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1 **The efficacy of cognitive behavioral therapy-based**
2 **interventions on patients with hypertension: a systematic**
3 **review and meta-analysis**

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35 **Abstract**

36 Recently, the benefits of cognitive behavioral therapy (CBT)-based interventions for
37 patients with hypertension have been recognized, but there has been no systematic
38 review that has comprehensively analyzed the efficacy of CBT on health outcomes in
39 this population. We aimed to explore the therapeutic effect of CBT-based interventions
40 on hypertension patients through a meta-analysis.

41 Relevant randomized controlled trials (RCTs) were obtained by searching electronic
42 databases. The primary outcomes were physiological indicators (blood pressure, blood
43 lipid profile). Secondary outcomes were psychological indicators (anxiety, depression),
44 and the quality of sleep. Stata version 15.0 software was used to analyze the results.

45 A total of 15 RCTs were included. The main analysis revealed that CBT-based
46 interventions reduced systolic pressure: -8.67 (95% CI: -10.67 to -6.67, P=0.000);
47 diastolic pressure: -5.82 (95% CI: -7.82 to -3.81, P=0.000); total cholesterol levels: -
48 0.43 (95% CI: -0.76 to -0.10, P=0.010); depressive symptoms: -3.13 (95% CI: -4.02 to
49 -2.24, P=0.000); anxiety symptoms: -3.63 (95% CI: -4.40 to -2.87, P=0.000); and
50 improved quality of sleep: -2.93 (95% CI: -4.40 to -1.47, P=0.000). Additionally, the
51 results of subgroup analysis indicated that long-term group-based CBT-based
52 interventions were particularly beneficial for blood pressure management in
53 hypertension patients.

54 CBT-based interventions are effective in reducing systolic pressure, diastolic pressure,
55 total cholesterol levels, anxiety symptoms, depressive symptoms, and improving
56 quality of sleep in hypertension patients.

57

58 **Key words:** hypertension, cognitive behavioral therapy, physiological indicators,
59 psychological indicators, quality of sleep

60

61 **1 Introduction**

62 Hypertension is a chronic disease characterized by continuously elevated arterial
63 blood pressure. It is an important cause of, and a risk factor for, cardiovascular and
64 cerebrovascular diseases (Mills et al., 2016), affecting the structure and function of the
65 heart, brain, kidneys, and other important organs (Ndanuko et al., 2016). It causes
66 myocardial infarction, heart failure, chronic kidney disease, and other complications,
67 including high fatality and disability rates (Biswas et al., 2003). The latest data indicates
68 that the number of adults with hypertension will reach 1.5 billion by 2025, which is
69 about 30% of the world's population (Hu et al., 2015; Li et al., 2015). It is now a global
70 problem, and is deleterious for human physical and mental health (Liu et al., 2017b)
71 and imposes a heavy burden on the patient, their family, and society. Therefore,
72 effectively preventing and treating hypertension is of particular importance.

73 Currently, drug therapy is the main treatment for high blood pressure (Mann,
74 2011), and lifestyle changes are also highly recommended (Williams et al., 2018).
75 However, due to the long course of the disease and duration of the need for medication,
76 patients are prone to negative emotions such as anxiety and depression during treatment
77 (Kretchy et al., 2014). Furthermore, these psychological problems have become an
78 important factor affecting the occurrence and development of hypertension (Jonas et
79 al., 1997; Rutledge and Hogan, 2002). Therefore, in the treatment of hypertension,
80 timely adoption of psychological interventions may be conducive to the treatment and
81 prognosis of the disease. Cognitive behavioral therapy (CBT) is a group of short-term
82 psychological therapies that aim to change unreasonable cognitions and thereby
83 eliminate dysfunctional behaviors (Creswell et al., 2010). CBT can effectively solve
84 general psychological problems and is often used to treat depression, anxiety, sleep
85 disorders, and chronic pain (McMain et al., 2015). In recent years, an increasing number
86 of studies (Abgrall-Barbry and Consoli, 2006; Liu et al., 2017a; Xue et al., 2008) have
87 applied CBT as an intervention for hypertension. Abgrall-Barbry and colleagues
88 (Abgrall-Barbry and Consoli, 2006) compared the therapeutic effects of CBT,
89 relaxation, meditation, and biofeedback therapy on hypertension, showing that these
90 methods had an anti-hypertensive effect, with CBT being the most efficacious. Xue and

91 colleagues (Xue et al., 2008) conducted a five-week group cognitive behavioral self-
92 management project for patients with mild-to-moderate essential hypertension to
93 evaluate its benefits for blood pressure management and found that patients' blood
94 pressure decreased significantly. Similarly, Lei Liu and colleagues (Liu et al., 2017a)
95 conducted a cohort study on hypertensive patients in the Chinese working population
96 and found that a psychological intervention based on CBT plus medication was more
97 effective in improving blood pressure compared to usual medication alone. However,
98 Nolan and colleagues (Nolan et al., 2018) conducted a remote intervention based on
99 CBT for hypertension patients and found the difference in systolic blood pressure
100 reduction between the intervention group and the control group was statistically
101 significant, whereas the change in diastolic blood pressure was not.

102 The results of the above studies of CBT-based interventions for hypertension are
103 inconsistent, and there are few relevant meta-analyses. To address this gap in the
104 research we undertook a systematic review of the literature to evaluate whether
105 comprehensive CBT-based interventions have a positive effect on physiological and
106 psychological indicators and the quality of sleep in hypertension patients. In doing so,
107 we aimed to provide a scientific basis for CBT intervention therapy in patients with
108 hypertension and to provide references for how to design appropriate CBT-based
109 interventions efficiently.

110

111 **2 Methods**

112 This systematic review was conducted in accordance with the Preferred Reporting
113 Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines (Moher et al.,
114 2009). The review protocol was registered at the PROSPERO International Prospective
115 Register of Systematic Reviews (Registration ID: CRD42020213587 PROSPERO
116 2020 website: <https://www.crd.york.ac.uk/prospero/#recordDetails>). Ethical approval
117 and patient consent were not required as this was a systematic review and meta-analysis
118 of previously published studies.

119

120 **2.1 Search strategy**

121 Databases searched included PubMed, Embase, Cochrane Central Register of
122 Controlled Trials, Scopus, Proquest, Web of Science, CINAHL and Chinese databases
123 (WanFang, China National Knowledge Infrastructure). Key search words were
124 “hypertension” and “cognitive behavioral therapy”. We searched using the form of
125 subject words + free words with Boolean operators AND/OR in the abstract, key words,
126 or title, with a language limitation of English and Chinese. In the process of retrieval,
127 the search terms were modified according to the search rules for the different databases.
128 We also searched the reference lists of the original papers to find additional relevant
129 articles. Our retrieval time was from inception to October 2020. Articles collected were
130 managed by Endnote X8 Software (Clarivate Analytics, PA, USA). Two researchers
131 conducted literature reviews separately. In case of disagreement, a third researcher was
132 consulted, and consensus reached.

133 **2.2 Study selection**

134 Inclusion criteria were developed using the population, intervention, control,
135 outcomes, study type (PICOS) approach:

136 (1) P: The target *population* was adults (≥ 18) with essential hypertension regardless of
137 disease stage and severity, including grade I hypertension, grade II hypertension, grade
138 III hypertension, and isolated systolic hypertension. Participants in this review were
139 diagnosed with hypertension according to established definitions or guidelines. Trials
140 that reported the recruitment of subjects with definite hypertension but without specific
141 diagnostic criteria were also included.

142 (2) I: *Interventions* were described as CBT or based on CBT principles. The strategies
143 had to be under the umbrella of CBT including cognitive therapy and behavioral therapy,
144 and common CBT techniques such as problem-solving, relaxation, goal-setting,
145 behavioral experiments, and cognitive restructuring. The interventions could be CBT
146 alone or CBT combined with other methods, delivered face-to-face or remotely (e.g.,
147 via telephone and internet) and used in individual or a group form.

148 (3) C: The *control* conditions included non-CBT interventions (e.g., medication,
149 education), or usual care or wait list. If there were multiple comparison groups, we
150 chose the usual care group.

151 (4) O: The primary *outcomes* were physiological indicators (blood pressure, blood lipid
152 profile: low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein
153 cholesterol (HDL-C), triglycerides (TG), total cholesterol). Secondary outcomes
154 included psychological indicators (anxiety, depression), and the quality of sleep. We
155 used the Pittsburgh Sleep Quality Index (PSQI) score to represent the quality of sleep.
156 Articles reporting one or more of the above outcomes were included.

157 (5) Studies had to involve a randomized controlled trial (RCT) design, with no
158 restrictions on the length of follow-up.

159 (6) Articles written in English or Chinese.

160 (7) Accessibility of full-text publication.

161 The study exclusion criteria were:

162 (1) Participants with cognitive impairment or substance abuse.

163 (2) Solely cognitive or behavioral interventions as opposed to a comprehensive,
164 integrated CBT approach;

165 (3) Lacking quantitative analysis;

166 (4) Literature reviews or protocols, incomplete in terms of data used or inconsistent
167 statistical methods;

168 (5) Duplicate publications;

169 (6) Judged to be of low quality on the PEDro tool (Verhagen et al., 1998);

170 (7) Not peer-reviewed journal articles.

171 **2.3 Data extraction**

172 The following information was extracted: (a) Basic information, including first
173 author, year of publication, country; (b) Study design, including information on
174 participants (number, age, gender, diseases), drop-out rates, frequency/length of follow-
175 up, intervention method, comparison group, outcomes. Data were extracted
176 independently by two researchers. Where data was incomplete the corresponding
177 author was contacted to obtain the data. The primary outcome variables were

178 physiological indicators (blood pressure, blood lipid profile: LDL-C, HDL-C, TG, total
179 cholesterol). Secondary outcomes included psychological indicators (anxiety,
180 depression), and the quality of sleep.

181 **2.4 Quality assessment**

182 Two reviewers independently read the full texts of the included articles and
183 assessed their methodological quality using the PEDro tool (Verhagen et al., 1998).
184 PEDro includes ten items: random allocation of subjects into groups, concealed
185 randomization, similarity of baseline information between groups, blinding to subjects,
186 blinding to assessors and researchers, attrition rate, use of “intention to treat” analysis,
187 use of variability measures, and use of between-group comparison methods. Based on
188 these ten items, PEDro categorizes the quality of studies into three levels: high quality
189 (8 or more points), moderate quality (4–7 points), and lower quality (3 points or less).
190 If there were disagreements in rating the quality of the included studies, they were
191 resolved through consultation with a third researcher.

