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REVIEW

Investigating the effect of transcendental meditation on blood pressure: a systematic review and meta-analysis

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Some evidence from previous randomized controlled trials and systematic reviews has demonstrated a positive association between hypertension and transcendental meditation (TM). However, other trials and reviews showed the effect of TM on blood pressure (BP) was unclear but did not use subgroup analysis to rigorously investigate this relationship. The American Heart Association has stated that TM is potentially beneficial but did not give a standard indication. The present study explored several subgroup analyses in systematic reviews to investigate the effect of TM on BP. Medline, Embase, Cochrane Library, Web of Science and Chinese BioMedical Literature Database were searched through August 2014. Randomized controlled trials of TM as a primary intervention for BP were included. Two reviewers independently used the Cochrane Collaboration's quality assessment tool to assess each study's quality. Twelve studies with 996 participants indicated an approximate reduction of systolic and diastolic BP of − 4.26 mm Hg (95% CI = − 6.06, − 2.23) and − 2.33 mm Hg (95% CI = − 3.70, − 0.97), respectively, in TM groups compared with control groups. Results from subgroup analysis suggested that TM had a greater effect on systolic BP among older participants, those with higher initial BP levels, and women, respectively. In terms of diastolic BP, it appears that TM might be more efficient in a short-term intervention and with individuals experiencing higher BP levels. However, some biases may have influenced the results, primarily a lack of information about study design and methods of BP measurement in primary studies.

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INTRODUCTION

Blood pressure (BP) is categorized as normal (systolic BP < 120 mm Hg and diastolic BP < 80 mm Hg), prehypertension (systolic BP = 120–139 mm Hg and diastolic BP = 80–89 mm Hg, or both), and hypertension (systolic BP > 140 mm Hg and diastolic BP > 90 mm Hg, or both).[1] Hypertension is associated with gender,[2] body weight, health behavior,[3] ethnicity[4] and job strain;[5] it is estimated to account for 12.8% of deaths worldwide[6] and is the most common treatable risk factor for cardiovascular disease, myocardial infarction, stroke, heart failure and renal failure.[7] Recent research found 30.5% of adult Americans had hypertension and 74.7% received treatment, but the controlled BP rate was 51.2%.[8] To improve the proportion of treated adults with controlled BP and avoid the side effects of antihypertensive drugs (for example, some diuretics could increase the risk of diabetes and chronic hyperkalemia[9]), nonpharmacological intervention (for example, lifestyle changes) has been proven to reduce BP.[10] Beyond diet, the American Heart Association recently stated that alternative approaches, including meditation, may lower BP.[10] Common meditation practices include transcendental meditation (TM), Sahaja Yoga meditation,[11] breathing awareness[12] and mindfulness-based stress reduction.[13] TM, a popular form of meditation, is a simple, effortless technique practiced for 15–20 min twice daily and taught by qualified individuals who have completed an extensive training program.[14]

Some evidence from previous randomized controlled trials (RCTs)[15–21] and systematic reviews[22,23] has demonstrated a positive association between hypertension and TM. However, other RCTs[24–28] and systematic reviews[29] showed that the effect of TM on BP was unclear but did not use subgroup analysis to rigorously investigate this relationship. In the American Heart Association statement,[10] the effect of TM was also regarded as a possible benefit. To confirm the quality of meditation trials, the present study used Cochrane Collaboration's RCT quality assessment tool to perform subgroup analyses to investigate the effect of TM on BP among different patient groups by decreasing the heterogeneity and potential biases of primary studies. Several new RCTs[20,21,28] were published after the most recent meta-analysis on this topic appeared in 2008,[23] which may affect results regarding the effect of meditation on BP. In addition, the number of included trials made it possible to explore TM and BP more extensively by subgroup analysis, including the effect of intervention duration, BP level, gender and age. Subgroup analysis enabled us to garner more specific information regarding in which condition TM is most useful.

MATERIALS AND METHODS

Search strategy

We performed a systematic literature search of Medline, Embase, Cochrane Library, Web of Science and Chinese BioMedical Literature Database for eligible studies in August 2014. To achieve maximum sensitivity and identify all trials exploring the effect of TM on BP, we used free text search and subject retrieval using

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these terms: 'TM', 'hypertension' and 'BP.' No restrictions were placed on year or language.

Selection of articles
Criteria for inclusion in this systematic review were: (1) the study was a RCT or quasi-randomized trial with human participants, regardless of treatment allocation and blinding; (2) TM was the primary intervention with no other types of meditation (for example, Zen meditation or mindfulness training) as a cointervention; (3) subjects practiced TM for at least 2 weeks; (4) control groups included health education, no treatment and waiting list; and (5) the baseline and endpoint values for systolic, diastolic and mean BP or MDs with either 95% confidence intervals (CI), standard error or s.d. values were shown in the studies.

Data extraction
Data extraction from eligible trials was performed by two investigators independently (JB Chang and CS Chen) using a predetermined data extraction form that included information about participants (for example, age, ethnicity, gender), information related to the intervention (duration) and control groups, and outcome measures. Any discrepancies were resolved by discussion with a third reviewer (ZG Bai). If information on study characteristics was incomplete but important, original study authors were contacted to request additional information.

Assessment of methodological quality
The quality of the included studies was independently assessed by two authors (JB Chang and PL Li) according to 2008 Cochrane Handbook[30] criteria, which were as follows: adequate sequence generation in treatment allocation, adequate concealment of treatment allocation, blinding of treatment allocation, incomplete outcome data, nonselective outcome reporting and other potential threats to study validity. Any discrepancy was resolved by consulting with a third reviewer (ZG Bai). Review Manager 5 was used to display the results.

Statistical analysis
In this review, we pooled the mean difference (MD) between TM and control groups, using random effects models to avoid overstating the effects of an intervention with STATA 12. Cochran's Q-test and I^2 statistic were used to examine overall heterogeneity between studies and within subgroups of studies. Values of 25, 50 and 75% in I^2 statistics reflect low, moderate and high heterogeneity, respectively.

