on CBT-I principals through internet could effectively change insomnia sufferers' maladaptive sleep beliefs and behaviors and lead to improvement in their sleep. Although adding rule-based personalized feedback did not generate additional improvement in sleep in the current study, it did increase treatment satisfaction. The rules for the feedback were based on simple algorithms that can be easily understood and implemented by nonprofessional workers, or even generated automatically by a computer program.

Table 6
Comparisons of sleep parameters from sleep diaries at pre- and post-treatment between the two treatment groups.

	Mean (SD)				ANOVA						Post-hoc
	FB		SH		Group		Time		Group × Time		
	Pre	Post	Pre	Post	F	p	F	p	F	p	
SOL (min)	104.73 (54.99)	33.83 (17.16)	98.19 (53.39)	49.08 (27.42)	.137	.714	53.950	<.001**	1.778	.192	pre > post
WASOd (min)	3.74 (8.44)	1.54 (4.13)	24.66 (29.49)	10.24 (11.67)	9.599	.004**	10.826	.002**	5.847	.021*	SH: pre > post FB: pre = post
WASO# (time)	.354 (.651)	.151 (.463)	1.266 (1.392)	.733 (.812)	7.242	.011*	11.302	.002**	2.266	.142	pre > post
TST (min)	352.29 (57.56)	372.47 (44.91)	356.99 (100.37)	366.96 (69.09)	.000	.985	2.077	.159	.239	.629	
SE (%)	76.54 (7.29)	88.01 (4.71)	70.07 (12.89)	84.47 (8.48)	1.932	.174	84.259	<.001**	.000	.999	pre < post
SQ	2.23 (0.70)	3.14 (0.80)	2.38 (0.61)	2.66 (0.99)	.478	.389	9.879	.004**	2.819	.103	pre < post

SOL: sleep onset latency; WASOd: duration of waking after sleep onset; WASO#: number of waking after sleep onset; TST: total sleep time; SE: sleep efficiency; SQ: subjective sleep quality.

Email and other forms of social media are commonly used among youngsters. Considering the high prevalence of sleep disturbance in young populations and its associated consequences [41,42], this low-cost strategy of combining self-help digital CBT-I with simple personalized feedback could be implemented through campus mental health services as a way to prevent sleep disturbance in youngsters from becoming a longer-term problem.

CRediT authorship contribution statement

Chien-Ming Yang: study conception and design, data collection, analysis and interpretation of results, draft manuscript preparation, Conceptualization, Data curation, Formal analysis, Writing — original draft, All authors reviewed the results and approved the final version of the manuscript. **Ya-Li Lu:** study conception and design, data collection, analysis and interpretation of results, draft manuscript preparation, Conceptualization, Data curation, Formal analysis, Writing — original draft, All authors reviewed the results and approved the final version of the manuscript. **Hsin-Chien Lee:** study conception and design, draft manuscript preparation, Conceptualization, Writing — original draft, All authors reviewed the results and approved the final version of the manuscript. **Shirley Li:** study conception and design, draft manuscript preparation, Conceptualization, Writing — original draft, All authors reviewed the results and approved the final version of the manuscript. **Sooyeon A. Suh:** study conception and design, draft manuscript preparation, Conceptualization, Writing — original draft, All authors reviewed the results and approved the final version of the manuscript. **Isa Okajima:** study conception and design, draft manuscript preparation, Conceptualization, Writing — original draft, All authors reviewed the results and approved the final version of the manuscript. **Ya-Chuan Huang:** analysis and interpretation of results, draft manuscript preparation, Formal analysis, Writing — original draft, All authors reviewed the results and approved the final version of the manuscript.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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