192 **2.5 Statistical analysis**

193 Stata version 15.0 software (Harris et al., 2008) was used for analysis, and a p-
194 value <0.05 was considered to be statistically significant. A separate meta-analysis was
195 performed for each outcome variable. The pooled mean difference (MD), with a 95%
196 confidence interval (CI) was used for continuous outcome variables. Standardized
197 mean difference (SMD) and 95% CI were used to measure the effect size of continuous
198 outcome variables. When the SMD was between 0.2 and 0.5, the effect size was small;
199 between 0.5 and 0.7, this was medium; and more than 0.7, this was large. The
200 significance level was set as 0.05 (two-sided).

201 The Chi-square test and I^2 were used for heterogeneity testing among the included
202 articles. If $I^2 < 50\%$ or $P > 0.05$, the level of homogeneity was considered good and if
203 $I^2 > 50\%$, it was considered to be heterogeneous. The random-effect model was adopted
204 no matter the heterogeneity. We conducted sensitivity analysis by removing each
205 individual study at a time from the meta-analysis to evaluate the stability of the pooled
206 results and investigate the potential source of the heterogeneity if it was significant. To
207 explore the heterogeneity, we performed subgroup analysis based on the country

208 (developed country vs. developing country); intervention type (CBT combined with
209 other interventions vs. CBT alone); treatment form (group vs. individual); treatment
210 course (≥ 12 weeks vs. < 12 weeks); duration of session (≥ 50 min vs. < 50 min); number
211 of session (≥ 10 vs. < 10); mode of delivery (remote vs. face-to-face); use of a
212 hypertension-specific manual (yes vs. no); drop-out rate ($\geq 20\%$ vs. $< 20\%$); patients
213 with comorbid mood symptoms (yes vs. no); and treatment used specific components
214 of CBT (yes vs. no). The definition of using components for CBT was based on the
215 Comprehensive Psycho-therapeutic Intervention Rating Scale and previous studies
216 (Koelen et al., 2014; Liu et al., 2019; Trijsburg et al., 2002; Yang et al., 2020). The
217 following components of CBT were included in the subgroup analysis:
218 psychoeducation, behavioral strategies, cognitive strategies, affective strategies,
219 interpersonal strategies, exposure, body-directed strategies, behavior experiments,
220 mindfulness and attention, homework assignments, goal-setting and planning, problem-
221 solving, stress management, dietary interventions, and physical activity. These
222 components were identified as “yes” (mentioned as an important technique), or “no”
223 (not mentioned and not a core technique).

224 Publication bias was evaluated using the Egger test. A p-value of less than 0.05
225 represented statistically significant publication bias. If the number of meta-analysis
226 studies was 10 or above, a funnel plot was used to analyze whether there was a
227 publication bias.

228

229 **3 Results**

230 **3.1 Literature search**

231 A total of 1781 articles were included, including 1780 articles from literature
232 retrieval and one article from references of a relevant review and meta-analysis. After
233 removing duplicate articles, 1376 articles were screened for titles and abstracts. From
234 these, 1304 publications were identified and discarded, including those that clearly did
235 not fulfill the inclusion criteria. Finally, 72 articles were retrieved for full-text screening.
236 During this assessment, two researchers read the full text of the article independently,
237 screened and excluded all articles strictly according to the inclusion rules, and carefully

238 recorded the reasons for the exclusion. In the case of any disagreement, a third
239 researcher was invited to review the article until consensus was reached. Through full-
240 text screening, 57 articles were excluded for the following reasons: protocol or review;
241 non-English or Chinese; unrelated subjects; non-CBT-based intervention; no control
242 group; non-RCT; PEDro \leq 3; no access to the full article, or insufficient data. The
243 specific process of identifying relevant articles for inclusion in the systematic review
244 and meta-analysis is described in **Figure 1**. This resulted in 15 studies being included
245 in the meta-analysis.

246 **[Insert Figure 1]**

247 **3.2 Study characteristics**

248 Full details of the included studies are displayed in **Table 1**. A total of 2195
249 participants were included in the 15 RCTs. Among these, 1102 participants were in
250 intervention groups and 1093 in control groups. The mean age of those in the
251 intervention groups was 55.40 and 55.23 in control groups. The mean proportions of
252 females were 48.92% and 47.38% in the intervention and control groups, respectively.
253 Twelve studies were undertaken in developing countries (Birashk et al., 2018; Hualei
254 et al., 2013; Jing, 2020; Mingming, 2017; Qing et al., 2019; Qingmei, 2010; Weiwei et
255 al., 2015; Xinju et al., 2017; Youyou, 2013; Yu et al., 2018; Yuanyuan, 2017; Yurong
256 et al., 2012) and three in developed countries (Clemow et al., 2018; Mensorio et al.,
257 2019; Sung et al., 2012).

258 Regarding interventions, a single CBT method was used in three studies (Clemow
259 et al., 2018; Sung et al., 2012; Yuanyuan, 2017), and CBT combined with drug therapy
260 or treatment as usual was used in the remaining 12 studies (Birashk et al., 2018; Hualei
261 et al., 2013; Jing, 2020; Mensorio et al., 2019; Mingming, 2017; Qing et al., 2019;
262 Qingmei, 2010; Weiwei et al., 2015; Xinju et al., 2017; Youyou, 2013; Yu et al., 2018;
263 Yurong et al., 2012). Additionally, control groups that adopted drug therapy or usual
264 interventions were described in 14 articles (Birashk et al., 2018; Clemow et al., 2018;
265 Hualei et al., 2013; Jing, 2020; Mensorio et al., 2019; Mingming, 2017; Qing et al.,
266 2019; Qingmei, 2010; Sung et al., 2012; Weiwei et al., 2015; Xinju et al., 2017; Youyou,
267 2013; Yu et al., 2018; Yurong et al., 2012). A wait list control group was used in only

268 one study (Yuanyuan, 2017). Two studies used remote interventions, including
269 interventions over the internet (Mensorio et al., 2019; Xinju et al., 2017), and 13 studies
270 used traditional face-to-face interventions (Birashk et al., 2018; Clemow et al., 2018;
271 Hualei et al., 2013; Jing, 2020; Mingming, 2017; Qing et al., 2019; Qingmei, 2010;
272 Sung et al., 2012; Weiwei et al., 2015; Youyou, 2013; Yu et al., 2018; Yuanyuan, 2017;
273 Yurong et al., 2012). Four studies used an individual CBT intervention (Mensorio et
274 al., 2019; Qing et al., 2019; Xinju et al., 2017; Yurong et al., 2012), five studies used a
275 group-based CBT intervention (Birashk et al., 2018; Clemow et al., 2018; Hualei et al.,
276 2013; Sung et al., 2012; Yuanyuan, 2017), while six did not report the treatment form
277 (Jing, 2020; Mingming, 2017; Qingmei, 2010; Weiwei et al., 2015; Youyou, 2013; Yu
278 et al., 2018). Only three studies reported using an intervention manual (Birashk et al.,
279 2018; Clemow et al., 2018; Yuanyuan, 2017). The specific settings of the interventions
280 were as follows: the mean number of sessions was 9.91, the mean duration of sessions
281 was 64.75 min, and the mean duration of treatment was 10.04 weeks. Four types of
282 outcome measures were included in this analysis: physiological indicators,
283 psychological indicators, quality of life, and quality of sleep. Thirteen studies reported
284 physiological indicators (Birashk et al., 2018; Clemow et al., 2018; Hualei et al., 2013;
285 Jing, 2020; Mensorio et al., 2019; Mingming, 2017; Qingmei, 2010; Sung et al., 2012;
286 Weiwei et al., 2015; Xinju et al., 2017; Youyou, 2013; Yu et al., 2018; Yurong et al.,
287 2012), 11 psychological indicators (Clemow et al., 2018; Hualei et al., 2013; Mensorio
288 et al., 2019; Mingming, 2017; Qing et al., 2019; Qingmei, 2010; Weiwei et al., 2015;
289 Xinju et al., 2017; Youyou, 2013; Yuanyuan, 2017; Yurong et al., 2012), three quality
290 of life (Mensorio et al., 2019; Qing et al., 2019; Sung et al., 2012), and two reported
291 quality of sleep (Jing, 2020; Mensorio et al., 2019; Xinju et al., 2017; Yu et al., 2018).
292 The mean drop-out rates were 14.57% and 12.13% in the intervention and control
293 groups. respectively. Detailed characteristics of the intervention methods and control
294 group activities are in **Table 1**.
295

296 3.3 Pre to post-treatment effects of CBT-based interventions

297 3.3.1 Effects on physiological indicators

298 Nine studies (Hualei et al., 2013; Jing, 2020; Mingming, 2017; Sung et al., 2012;
299 Weiwei et al., 2015; Xinju et al., 2017; Youyou, 2013; Yu et al., 2018; Yurong et al.,
300 2012), with a total sample of 1377 participants, analyzed the effect of CBT-based
301 interventions on blood pressure. The number of people in the intervention and control
302 groups were 701 and 676, respectively. CBT-based interventions were more beneficial
303 in reducing systolic pressure compared to the control conditions, with a mean reduction
304 of systolic pressure of -8.67 (95% CI: -10.67 to -6.67, $P=0.000$), and a large effect size
305 (SMD -0.87 (95% CI: -1.18 to -0.55, $P=0.000$)). The heterogeneity was statistically
306 significant ($I^2=58.50%$, $P=0.013$) (**Table 2**). The forest plot of the effect is presented in
307 **Figure 2A**.

308 Subgroup analysis was performed to examine the effect of CBT-based
309 interventions with different characteristics on improving systolic pressure. The results
310 demonstrated that CBT-based interventions with the following characteristics had a
311 better effect on systolic pressure: when they involved group treatment, patients did not
312 have comorbid mood symptoms (**Table 3**).

313 Similarly, CBT-based interventions significantly reduced diastolic pressure, with
314 a reduced pooled mean across these studies of -5.82 (95% CI: -7.82 to -3.81, $P=0.000$)
315 with a large effect size (SMD -0.77 (-1.07 to -0.47, $P=0.000$)). Statistically significant
316 heterogeneity was observed ($I^2=80.20%$, $P=0.000$). The forest plot of the effect is
317 presented in **Figure 2B**.

318 **[Insert Figure 2]**

319 As shown in **Table 4**, CBT-based interventions statistically reduced diastolic
320 pressure when the CBT intervention format involved a group-based intervention, and
321 when more than 10 sessions were given.