Data for analysis were extracted for participants who completed the entire trial, in addition to the completion rate. If data were unreported directly in the original trials, we converted the required data from the reported information or figures by mathematical methods supplied (fore example, converting standard error to s.d.). In addition, estimated MDs in standard error and 95% CIs are listed per study.

Besides pooling all eligible studies, we stratified for subgroup analysis according to the characteristics of participants, that is, by intervention durations of 2, 3, 4, 6 and 12 months; BP levels of normal, prehypertension and hypertension; gender; and age groups of adolescents (<25), adults (25–65) and older adults (>65).

RESULTS

Search strategy results
Figure 1 shows the literature search process. The initial 160 studies were identified, of which 142 were determined to be irrelevant after review of titles and abstracts by two reviewers (61 duplicate reports, 31 review papers and 51 studies with no TM intervention). Of the remaining 18 trials, four were excluded because they measured acute effects, one was excluded because it did not report BP and another study was excluded because it was not an RCT. Twelve trials[15–21,24–28] met the eligibility criteria and were selected for analysis.

Study characteristics
Table 1 shows the characteristics of the 12 eligible studies. All were randomized, controlled, parallel trials with results published in peer-reviewed journals. All studies compared TM with a health education control except two,[15,28] which used individuals on a waiting list as controls. The data from seven studies[16,18,20,24–27] were extracted for participants who completed the intervention, in addition to completion rates. The mean age of participants was 41.91 years and respondents ranged from adolescents to older adults. Most participants were Black and had hypertension or high normal BP.[31] In the TM groups, 495 participants were enrolled and the completion rate was 62.83%; in control groups, 501 individuals were enrolled and the completion rate was 64.78%. Overall, 574 (57.63%) participants were men. Some studies recruited participants using antihypertension drugs and there were no statistical differences between the TM and control groups. The duration of included studies ranged from 2 months to 60 months with a median duration of 4 months; some articles reported final data and others also reported procedural data. All BP measurements were conducted by medical staff members such as physician assistants.

Quality of study methods
As Figure 2 indicates, the sequence generation methods of five included studies[17,18,20,25,26] were not clearly reported. Most of the studies[15–17,19–21,25,27,28] were blinded to outcome assessors but not to the participants. The risk of attrition was unclear in half of the trials because the loss ratio at follow-up was $>25\%$, or information regarding attrition rates was unavailable. All 12 studies reported the planned outcomes in the research protocol or methods section. We suspect that sources of funding support represented the other most important bias; 75% of studies were rated at low risk of bias owing to grants from the National Institutes of Health. The risk of this bias among remaining studies was unclear owing to funding from other institutions.

Effect of TM on systolic and diastolic BP
Figure 3 and Figure 4 present the meta-analysis results of the effect of TM versus control on systolic and diastolic BP. Those data were retrieved either from statistical imputation or directly from the original authors. Two studies[16,17] were excluded because the data that were used to conduct gender subgroup analysis and another study[15] were excluded because data on diastolic BP were unavailable.

The pooled MD was -4.26 (95% CI $=-6.09$, -2.42; $P<0.01$; $I^2=36\%$) in Figure 3, indicating a significant difference between TM and control in terms of systolic BP. Ten of 12 studies reporting diastolic BP also showed a significant reduction in the TM group, with an MD of -2.33 (95% CI $=-3.70$, -0.97; $P<0.01$; $I^2=38\%$).

Subgroup analysis
Age. Eleven studies[15,16,18–21,24–28] were used to explore the effect of TM by age. As Figure 5 shows, the effect of TM on systolic BP was greater among individuals older than 65 (MD $=-8.57$) than those 25–65 years old (MD $=-3.26$) and the subgroup differences were significant ($P<0.05$). The same trend was not found for diastolic BP. Results regarding diastolic BP indicated that individuals younger than 25 experienced the strongest effect

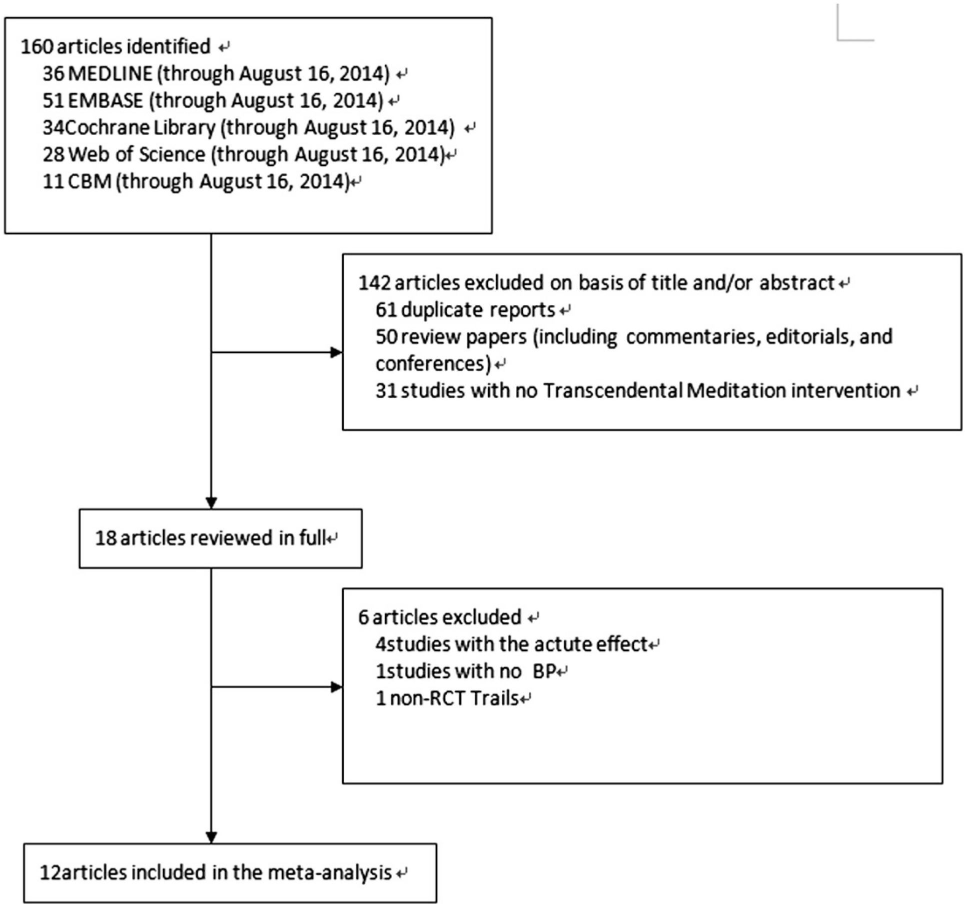

Figure 1. Literature flow diagram.