322 Two studies (Hualei et al., 2013; Youyou, 2013) with a total sample of 679
323 participants analyzed the effect of CBT-based interventions on total cholesterol, TG,
324 and LDL-C. The numbers of people in the intervention and control groups were 342
325 and 337, respectively. Meta-analysis showed a significant reduction in total cholesterol,

326 with mean reduction of -0.43 (95% CI: -0.76 to -0.10, P=0.010), and a medium effect
327 size of SMD -0.49 (95% CI: -0.64 to -0.33, P=0.000). The heterogeneity was
328 statistically significant ($I^2=74.60\%$, P=0.047) (**Table 2**). The forest plot of the effect is
329 presented in **Figure 3A**. The meta-analysis did not show a significant reduction in either
330 TG (0.00, 95% CI: -0.07 to 0.07, P=0.978) or LDL-C (0.10, 95% CI: -0.15 to 0.34,
331 P=0.441). The heterogeneity was not statistically significant for TG ($I^2=0.00\%$,
332 P=0.419) or LDL-C ($I^2=0.00\%$, P=0.401) (**Table 2**). The forest plot of the effect is
333 presented in **Figure 3B and 3C**.

334 **[Insert Figure 3]**

335 **3.3.2 Effects on psychological indicators**

336 The effect on depressive symptoms was analyzed in nine studies (Clemow et al.,
337 2018; Hualei et al., 2013; Mensorio et al., 2019; Mingming, 2017; Qing et al., 2019;
338 Qingmei, 2010; Weiwei et al., 2015; Xinju et al., 2017; Youyou, 2013) with a total
339 sample of 1620 participants. The number of people in the intervention and control
340 groups was 810 and 810, respectively. CBT-based interventions were more beneficial
341 for treating depressive symptoms than the control condition, with a mean reduction of
342 depression of -3.13 (95% CI: -4.02 to -2.24, P=0.000) and a large effect size (SMD -
343 1.07 (95% CI: -1.82 to -0.31, P = 0.005)). The heterogeneity was statistically significant
344 ($I^2=99.10\%$, P=0.000) (**Table 2**). The forest plot of the effect is presented in **Figure**
345 **4A**.

346 Subgroup analysis was performed to examine the effect of CBT-based
347 interventions with different characteristics on improving depressive symptoms. As
348 shown in **Table 5**, the results demonstrated that CBT-based interventions with the
349 following characteristics had a better effect on depressive symptoms: face-to-face
350 treatment delivery, greater than 10 sessions, and in participants with comorbid mood
351 symptoms. The subgroup analysis also examined the effects of CBT-based
352 interventions with different components on improving depressive symptoms. CBT-
353 based interventions showed a better effect when they used physical activity as the core
354 technique, and when they did not use behavioral strategies, homework assignment
355 strategies, or problem-solving strategies as core techniques.

356 The effect on anxiety symptoms was analyzed in 10 studies (Hualei et al., 2013;
357 Mensorio et al., 2019; Mingming, 2017; Qing et al., 2019; Qingmei, 2010; Weiwei et
358 al., 2015; Xinju et al., 2017; Youyou, 2013; Yuanyuan, 2017; Yurong et al., 2012) with
359 a total sample of 1673 participants. The number of people in the intervention and
360 control groups was 836 and 837, respectively. CBT-based interventions were more
361 beneficial for anxiety symptoms than the control interventions, with a mean reduction
362 of anxiety of -3.63 (95% CI: -4.40 to -2.87, $P=0.000$), and a large effect size, with SMD
363 -1.27 (95% CI: -1.68 to -0.86, $P=0.000$). The heterogeneity was statistically significant
364 ($I^2=98.50\%$, $P=0.000$) (**Table 2**). The forest plot of the effect is presented in **Figure**
365 **4B**.

366 **[Insert Figure 4]**

367 Subgroup analysis was performed to examine the effect of CBT-based
368 interventions with different characteristics on improving anxiety symptoms. As shown
369 in **Table 6**, CBT-based interventions statistically reduced anxiety symptoms and were
370 more effective as an individual treatment and when it emphasized cognitive strategies
371 as the core technique.

372 **3.3.3 Effects on quality of sleep**

373 Two studies (Xinju et al., 2017; Yu et al., 2018), with a total sample of 290
374 participants, analyzed the effect of CBT-based interventions on sleep quality. The
375 number of people in the intervention group and the control group was 155 and 135,
376 respectively. CBT-based interventions were more beneficial in improving the quality
377 of sleep than the control condition, with a mean reduction of the PSIQ score of -2.93
378 (95% CI: -4.40 to -1.47, $P=0.000$), and large effect size of SMD -0.94 (95% CI: -1.29
379 to -0.59, $P=0.000$). The heterogeneity was statistically significant ($I^2=73.20\%$, $P=0.050$)
380 (**Table 2**). The forest plot of the effect is presented in **Figure 3D**.

381 **3.3.4 Effects on health-related behaviors**

382 One study (Jing, 2020), with 100 participants, analyzed the effect of the CBT-
383 based intervention on health-related behaviors and found that the intervention group's
384 health behavior scores, including medication compliance, quitting smoking and
385 drinking, reasonable diet, and exercise, were relatively higher than the control group.

387 **3.4 Risk of bias and quality assessment**

388 We used the PEDro tool to assess the quality of the included studies. All were of
389 medium quality and the score was 5.13 on average. Specifically, three studies scored 4
390 (Birashk et al., 2018; Yu et al., 2018; Yurong et al., 2012), nine studies scored 5 (Hualei
391 et al., 2013; Jing, 2020; Mingming, 2017; Qing et al., 2019; Qingmei, 2010; Sung et
392 al., 2012; Weiwei et al., 2015; Youyou, 2013; Yuanyuan, 2017), one study scored 6
393 (Xinju et al., 2017), and two studies (Clemow et al., 2018; Mensorio et al., 2019) scored
394 7.

395 **3.5 Publication bias**

396 Since only two studies were included to analyze the effect of CBT-based
397 interventions on total cholesterol, HDL-C and the quality of sleep, no T or p-value of
398 the Egger analysis was available for these variables. As can be seen in **Table 7**, we
399 found minimal publication bias on the following outcome variables: systolic pressure
400 (P=0.487), diastolic pressure (P=0.958) and depressive symptoms (P=0.076). However,
401 there was significant publication bias for anxiety symptoms (P=0.008). The one-study-
402 removed method was used to assess sensitivity, and it was found that removing one
403 study at a time did not change the overall results for all outcome variables.

404

405 **4 Discussion**

406 In this paper we have presented the results of a meta-analysis of the efficacy of
407 CBT-based interventions for hypertension patients. The results indicated that CBT-
408 based interventions were superior to control interventions, significantly reducing
409 systolic pressure, diastolic pressure, total cholesterol levels, depressive symptoms and
410 anxiety symptoms, as well as improving the quality of sleep.

411 **4.1 Pre to post-treatment effects of CBT-based interventions**

412 **4.1.1 Effects on physiological indicators**

413 Consistent with previous research (Clemow et al., 2018; Shapiro et al., 1997), we
414 found that CBT-based interventions significantly reduced systolic and diastolic blood
415 pressure in patients with hypertension. It has been reported that high blood pressure
416 control using the recommended guidelines (Hypertension, 2013; James et al., 2014) is

417 the most effective way to reduce cardiovascular mortality in hypertension patients
418 (Burnier, 2017). However, studies have shown that 50% of people with hypertension
419 receiving “usual treatment” had uncontrolled blood pressure (Conn et al., 2015),
420 primarily due to inadequate medication adherence (Burnier, 2014; De Geest et al.,
421 2014). In this context CBT-based interventions could improve medication compliance
422 by correcting patients’ misconceptions about medication usage, thereby reducing blood
423 pressure. Another possible explanation for the effectiveness of CBT is that patients’
424 health-related behaviors improved. Previous research indicates that CBT interventions
425 can result in increased physical activity (Xue et al., 2008), modifications to unhealthy
426 eating patterns (Mensorio et al., 2019), and promote quitting smoking and drinking
427 alcohol (Jing, 2020) in hypertension patients, thereby improving their blood pressure
428 control.

429 Further subgroup analysis showed that the use of a CBT group-based approach
430 and an intervention lasting longer than 10 sessions is more effective in reducing systolic
431 blood pressure and diastolic blood pressure compared with individual treatment and
432 interventions of less than 10 sessions. This may be because group-based interventions
433 facilitate social support among patients, reinforcing the effects of the intervention
434 (Wolgensingler, 2015), and longer intervention times are required to change the
435 maladaptive cognitions and behavior of patients with hypertension.

436 We found that the total cholesterol levels of patients in the intervention groups was
437 reduced by a greater amount compared to that of patients in the control groups. Patients
438 with high blood pressure are more prone to negative emotions, such as depression and
439 anxiety, causing increased sympathetic nervous activity, which results in a series of
440 physiological and pathological changes, including excessive secretion of
441 catecholamines, disordered lipid metabolism, and increased heart rate (Chen and Huang,
442 2006; Lehto et al., 2008). Through the CBT intervention, negative emotions can be
443 alleviated, and the sympathetic excitability of the patients reduced, thereby promoting
444 stability in lipid metabolism. Similarly, studies by Mao (Youyou, 2013) found that
445 CBT-based interventions significantly reduced total cholesterol in patients with
446 hypertension. As only two studies reported TG and low-density lipoprotein results, we

447 did not find a significant reduction in these. We should therefore be cautious in drawing
448 conclusions in this area and need to include more studies to confirm our findings.

449 **4.1.2 Effects on psychological indicators**

450 We found that CBT-based interventions had a larger effect on depressive and
451 anxiety symptoms in hypertension patients compared to the control interventions. This
452 study is the first meta-analysis on the effect of comprehensive CBT-based intervention
453 on negative emotions in patients with hypertension, and the tentative conclusion is that
454 such interventions have a significant impact on anxiety and depressive symptoms in
455 these patients.

456 Subgroup analysis on depression and anxiety found that face-to-face and
457 individualized, rather than group-based, treatment had a more significant effect on the
458 improvement of depressive and anxiety symptoms in hypertension patients, in
459 agreement with Liu and colleagues' previous study (Liu et al., 2019). We also found
460 hypertension patients benefited more in relation to their depression and anxiety when
461 the intervention emphasized a cognitive strategy as the core technique. Previous studies
462 have also suggested that CBT-based intervention using this strategy are more effective
463 in reducing depression and anxiety symptoms in hypertension patients (Qing et al.,
464 2019; Qingmei, 2010). In addition, the number of sessions offered during the
465 intervention was important. Interventions involving greater than 10 sessions were more
466 effective in improving depressive symptoms, possibly because cognitive reconstruction
467 of dysfunctional thoughts takes time (Liu et al., 2019).

468 **4.1.3 Effects on quality of sleep**

469 Two studies reporting sleep quality were included in our meta-analysis, and the
470 results showed that CBT-based interventions were able to significantly reduce the PSQI
471 score and improve sleep quality in patients with hypertension. Similarly, a review by
472 Takaesu and colleagues (Takaesu and Inoue, 2012) found that CBT-based interventions
473 can relieve symptoms of insomnia in patients with metabolic syndrome comorbidities,
474 while also preventing the recurrence of insomnia. The proposed mechanism for this is
475 that offering sleep hygiene education, stimulation control and relaxation therapy helps

476 patients to gradually establish an improved sleep-wake biological rhythm, thus
477 improving their sleep quality.

478 **4.2 Strengths and limitations of the study**

479 We undertook a systematic review and meta-analysis on the efficacy of CBT-
480 based interventions for patients with hypertension using a reasonable number of RCTs
481 with a moderate quality study design and minimal publication bias. Despite the findings
482 of this systematic review, there are several limitations that need to be acknowledged.
483 Firstly, this meta-analysis showed high heterogeneity. The possible reason is that as yet
484 there is no standardized procedure for CBT-based interventions for hypertension, so
485 there have been notable differences in study design, treatment form, duration of
486 treatment, number of sessions, duration of sessions, intervention composition, and the
487 professional background of therapists, including nurses, general practitioners or
488 psychologists. Further, the studies were from different types of institution, including 10
489 from hospitals (Birashk et al., 2018; Jing, 2020; Mensorio et al., 2019; Mingming, 2017;
490 Qing et al., 2019; Qingmei, 2010; Weiwei et al., 2015; Xinju et al., 2017; Youyou, 2013;
491 Yurong et al., 2012), two from medical centers (Clemow et al., 2018; Sung et al., 2012),
492 two from community health service centers (Hualei et al., 2013; Yu et al., 2018), and
493 one from a nursing home (Yuanyuan, 2017). Secondly, only the results before and after
494 the intervention were compared and analyzed, and long-term follow-up results were not
495 discussed due to insufficient data. Therefore, the long-term effect of CBT-based
496 interventions on patients with hypertension was unclear. Thirdly, only two studies
497 (Clemow et al., 2018; Mensorio et al., 2019) used concealed randomization and one
498 (Mensorio et al., 2019) had assessors who were blind to participants' group allocation,
499 while none of the others achieved the corresponding blinding methods, leading to the
500 overall quality of evidence being relatively low due to a high risk of bias. Fourth, two
501 articles (Sung et al., 2012; Yu et al., 2018) did not fully realize randomized grouping.
502 We conducted a strict quality evaluation on these two papers and after finding that they
503 met the remaining inclusion conditions, we decided to include them in the analysis. Last
504 but not the least, medication (Ferdinand and Nasser, 2017), psychological factors
505 (Hamer et al., 2010; Liu et al., 2017b), including stress, distress, as well as lifestyle

506 factors (Beilin et al., 1999; Huntgeburth et al., 2005; Omboni, 2020; Samadian et al.,
507 2016), including smoking, alcohol, have not been included in the meta-analysis due to
508 insufficient data, but also due to the fact that they have an influence on blood pressure
509 management. More research is needed to explore these relationships.

510 **4.3 Implications**

511 An increasing number of studies have applied CBT-based interventions in the
512 management of chronic pain, diabetes, coronary heart disease, and other chronic
513 diseases, and found a positive effect. At present, relatively few RCTs have applied CBT
514 interventions in patients with hypertension. However, this meta-analysis found a
515 positive effect of CBT-based interventions on blood pressure management. Given other
516 researchers (Shapiro et al., 1997) have found that CBT offered as an adjunctive
517 treatment was twice as effective as the control treatment in reducing drug requirements,
518 future studies could examine its impact in terms of decreasing the costs and side effects
519 of antihypertensive medications. This will have a profound impact on the prevention
520 and management of hypertension.

521 **4.4 Conclusion**

522 The findings of this systematic review and meta-analysis suggest that CBT-based
523 interventions are efficacious in reducing systolic pressure, diastolic pressure, total
524 cholesterol level, anxiety symptoms, depressive symptoms, and improving quality of
525 sleep in patients with hypertension. In addition, CBT maybe more effective for blood
526 pressure management in these patients when it is offered long term and in group-based
527 settings.

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540 **Conflict of interest**

541 No conflict of interest has been declared by the authors.

542 **Clinical trial registration**

543 N/A.

544 **Declaration of interest**

545 None.

546 **Contributor's statements**

547 Y.N Li: Data collection, Software, Writing- Original draft preparation.

548 Nicholas Buys: Data collection, Writing- Reviewing and Editing.

549 Z.J Li: Writing- Reviewing and Editing.

550 Jing Sun: Conceptualization, Methodology, Software, Writing- Reviewing and Editing.

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TABLE 1 | Characteristics of randomized controlled trials included in this meta-analysis.

Author	Country	Setting	Sample size (intervention/ control)	Gender: female,n(%)	Age(Mean±SD)	Hypertension diagnosis	Intervention	Format	Manual	Control group	Outcome measure	Drop out rate(%)	Quality of article
Birashk et al. (2018) (Birashk et al., 2018)	Iran	health center and hospital	60 (20/20/20) ¹	NR	NR	essential hypertension	CBT+drug therapy	group	yes	MBSR; drug therapy	①	I: 25.00 C1: 25.00 C2: 20.00	4(mode rate)
Chao et al. (2019) (Qing et al., 2019)	China	hospital	400 (200/200)	I: 92(46.00) C: 93(46.50)	I: 50.94±6.84 C: 51.48±6.83	WHO diagnostic criteria for hypertension	CBT+TAU	individual	no	TAU	②③	NR	5(mode rate)
Clemow et al. (2018) (Clemow et al., 2018)	USA	urban medical center	92 (46/46)	I: 38(83.00) C: 33(72.00)	I: 48.40±8.40 C: 48.70±9.00	SBP: 140-180mm Hg DBP: 90-110 mm Hg	CBT	group	yes	TAU	①②	I: 13.04 C: 10.87	7(mode rate)
Fu (2010) (Qingmei, 2010)	China	hospital	80 (40/40)	I: 19(47.50) C: 17(42.50)	I: 43.12±6.45 C: 43.28±6.25	WHO diagnostic criteria for hypertension	CBT+drug therapy	NR	no	drug therapy	①②	NR	5(mode rate)
Huang et al.(2013) (Hualei et al., 2013)	China	community health service center	599 (302/297)	I: 187(61.92) C: 181(60.94)	I: 47.41±8.09 C: 47.96±7.94	mild hypertension SBP: 140-159mm Hg DBP: 90-99 mm Hg	CBT+drug therapy	group	no	drug therapy	①②	NR	5(mode rate)
Li (2017) (Mingming, 2017)	China	hospital	120 (60/60)	I: 28(46.67) C: 27(45.00)	I: 60.83±10.66 C: 59.05±11.12	Chinese guidelines for hypertension prevention and treatment	CBT+drug therapy	NR	no	drug therapy	①②	NR	5(mode rate)
Liu (2017) (Yuanyuan, 2017)	China	nursing home	80 (40/40)	I: 15(46.90) C: 17(51.50)	I: 70.94±3.62 C: 70.24±3.58	WHO diagnostic criteria	CBT	group	yes	wait-list	②	I: 20.00 C: 17.50	5(mode rate)
Liu et al. (2018) (Yu et al., 2018)	China	community health service center	184 (102/82)	I: 39(38.24) C: 43(52.44)	I: 70.98±4.13 C: 72.16±4.36	Chinese guidelines for hypertension prevention and treatment 2010	CBT+TAU	NR	no	TAU	①④	NR	4(mode rate)
Mao (2013) (Youyou, 2013)	China	hospital	80 (40/40)	I: 20(50.00) C: 20(50.00)	I: 55.35±6.37 C: 54.80±5.98	WHO diagnostic criteria	CBT+TAU	NR	no	TAU	①②	NR	5(mode rate)
Mensorio et al. (2019) (Mensorio et al., 2019)	Spain	public hospital	106 (55/51)	47 (44.34)	53.00±8.90	NR	SII based on CBT+UMC	individual	no	UMC	①②③	I: 21.82 C: 5.88	7(mode rate)

Shen et al. (2012) (Yurong et al., 2012)	China	hospital	80 (40/40)	32 (40.00)	50.00±3.70	essential hypertension	CBT+drug therapy	individual	no	drug therapy	①②	NR	4(mode rate)
Su (2020) (Jing, 2020)	China	hospital	100 (50/50)	I: 23(46.00) C: 22(44.00)	I: 59.86±2.75 C: 59.82±2.71	essential hypertension	CBT+TAU	NR	no	TAU	①	NR	5(mode rate)
Sung et al. (2012) (Sung et al., 2012)	Korea	local health center	56 (28/28)	I: 20(72.00) C: 14(50.00)	I: 66.00±7.00 C: 63.00±11.00	SBP: 140-159mm Hg DBP: 90-99 mm Hg	Forest Therapy based on CBT	group	no	self-monitoring	①③	I: 0.00 C: 0.00	5(mode rate)
Tian et al. (2015) (Weiwei et al., 2015)	China	hospital	52 (26/26)	I: 0(0.00) C: 0(0.00)	I: 42.60±9.60 C: 43.20±9.80	Chinese guidelines for hypertension prevention and treatment 2010	CBT+TAU	NR	no	TAU	①②	NR	5(mode rate)
Yang et al. (2017) (Xinju et al., 2017)	China	hospital	106 (53/53)	I: 33(62.26) C: 34(64.15)	I: 56.16±9.70 C: 56.48±11.16	JNC-8 Diagnostic criteria for hypertension	iCBT+TAU	individual	no	TAU	①②④	I: 7.55 C: 5.66	6(mode rate)

I: I=CBT+drug therapy; C1= drug therapy; C2=MBSR; MBSR=mindfulness - based stress reduction; TAU=treat as usual; UMC=usual medical care; SII=self-administered Internet-based intervention

Outcome measure: ①physiological indicator=blood pressure, blood glucose, blood lipid profile (LDL - C, HDL - C, TG, total cholesterol), heart rate, BMI, waist, hip perimeter, oxidative stress, interleukin 6; ②psychological indicators=depression, anxiety stress; ③QOL; ④quality of sleep

TABLE 2 | Total effect of CBT - based interventions on blood pressure, total cholesterol, triglyceride, LDL - C, depressive symptom, anxiety symptom, and the quality of sleep.