Table 1. Participant characteristics

Reference	*TM/control (n)*	*Age (M)*	*Ethnicity*	*Hypertension*	*Intervention duration*	*Anti-hypertension medicine*	*Completion rate*	*Male (n)*
Alexander CN[15]	20/11	80.7	—	Yes	3 months	—	100	5.5
Schneider RH[16]	36/38	67.0	Black	Yes	1,2,3 months	Yes	87	31.8
Wenneberg SR[24]	14/12	24.6	White	No	4 months	No	60.94	26
Castillo-Richmond[25]	31/29	53.5	Black	Prehypertension	6 months	Yes	35.29	19
Barnes VA[26]	15/18	16.6	Black	No	2 months	No	94.29	19
Barnes VA[18]	50/50	16.0	Black	Prehypertension	2,4,8 months	No	64.10	63
Schneider RH[27]	54/44	49.3	Black	Yes	3,6,9,12 months	Yes	75.97	48
Paul-Labrador[19]	52/51	67.5	—	Prehypertension	4 months	Yes	81.56	84
Nidich SI[28]	Trial 94/114	25.5	Mostly White	No	3 months	No	69.46	85
	Subgroup 48/64	28.5	Mostly White	Prehypertension	3 months	No	70.44	44
Schneider RH[21]	99/102	59.0	Black	Prehypertension	12 months, 5.4 years average	Yes	62.69	115.5
Barnes VA[20]	30/32	16.2	Black	Prehypertension	4 months	No	39.74	45

Abbreviation: TM, transcendental meditation. Prehypertension = 120–139 mm Hg systolic blood pressure and 80–89 mm Hg diastolic blood pressure, or both.

(MD = −3.68; $P < 0.01$) and there were no statistically significant differences among other subjects, as Figure 6 shows.

BP level

Eleven trials[15,16,18–21,24–28] compared TM and control groups by individuals with normal BP, prehypertension or hypertension. There were no subgroup differences in systolic BP. However, results indicated that the effect was increased by initial systolic BP among normal (MD = −2.40), prehypertension (MD = −4.09) and hypertension groups (MD = −7.20; 95% CI = −14.17, −0.22; $P = 0.04$; $I^2 = 60\%$), as Figure 7 shows. The difference between subgroups in diastolic BP was significant ($P < 0.05$), especially between normal (MD = −1.99) and high (MD = −5.55) BP groups.

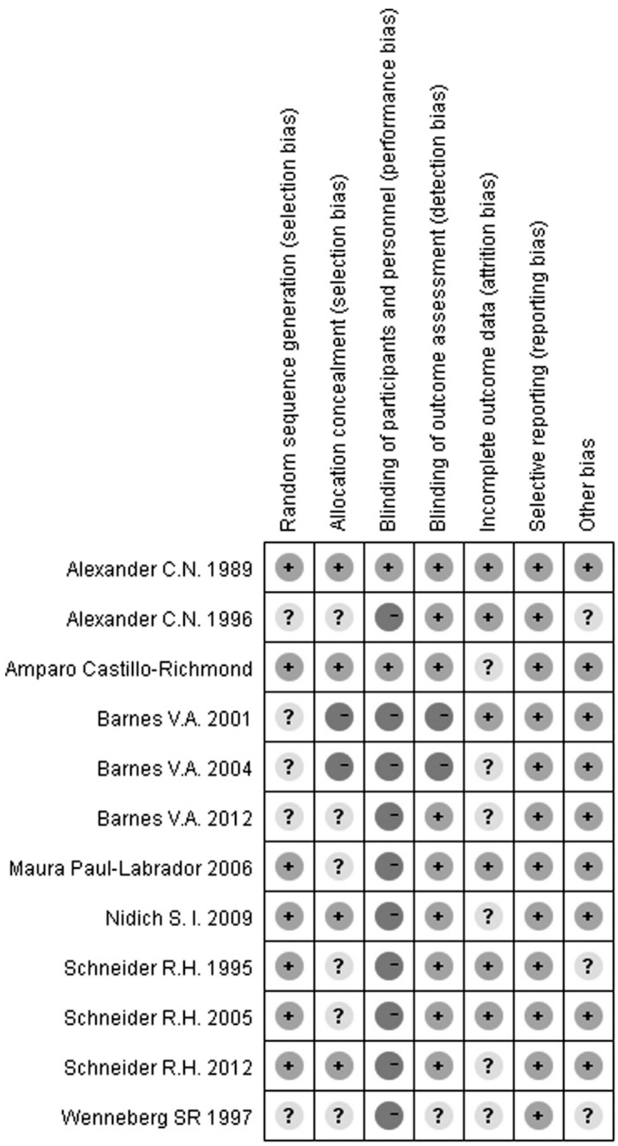

Figure 2. Summary of risk of bias assessment in included studies.

Results suggested that the reduction in BP was greater among individuals with higher BP, as Figure 8 shows.

Intervention duration

Eleven of 12 studies[15,16,18–21,24–28] were included in an analysis of the effect of intervention duration on BP. Some data were also extracted from trials that reported procedural data. The results showed a difference between TM and control groups in systolic BP at 2 months (MD = −4.57), 3 months (MD = −5.87), 4 months (MD = −3.32) and 12 months (MD = −3.61), excluding 6 months (MD = −2.29, $P > 0.05$), as Figure 9 shows. Figure 10 showed that the effect on diastolic BP was weakened by intervention duration at 2 months (MD = −4.44), 3 months (MD = −3.86), 4 months (MD = −2.30; $P < 0.05$), 6 months (MD = −1.13; $P > 0.05$) and 12 months (MD = −1.56). In addition, there were subgroup differences between 2 months and 12 months ($P < 0.05$).