Index	Outcomes: post-to pre - treatment effect							
	Studies,n	Participants	I ² % (P)	Q-test	MD (95%,CI)	P	SMD (95%,CI)	P
Systolic pressure	9	1377	58.50 (0.013)	19.27	-8.67 (-10.67, -6.67)***	0.000	-0.87 (-1.18, -0.55)***	0.000
Diastolic pressure	9	1377	80.20 (0.000)	40.45	-5.82 (-7.82, -3.81)***	0.000	-0.77 (-1.07, -0.47)***	0.000
Total cholesterol	2	679	74.60 (0.047)	3.94	-0.43 (-0.76, -0.10)*	0.010	-0.49 (-0.64, -0.33)***	0.000
Triglyceride	2	679	0.00 (0.419)	0.65	0.00 (-0.07, 0.07)	0.978	0.05 (-0.10, 0.20)	0.502
LDL	2	679	0.00 (0.401)	0.71	0.10 (-0.15, 0.34)	0.441	-0.00 (-0.21, 0.20)	0.971
Depression	9	1620	99.10 (0.000)	870.24	-3.13 (-4.02, -2.24)***	0.000	-1.07 (-1.82, -0.31)**	0.005
Anxiety	10	1673	98.50 (0.000)	600.01	-3.63 (-4.40, -2.87)***	0.000	-1.27 (-1.68, -0.86)***	0.000
The quality of sleep	2	290	73.20 (0.050)	3.74	-2.93 (-4.40, -1.47)***	0.000	-0.94 (-1.29, -0.59)***	0.000

*P<0.05, **P<0.01, ***P<0.001

MD=Mean difference; SMD=Standard mean difference

TABLE 3 | Subgroup analysis on the effect of CBT - based interventions on systolic pressure.

Subgroups	Systolic pressure: post- to pre - treatment effect						
	Studies (n)	Participants (n)	I ² % (P)	Q-test	MD (95%,CI)	SMD (95%,CI)	P (between)
Behavioral strategies							0.210
Important	2	136	44.90 (0.178)	1.81	-12.54 (-19.15, -5.93)***	-0.86 (-1.38, -0.35)**	
Not important	7	1241	57.20 (0.030)	14.01	-8.09 (-10.07, -6.12)***	-0.87 (-1.25, -0.49)***	
Cognitive strategies							0.940
Important	5	917	75.20 (0.003)	16.11	-8.59 (-12.09, -5.10)***	-0.81 (-1.23, -0.40)***	
Not important	4	460	0.00 (0.405)	2.91	-8.73 (-10.25, -7.21)***	-0.93 (-1.51, -0.35)**	
Body directed strategies							0.730
Important	6	993	67.40 (0.009)	15.36	-8.93 (-11.45, -6.41)***	-1.03 (-1.55, -0.50)***	
Not important	3	384	42.60 (0.175)	3.48	-8.10 (-12.13, -4.07)***	-0.63 (-0.83, -0.42)***	
Mindfulness and attention							0.090
Important	2	162	15.90 (0.275)	1.19	-5.11 (-9.39, -0.83)*	-0.43 (-0.74, -0.11)**	
Not important	7	1215	57.60 (0.028)	14.15	-9.27 (-11.34, -7.20)***	-0.99 (-1.38, -0.59)***	
Homework assignment							0.650
Important	2	719	69.30 (0.071)	3.26	-11.33 (-22.50, -0.16)*	-0.48 (-0.63, -0.33)***	
Not important	7	658	60.60 (0.019)	15.22	-8.72 (-11.04, -6.41)***	-1.00 (-1.44, -0.56)***	
Dietary intervention							0.480
Important	3	364	0.00 (0.510)	1.35	-8.33 (-9.81, -6.84)***	-1.06(-1.82, -0.29)**	
Not important	6	1013	72.00 (0.003)	17.85	-9.77 (-13.48, -6.06) ***	-0.76 (-1.10, -0.41)***	
Physical activity							0.720
Important	4	484	25.30 (0.260)	4.02	-8.35 (-10.38, -6.32)***	-0.92 (-1.48, -0.36)**	
Not important	5	893	73.80 (0.004)	15.26	-9.11 (-12.81, -5.42)***	-0.82 (-1.25, -0.39)***	
Treatment form							0.710
Group	2	655	0.00 (0.697)	0.15	-7.22 (-9.54, -4.91)***	-0.48 (-0.63, -0.32)***	
Individual	2	186	89.60 (0.002)	9.57	-9.42 (-20.90, 2.06)	-0.71 (-1.47, 0.04)	
Number of session							0.340
≥10	2	679	0.00 (0.715)	0.13	-6.87 (-9.02, -4.72)***	-0.48 (-0.63, -0.33)***	
<10	3	238	84.40 (0.002)	12.82	-10.21 (-16.71, -3.72)**	-1.09 (-1.94, -0.24)*	
Treatment course							0.150
≥12w	2	679	0.00 (0.715)	0.13	-6.87 (-9.02, -4.72)***	-0.48 (-0.63, -0.33)***	
<12w	5	414	73.10 (0.005)	14.87	-10.82 (-15.82, -5.82)***	-0.85 (-1.32, -0.39)***	
Patients with comorbid mood symptoms							0.700

Yes	2	200	71.30 (0.062)	3.48	-11.13 (-23.43, 1.18)	-0.55 (-0.83, -0.27)***
No	7	1177	61.60 (0.016)	15.64	-8.69 (-10.79, -6.59)***	-0.97 (-1.38, -0.56)***

*P<0.05, **P<0.01, ***P<0.001

MD=Mean difference; SMD=Standard mean difference

TABLE 4 | Subgroup analysis on the effect of CBT - based interventions on diastolic pressure.

Subgroups	Diastolic pressure: post- to pre - treatment effect						
	Studies (n)	Participants (n)	I ² % (P)	Q-test	MD (95%,CI)	SMD (95%,CI)	P (between)
Behavioral strategies							0.920
Important	2	136	85.10 (0.010)	6.69	-6.08 (-14.58, 2.43)	-0.74 (-1.93, 0.45)	
Not important	7	1241	80.90 (0.000)	31.37	-5.63 (-7.73, -3.52)***	-0.77 (-1.09, -0.46)***	
Cognitive strategies							0.300
Important	5	917	84.50 (0.000)	25.80	-5.05 (-7.95, -2.16)**	-0.71 (-1.15, -0.28)**	
Not important	4	460	60.40 (0.056)	7.57	-7.07 (-9.52, -4.61)***	-0.86 (-1.26, -0.45)***	
Body directed strategies							0.360
Important	6	993	82.10 (0.000)	27.99	-5.17 (-7.65, -2.68)***	-0.75 (-1.18, -0.32)**	
Not important	3	384	73.80 (0.022)	7.64	-7.15 (-10.64, -3.66)***	-0.84 (-1.19, -0.48)***	
Mindfulness and attention							<0.001
Important	2	162	0.00 (0.615)	0.25	-0.08 (-2.57, 2.41)	-0.02 (-0.33, 0.29)	
Not important	7	1215	65.80 (0.007)	17.55	-6.97 (-8.59, -5.35)***	-0.96 (-1.24, -0.68)***	
Homework assignment							0.710
Important	2	719	66.30 (0.085)	2.97	-6.35 (-9.57, -3.13)***	-0.66 (-0.89, -0.42)***	
Not important	7	658	83.90 (0.000)	37.24	-5.55 (-8.30, -2.79)***	-0.80 (-1.24, -0.36)***	
Dietary intervention							0.590
Important	3	364	73.60 (0.023)	7.57	-6.54 (-9.41, -3.67)***	-0.95 (-1.37, -0.53)***	
Not important	6	1013	83.30 (0.000)	29.90	-5.43 (-8.27, -2.58)***	-0.68 (-1.07, -0.30)***	
Physical activity							0.290
Important	4	484	63.80 (0.040)	8.28	-6.95 (-9.25, -4.66)***	-0.93 (-1.23, -0.63)***	
Not important	5	893	85.00 (0.000)	26.59	-4.85 (-8.03, -1.66)**	-0.66 (-1.13, -0.19)**	
Treatment form							0.910
Group	2	655	33.10 (0.221)	1.49	-4.32 (-7.22, -1.42)**	-0.42 (-0.84, -0.01)*	
Individual	2	186	95.50 (0.000)	22.18	-4.90 (-15.02, 5.23)	-0.65 (-1.20, 0.70)	
Number of session							0.810
≥10	2	679	0.00 (0.406)	0.69	-4.83 (-6.13, -3.54)***	-0.56 (-0.72, -0.41)***	
<10	3	238	92.00 (0.000)	25.01	-5.58 (-11.52, 0.36)	-0.89 (-1.90, 0.12)	
Treatment course							0.770
≥12w	2	679	0.00 (0.406)	0.69	-4.83 (-6.13, -3.54)***	-0.56 (-0.72, -0.41)***	
<12w	5	414	86.60 (0.000)	29.76	-5.47 (-9.60, -1.34)**	-0.72 (-1.30, -0.15)*	
Patients with comorbid mood symptoms							0.950
Yes	2	200	74.40 (0.048)	3.90	-5.95 (-10.76, -1.14)*	-0.68 (-1.04, -0.32)***	
No	7	1177	83.60 (0.000)	36.55	-5.77 (-8.13, -3.41)***	-0.81 (-1.18, -0.43)***	

*P<0.05, **P<0.01, ***P<0.001

MD=Mean difference; SMD=Standard mean difference

TABLE 5 | Subgroup analysis on the effect of CBT - based interventions on depressive symptom.