Gender

Two studies with women[17,27] and three studies with men[17,24,27] allowed gender analysis of the difference between TM and control groups regarding BP. Results for systolic BP indicated differences by female (MD = −8.18) and male (MD = −2.37) gender, as Figure 11 shows. Results for diastolic BP also indicated differences by female (MD = −4.68) and male (MD = −4.72) gender, as shown in Figure 12. The systolic BP of men decreased less than women and there was no statistically significant difference between TM and control groups. However, TM had the same effect on diastolic BP among men and women.

DISCUSSION

Twelve studies with 996 participants were assessed to examine the effect of TM on BP outcomes. The studies suggested that the reduction of systolic BP and diastolic BP was significantly different between TM groups and control groups, with approximate reductions of 4.26 mm Hg and 2.33 mm Hg, respectively, among participants in TM groups. This indicates that TM may reduce the risk of cardiovascular disease by significantly reducing BP.[32] The heterogeneity across the included studies was low and was resolved through subgroup analyses because of the wide variation in intervention duration and participant demographics (BP level, gender and age). On the basis of the results of subgroup analyses, we observed two interesting phenomena. TM had a greater effect on individuals older than 65, those with initial systolic BP > 140 mm Hg, and women relative to younger participants (< 65 years old), those with initial systolic BP 120–139 mm Hg and men, respectively. In addition, diastolic BP reduction did not appear to be related to age or gender, but rather intervention duration and initial diastolic BP level. This suggests that TM might be more efficient in reducing diastolic BP in a short-term intervention (2 months) and for individuals with initial diastolic BP > 90 mm Hg than other subjects.

The quality of two included trials[29,33] related to TM has been criticized and a previous report found the methodological quality of 286 RCTs using meditation practices to be generally poor, with only 14% being rated high-quality (that is, Jadad scores ⩾3 points).[34] However, using traditional tools to assess the quality of trials involving meditation is difficult because double blinding is not possible and using experienced experts as investigators generates bias during the implementation of clinical trials in terms of either enthusiasm or skepticism.[35] We tried to objectively judge the quality of included studies by using the Cochrane Collaboration's tool for assessing risk of bias, which has been regarded as making the process clearer and more accurate, especially with open RCTs.[30] The quality of studies meeting inclusion criteria was acceptable overall, with all 12 studies indicating a low risk of reporting bias and most trials having a low risk of detection and other biases.

The pooled effects of TM on systolic and diastolic BP were significantly different (−4.26 and −2.33, respectively), and this meta-analysis found slightly lower effects than research[23] (−4.7 and −3.2, respectively) published in 2008. This difference could be explained by two reasons. One is that three new studies[20,21,28] published after 2008 were included. Another is that the prior study pooled the different intervention duration effects and this study pooled data from 3 months or 4 months (if possible) rather the final result.[18,27] Finally the number of participants was extracted differently in the prior study; the present study used the number of participants who completed the trial because of the low completion rate in some studies.

On the basis of the results of subgroup analysis, we found the effect of TM on systolic BP might be related to age, BP level and gender and its effect on diastolic BP might be related to initial BP level and intervention duration. Although the mechanism by which TM reduces BP is unclear, we considered these conclusions to be reasonable. First, the effect of TM on systolic BP increased with age, from adolescents to older adults (subgroup difference: $P < 0.05$). In terms of diastolic BP, the phenomenon was opposite,

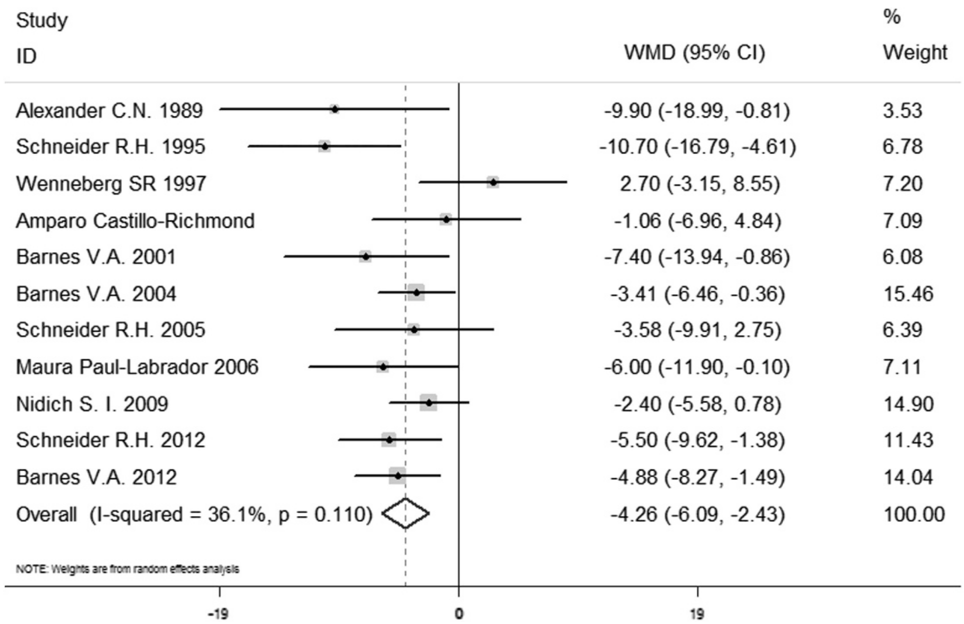

Figure 3. Effect size of transcendental meditation versus control group for systolic blood pressure. CI, confidence interval; TM, transcendental meditation.

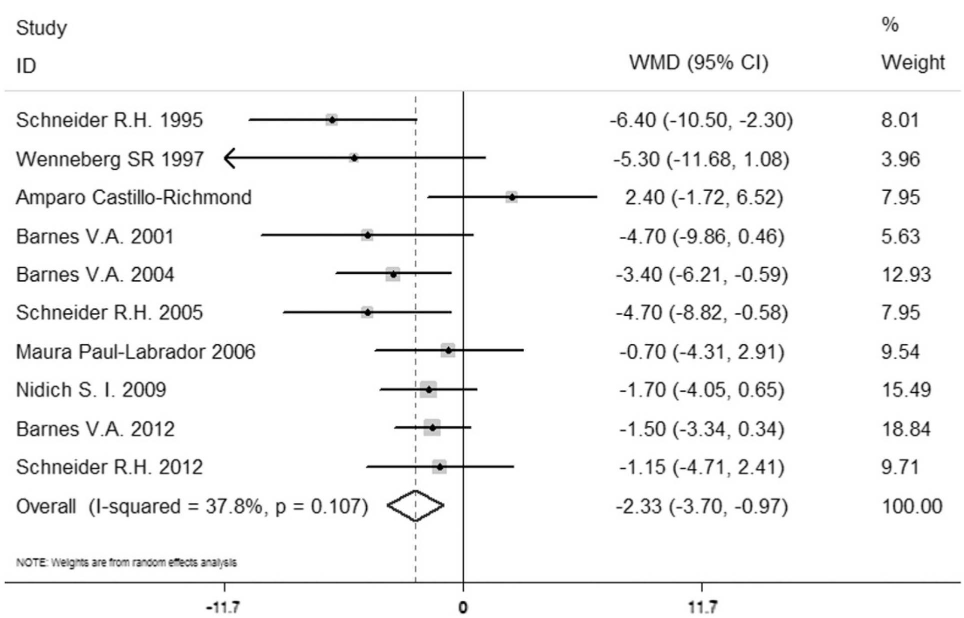

Figure 4. Effect size of transcendental meditation versus control group for diastolic blood pressure. CI, confidence interval; TM, transcendental meditation.

with statistically significant differences among adolescents but no significant differences among adults and older adults. Second, the difference between subgroups in diastolic BP was significant ($P < 0.05$) and represented an obvious trend in systolic BP. This implies that TM had greater effects among individuals with higher BP. Third, a previous study[21] that showed the long-term effect of TM decreased BP warrants scrutiny. The pooled data showed the reduction of systolic BP was statistically different between TM and control groups from 2 months to 12 months, except at 6 months. However, regarding diastolic BP, intervention duration weakened the effect of TM, at 2 months (MD = −4.44), 3 months (MD = −3.86), 4 months (MD = −2.30; $P < 0.05$), 6 months (MD = −1.13; $P > 0.05$) and 12 months (MD = −1.56). Although there was no statistical difference between subgroups overall, but the effect between 2 months and 12 months was significantly different ($P < 0.05$). Finally, the results showed that the effect of TM on average systolic BP is stronger among women than men. However, in terms of diastolic BP, the effect was only significant among women.

Some biases may have influenced the results of this study. Regarding the quality of primary studies, only four of 12 studies clearly reported allocation concealment, and the loss ratio at follow-up in six studies was >25%, as shown in Table 1. Most studies reported data for participants who completed the intervention, although the reasons for dropout were clearly reported. Both selection bias and attrition bias represent the

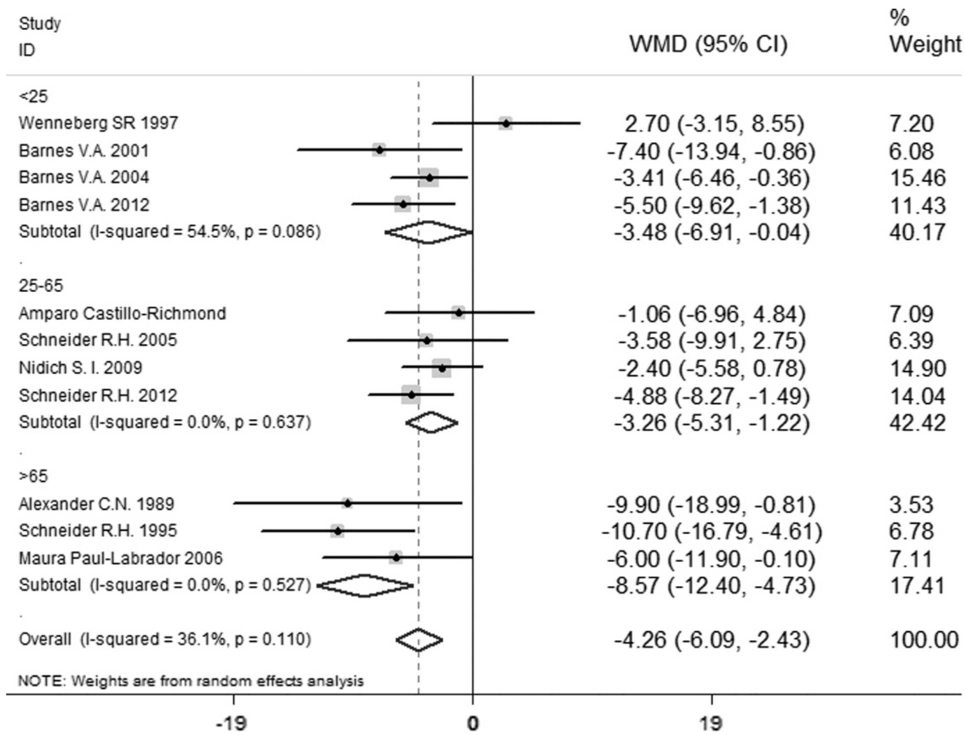

Figure 5. Effect size of transcendental meditation versus control group for systolic blood pressure by age. CI, confidence interval; TM, transcendental meditation.