Subgroups	Depressive symptom: post- to pre - treatment effect						
	Studies (n)	Participants (n)	I ² % (P)	Q-test	MD (95%,CI)	SMD (95%,CI)	P (between)
Behavioral strategies							0.003

Important	2	183	0.00 (0.909)	0.01	-1.06 (-2.39, 0.26)	-0.21 (-0.50, 0.08)	
Not important	7	1437	99.30 (0.000)	868.70	-3.53 (-4.50, -2.56)***	-1.31 (-2.25, -0.37)**	
Cognitive strategies							<0.001
Important	7	1409	99.30 (0.000)	863.37	-3.88 (-4.93, -2.84)***	-1.24 (-2.21, -0.28)*	
Not important	2	211	0.00 (0.673)	0.18	-0.80 (-1.24, -0.36)***	-0.47 (-0.76, -0.19)**	
Body directed strategies							0.110
Important	6	1329	99.30 (0.000)	721.97	-2.80 (-3.79, -1.81)***	-1.01 (-2.03, 0.01)	
Not important	3	291	98.50 (0.000)	133.60	-8.46 (-15.37, -1.55)*	-1.18 (-2.38, 0.03)	
Homework assignment							0.005
Important	3	810	82.10 (0.004)	11.14	-0.48 (-1.13, 0.18)	-0.31 (-0.63, 0.02)	
Not important	6	810	99.40 (0.000)	833.99	-6.56 (-10.76, -2.35)**	-1.44 (-2.48, -0.40)**	
Problem solving							0.003
Important	2	183	0.00 (0.909)	0.01	-1.06 (-2.39, 0.26)	-0.21 (-0.50, 0.08)	
Not important	7	1437	99.30 (0.000)	868.70	-3.53 (-4.50, -2.56)***	-1.31 (-2.25, -0.37)**	
Dietary intervention							0.006
Important	4	651	99.30 (0.000)	424.61	-9.96 (-16.87, -3.06)**	-1.78 (-2.96, -0.61)**	
Not important	5	969	77.10 (0.002)	17.46	-0.24 (-0.44, -0.04)*	-0.44 (-0.84, -0.04)*	
Physical activity							0.002
Important	5	771	99.30 (0.000)	611.22	-7.93 (-12.77, -3.10)**	-1.55 (-2.59, -0.50)**	
Not important	4	849	71.30 (0.015)	10.47	-0.15 (-0.32, 0.02)	-0.41 (-0.88, 0.07)	
Country							0.003
Developed country	2	183	0.00 (0.909)	0.01	-1.06 (-2.39, 0.26)	-0.21 (-0.50, 0.08)	
Developing country	7	1437	99.30 (0.000)	868.70	-3.53 (-4.50, -2.56)***	-1.31 (-2.25, -0.37)**	
Treatment form							0.290
Group	2	691	0.00 (0.589)	0.29	-0.05 (-0.14, 0.03)	-0.10 (-0.25, 0.05)	
Individual	3	597	99.30 (0.000)	287.73	-4.63 (-13.10, 3.83)	-1.02 (-2.78, 0.74)	
Treatment delivery way							<0.001
Remote	2	197	0.00 (0.482)	0.50	-0.71 (-1.70, 0.27)	-0.20 (-0.48, 0.08)	
Face to face	7	1423	99.30 (0.000)	868.82	-3.79 (-4.80, -2.79)***	-1.31 (-2.26, -0.37)**	
Number of session							0.510
≥10	4	851	98.40 (0.000)	186.67	-5.90 (-9.23, -2.58)**	-1.08 (-2.11, -0.04)*	
<10	4	649	99.50 (0.000)	661.83	-3.53 (-9.69, 2.63)	-1.17 (-2.56, 0.23)	
Treatment course							0.040
≥12w	4	1170	99.60 (0.000)	824.84	-9.45 (-17.33, -1.57)*	-1.42 (-2.93, 0.09)	
<12w	5	450	90.30 (0.000)	41.25	-0.93 (-1.77, -0.10)*	-0.76 (-1.34, -0.18)*	
Patients with comorbid mood symptoms							0.001
Yes	4	680	99.50 (0.000)	605.03	-9.72 (-15.45, -3.99)**	-1.85 (-2.94, -0.77)**	
No	5	940	66.90 (0.017)	12.09	-0.17 (-0.34, 0.01)	-0.37 (-0.75, 0.00)	

*P<0.05, **P<0.01, ***P<0.001

MD=Mean difference; SMD=Standard mean difference

TABLE 6 | Subgroup analysis on the effect of CBT - based interventions on anxiety symptom.

Subgroups	Anxiety symptom: post- to pre - treatment effect						
	Studies (n)	Participants (n)	I ² % (P)	Q-test	MD (95%,CI)	SMD (95%,CI)	P (between)
Behavioral strategies							0.250
Important	3	236	96.20 (0.000)	52.80	-5.77 (-10.42, -1.13)*	-1.40 (-2.31, -0.49)**	
Not important	7	1437	98.70 (0.000)	479.63	-3.01 (-3.82, -2.20)***	-1.22 (-1.72, -0.73)***	
Cognitive strategies							0.002
Important	8	1462	98.80 (0.000)	591.31	-4.43 (-5.33, -3.53)***	-1.45 (-1.94, -0.97)***	

Not important	2	211	86.70 (0.006)	7.49	-1.26 (-3.01, 0.49)	-0.58 (-0.85, -0.30)***	
Body directed strategies							0.200
Important	7	1382	98.30 (0.000)	344.85	-2.85 (-3.60, -2.10)***	-1.18 (-1.57, -0.79)***	
Not important	3	291	99.20 (0.000)	244.65	-7.72 (-15.17, -0.27)*	-1.56 (-3.06, -0.05)*	
Homework assignment							0.070
Important	4	875	97.10 (0.000)	102.06	-2.72 (-4.09, -1.35)***	-1.04 (-1.59, -0.48)***	
Not important	6	798	99.00 (0.000)	497.94	-5.82 (-8.85, -2.80)***	-1.43 (-2.03, -0.83)***	
Dietary intervention							0.010
Important	4	651	98.90 (0.000)	279.55	-7.41 (-12.27, -2.55)**	-1.60 (-2.48, -0.72)***	
Not important	6	1022	96.20 (0.000)	130.71	-1.32 (-1.85, -0.79)***	-1.05 (-1.44, -0.65)***	
Physical activity							0.020
Important	5	771	99.00 (0.000)	389.78	-5.88 (-9.24, -2.52)**	-1.36 (-2.12, -0.60)***	
Not important	5	902	96.90 (0.000)	130.35	-1.69 (-2.33, -1.05)***	-1.18 (-1.66, -0.71)***	
Treatment form							0.730
Group	2	664	98.90 (0.000)	93.37	-6.14 (-17.54, 5.25)	-1.59 (-3.25, 0.07)	
Individual	4	677	90.60 (0.000)	31.90	-4.11 (-6.24, -1.99)***	-1.04 (-1.50, -0.57)***	
Treatment delivery way							0.650
Remote	2	197	62.90 (0.101)	2.69	-3.16 (-5.39, -0.94)**	-0.72 (-1.01, -0.43)***	
Face to face	8	1476	98.80 (0.000)	580.57	-3.71 (-4.54, -2.89)***	-1.42 (-1.92, -0.93)***	
Number of session							0.400
≥10	3	759	99.20 (0.000)	250.48	-6.93 (-11.08, -2.78)**	-1.65 (-2.92, -0.38)*	
<10	6	794	98.60 (0.000)	349.26	-4.68 (-7.80, -1.57)**	-1.26 (-1.70, -0.82)***	
Duration of session							0.340
≥50min	5	876	98.90 (0.000)	352.67	-3.45 (-4.36, -2.54)***	-1.71 (-2.60, -0.82)***	
<50min	2	480	91.50 (0.001)	11.83	-4.84 (-7.56, -2.13)***	-1.36 (-1.80, -0.93)***	
Treatment course							0.080
≥12w	4	1170	99.30 (0.000)	459.21	-7.23 (-12.16, -2.30)**	-1.58 (-2.33, -0.83)***	
<12w	6	503	96.30 (0.000)	134.03	-2.77 (-3.94, -1.60)***	-1.06 (-1.54, -0.59)***	
Patients with comorbid mood symptoms							0.000
Yes	5	745	99.10 (0.000)	462.18	-7.86 (-11.71, -4.01)***	-1.71 (-2.56, -0.86)***	
No	5	928	91.20 (0.000)	45.36	-0.77 (-1.16, -0.38)***	-0.81 (-0.95, -0.68)***	

*P<0.05, **P<0.01, ***P<0.001

MD=Mean difference; SMD=Standard mean difference

TABLE 7 | Egger's regression analysis on publication bias.

Variables	T	P	95%, CI
Systolic pressure	-0.73	0.487	(-3.55, 1.87)
Diastolic pressure	-0.05	0.958	(-5.47, 5.22)
Total cholesterol	—	—	—
Triglycerides	—	—	—
LDL - L	—	—	—
Depression	-2.08	0.076	(-16.15, 1.01)
Anxiety	-3.54	0.008	(-12.44, -2.62)
The quality of sleep	—	—	—