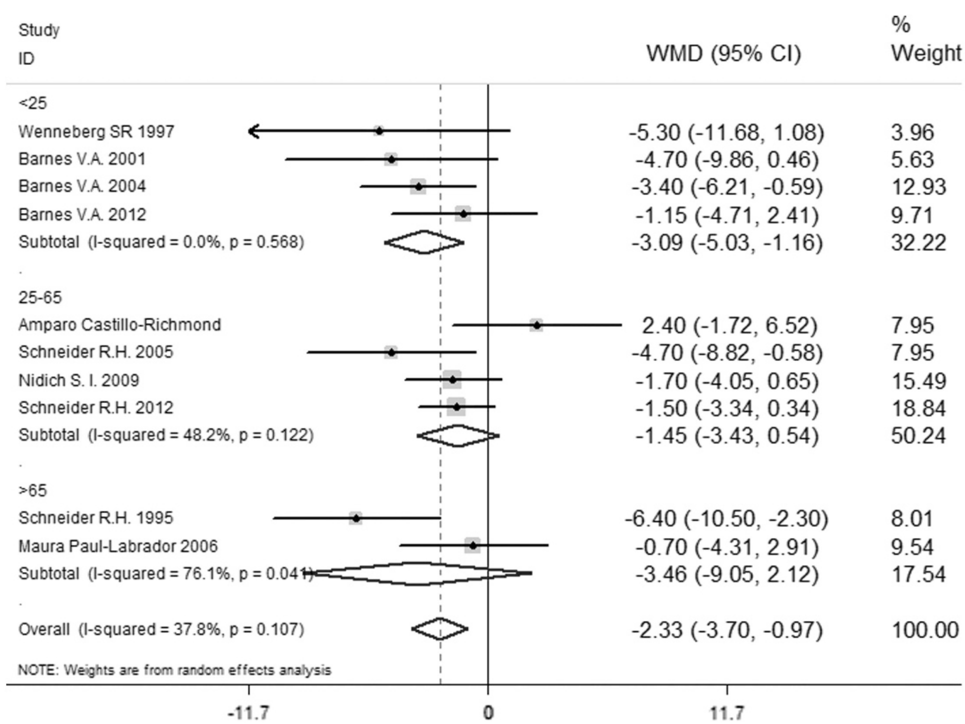

Figure 6. Effect size of transcendental meditation versus control group for diastolic blood pressure by age. CI, confidence interval; TM, transcendental meditation.

main biases in our study. In terms of data extraction, some studies extracted more than once used in different subgroup, which was relevant to these studies provided more information fit to the subgroup. This meant that each trial had a different effect on the results of subgroup analysis. For example, the BP level subgroup only included data from one trial. Another important bias in present study was our inability to analyze the effect of antihypertension medicine because of the lack of relevant data in the original studies. Regarding outcome measures, one study[36] indicated that BP is variable. Although all BP measurements were

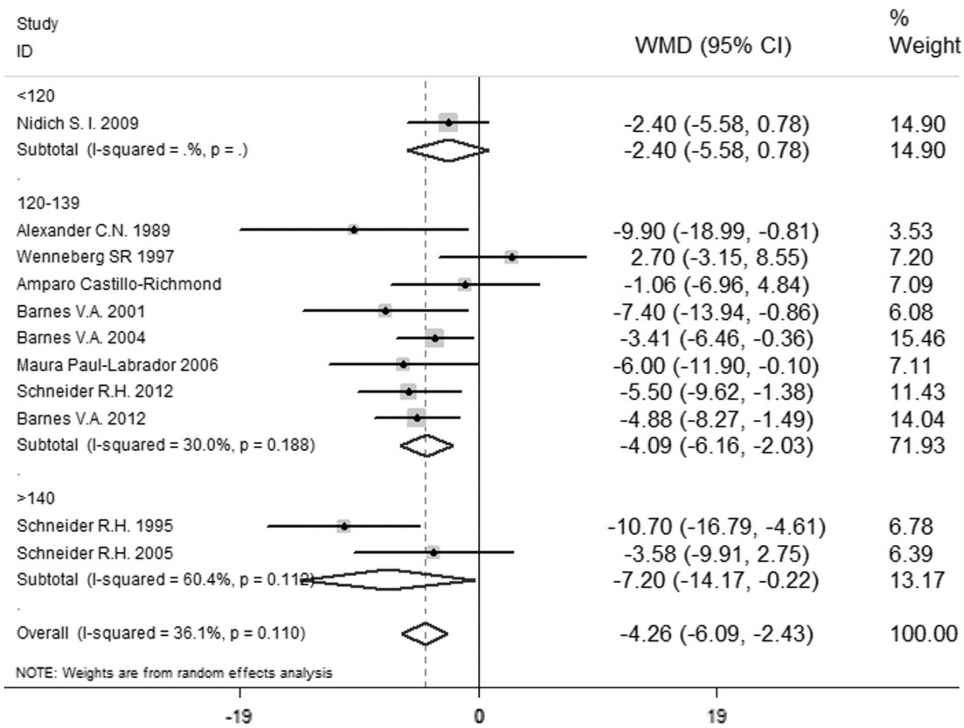

Figure 7. Effect size of transcendental meditation versus control group for systolic blood pressure by blood pressure level. CI, confidence interval; TM, transcendental meditation.

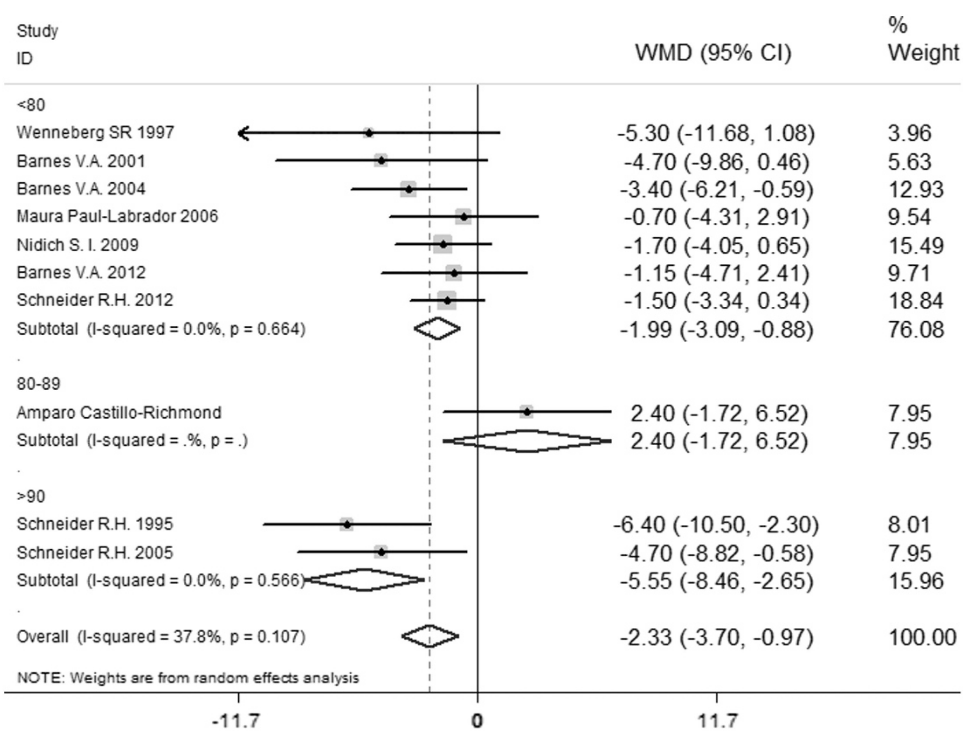

Figure 8. Effect size of transcendental meditation versus control group for diastolic blood pressure by blood pressure level. CI, confidence interval; TM, transcendental meditation.

conducted by medical staff members, this is a novel and important risk factor in our study because we ignored the type of BP monitoring and measurement time. For instance, BP is naturally lower in winter compared with summer and some studies occurred during >6 months, which means reductions in BP may have been caused by seasonal changes.

Owing to these limitations, the results of this meta-analysis should be confirmed by more high-quality RCTs. It is important to

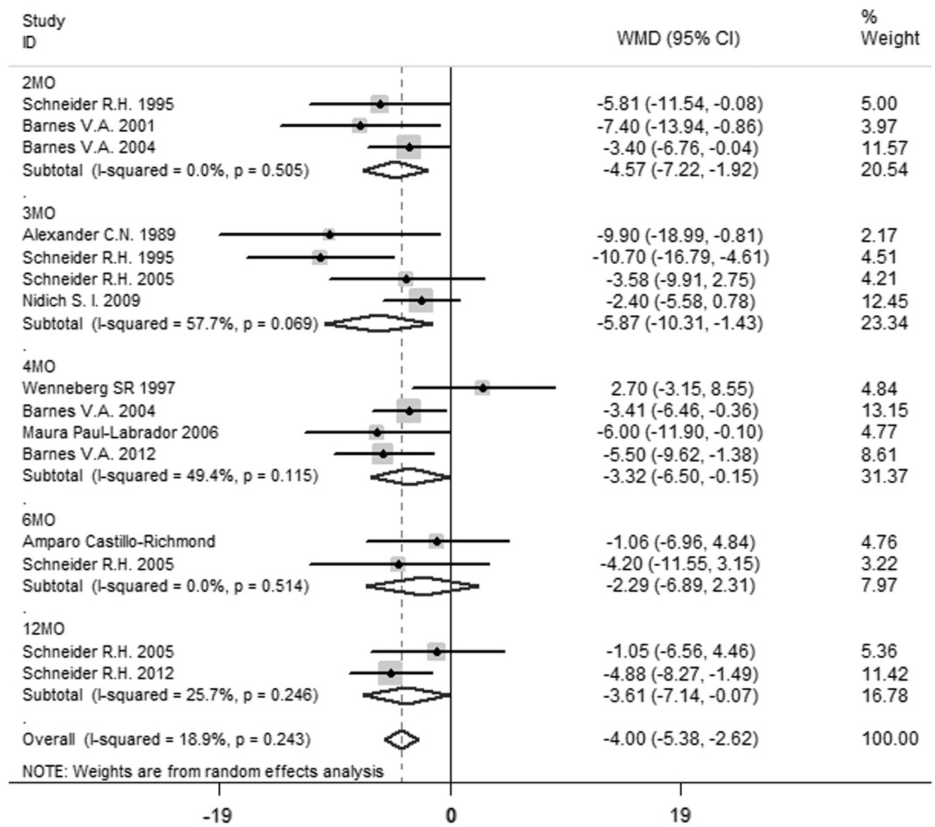

Figure 9. Effect size of transcendental meditation versus control group for systolic blood pressure by intervention duration. CI, confidence interval; TM, transcendental meditation.