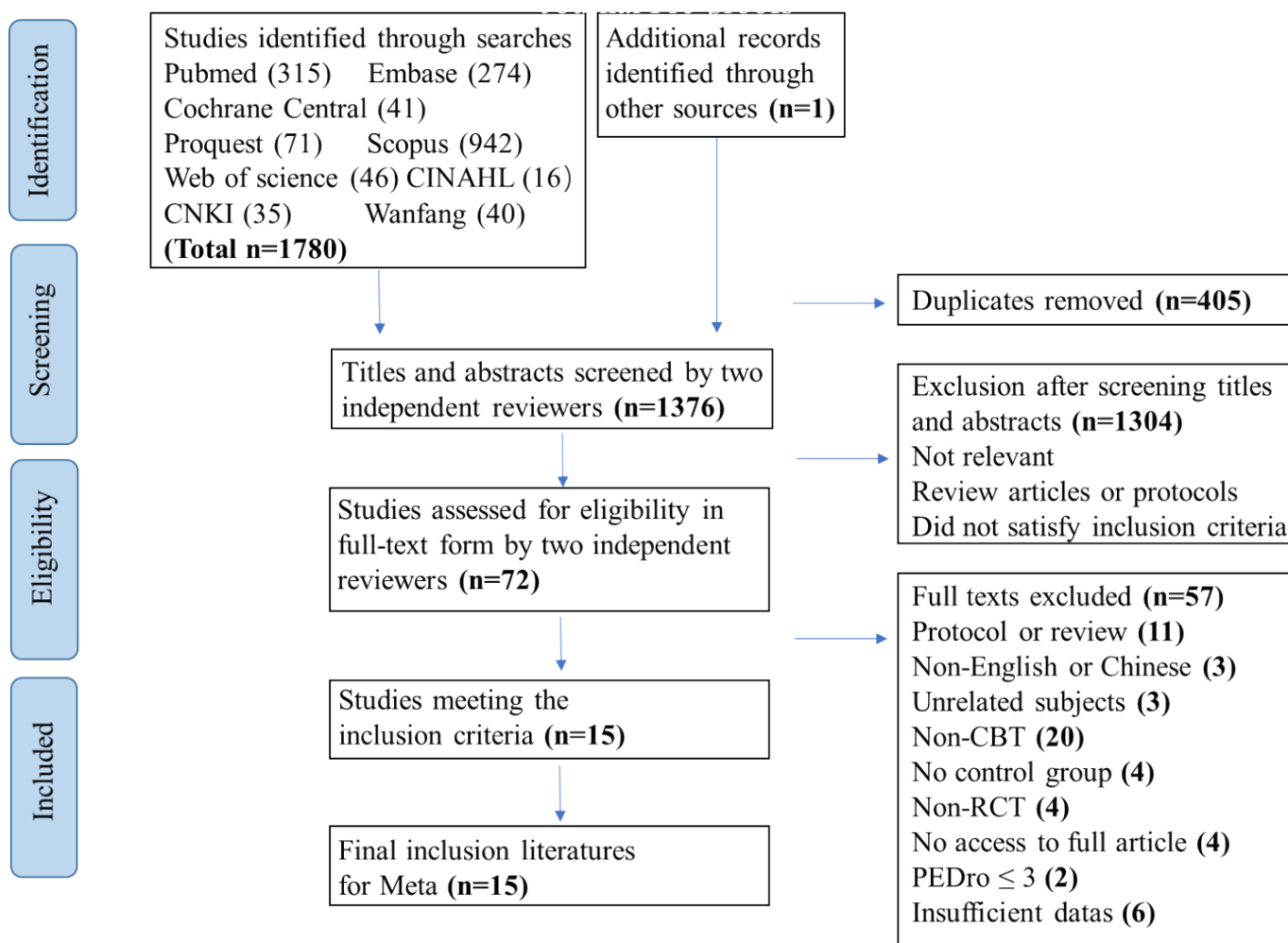


FIGURE 1 | PRISMA flow diagram.

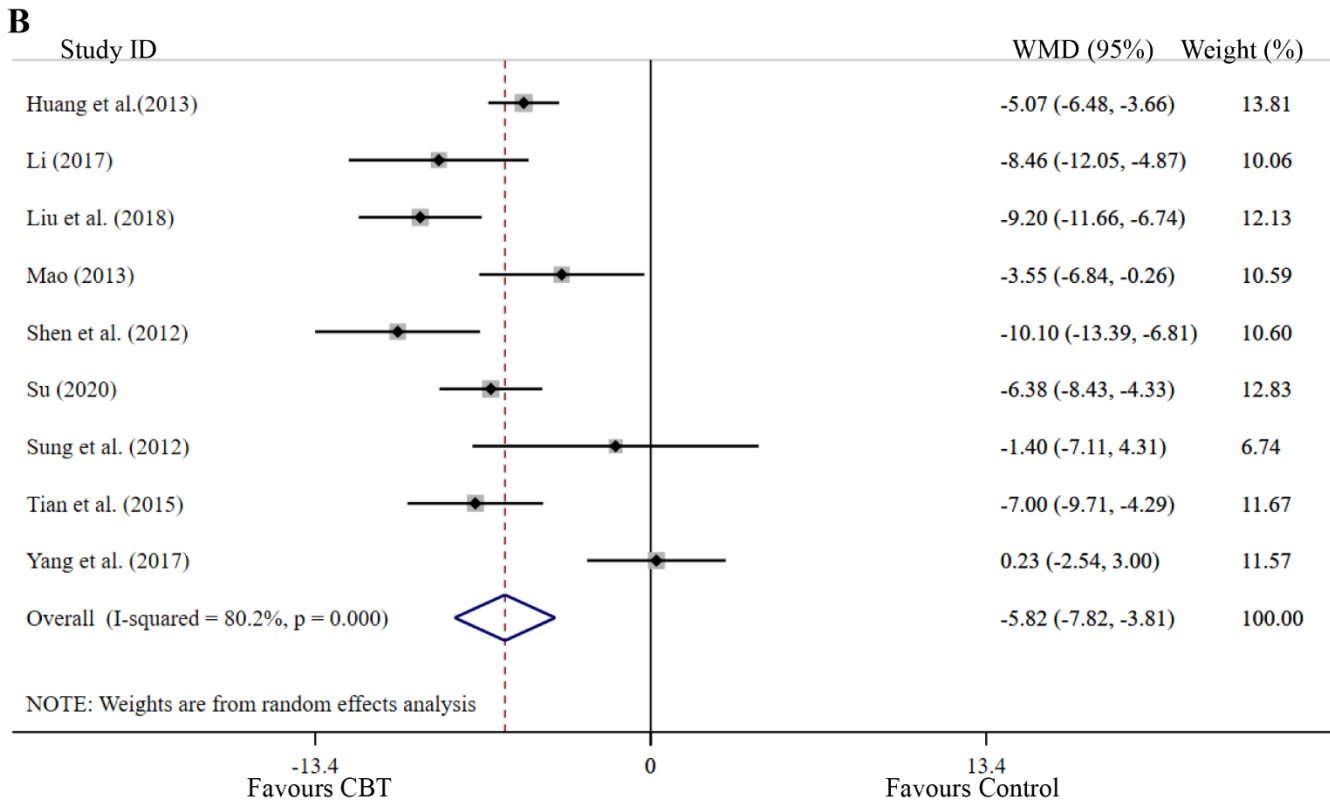
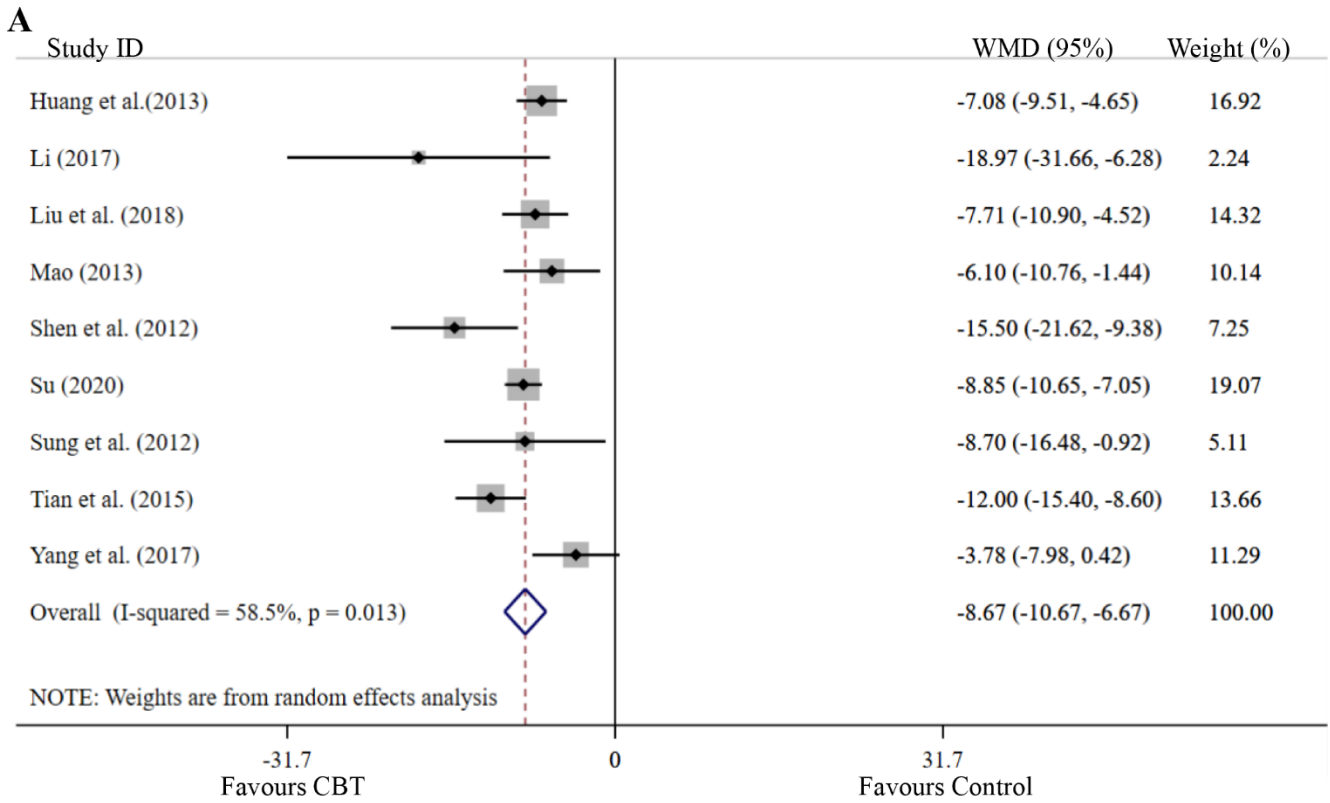


FIGURE 2 | Forest plots of the effects of CBT - based interventions on blood pressure. A: Systolic blood pressure; B: Diastolic blood pressure.

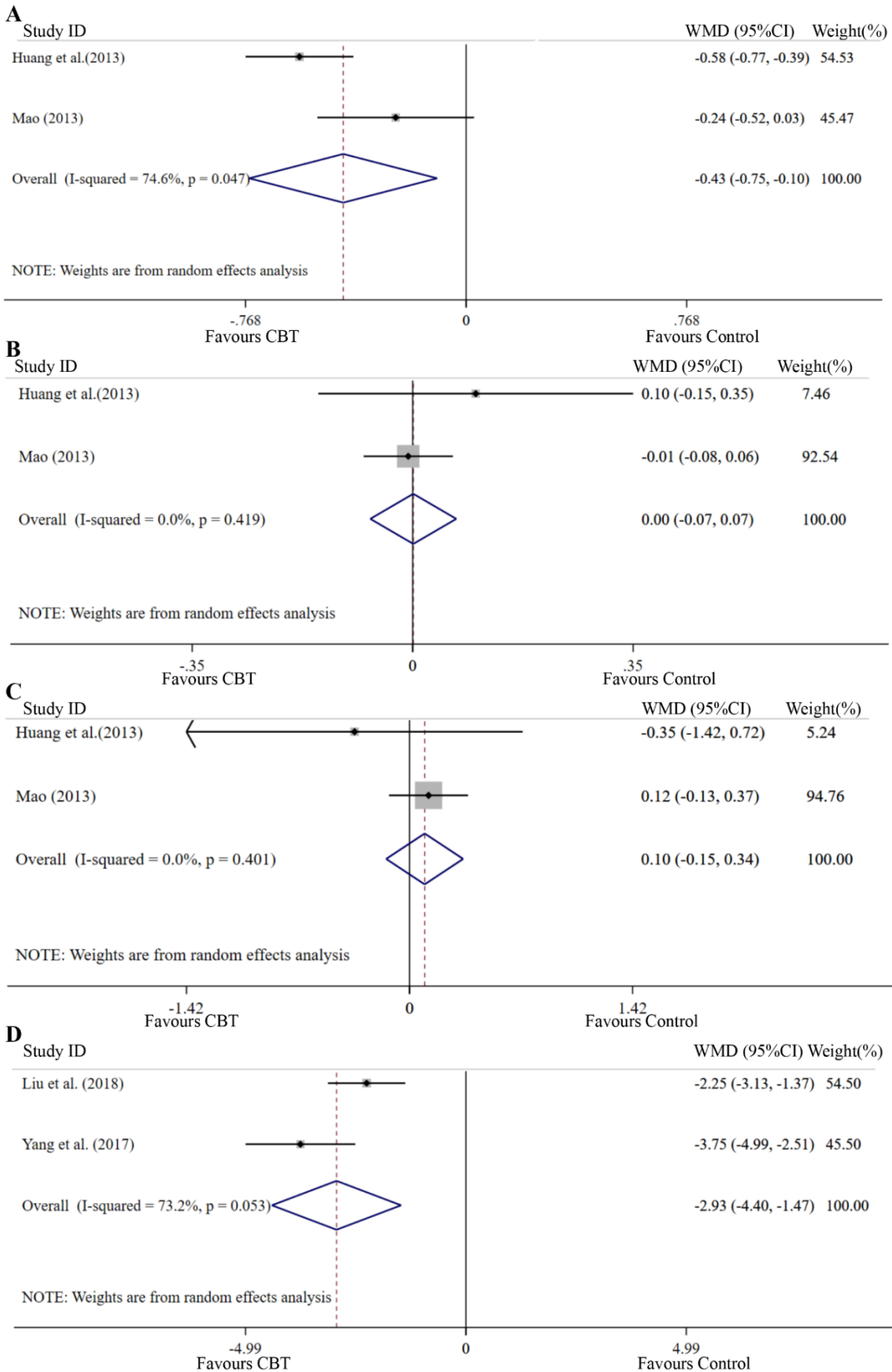


FIGURE 3 | Forest plots of the effects of CBT - based interventions on: A: Total cholesterol; B: Triglyceride; C: LDL - C. D: Quality of sleep.

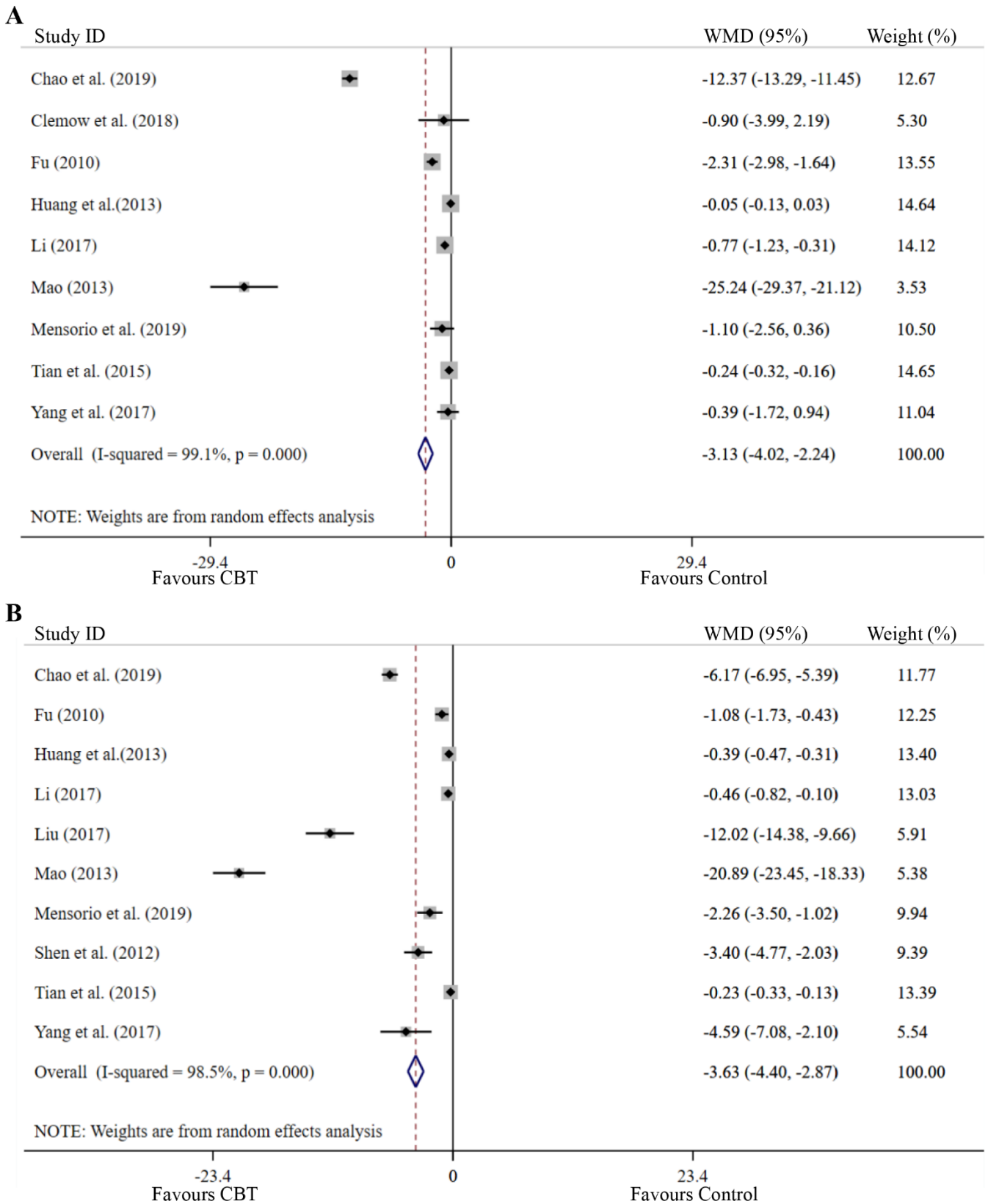


FIGURE 4 | Forest plots of the effects of CBT - based interventions on: A: Depression symptom; B: Anxiety symptom.

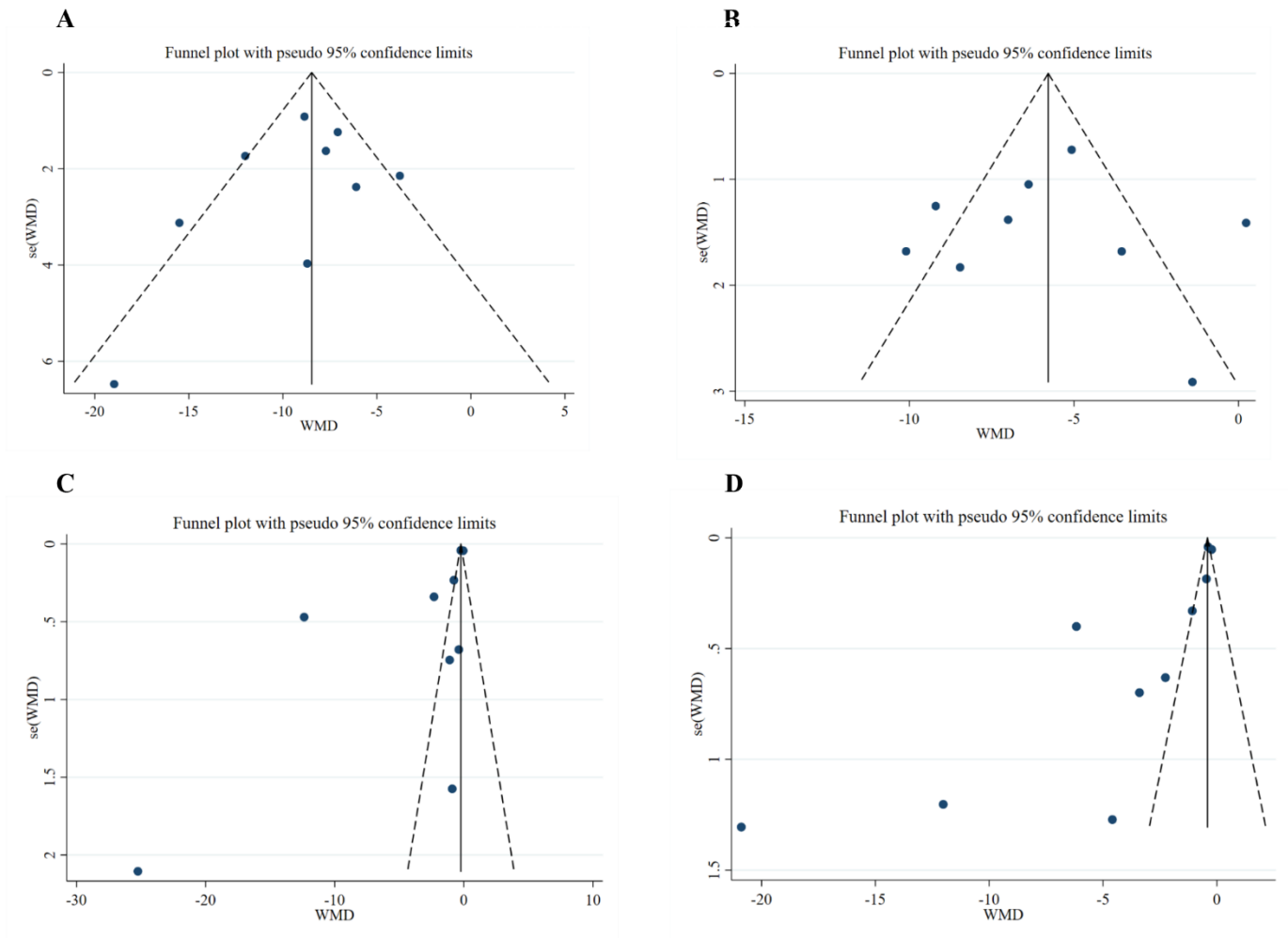


FIGURE 5 | Funnel plots for: A: Systolic blood pressure; B: Diastolic blood pressure; C: Depression symptom; D: Anxiety symptom.

Highlights

1. CBT-based intervention has a positive effect on health outcomes in patients with hypertension.
2. CBT-based intervention might be more effective for blood pressure management in hypertension patients when it is group-based, long term, and cognitive therapy based.
3. CBT-based intervention might be used as an adjunctive treatment for hypertension patients to reduce drug requirements.