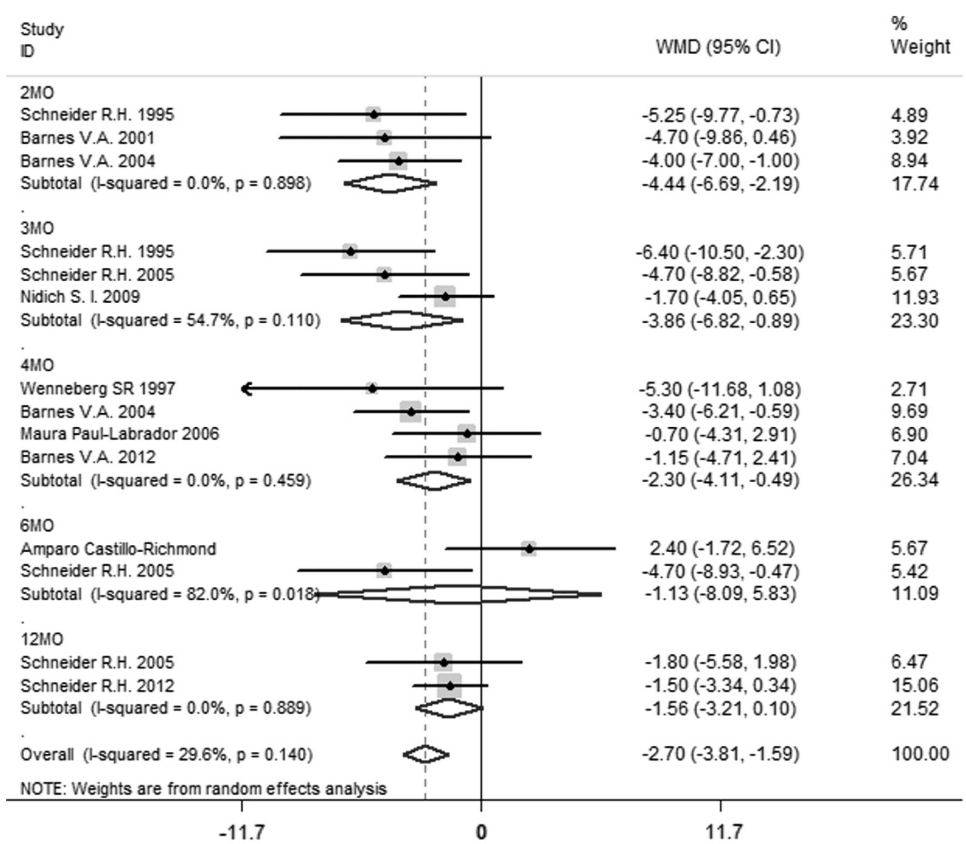

Figure 10. Effect size of transcendental meditation versus control group for diastolic blood pressure by intervention duration. CI, confidence interval; TM, transcendental meditation.

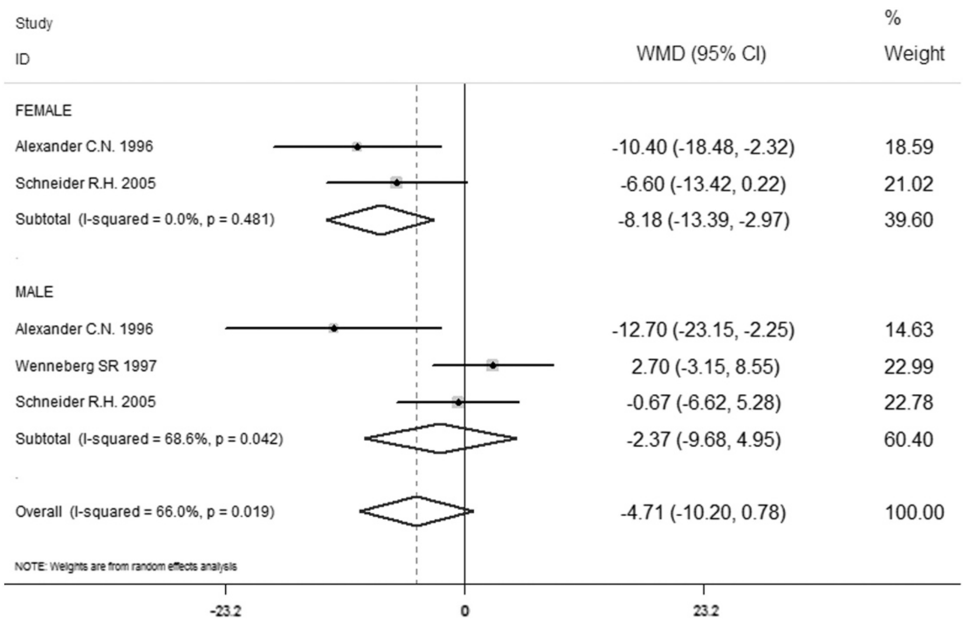

Figure 11. Effect size of transcendental meditation versus control group for systolic blood pressure by gender. CI, confidence interval; TM, transcendental meditation.

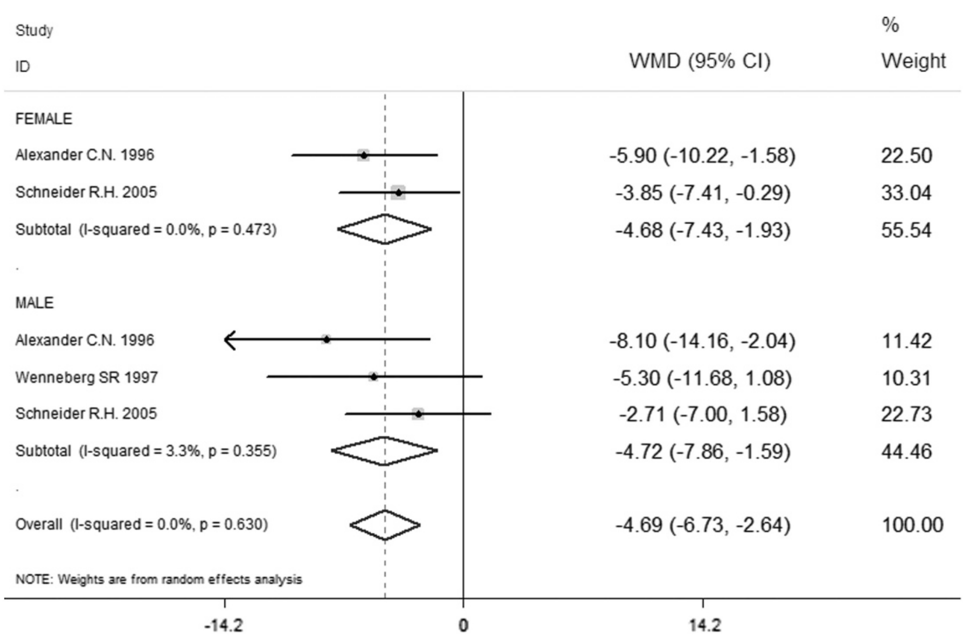

Figure 12. Effect size of transcendental meditation versus control group for diastolic blood pressure by gender. CI, confidence interval; TM, transcendental meditation.

accurately report the items listed in the Consolidated Standards of Reporting Trials recommendations[36] to help investigators develop more comprehensive reports, especially in terms of random methods and follow-up. By doing so, scholars can assess the quality of primary studies more accurately and efficiently. Future investigators should also focus on the variation of BP at different times of day, seasons, clinical perspectives[37] and use ambulatory BP monitoring.[38] In addition, hypertension medication influence in TM should also be considered.

Although previous systematic reviews have examined the long-term effects[27] and overall effects[23,29] of TM on BP, we made additional contributions to the existing knowledge. First, we used Cochrane Collaboration's tool for assessing risk of bias to assess the quality of trials. In addition, we used subgroup analyses to decrease heterogeneity and assess the probable effect of TM on BP in four areas (intervention duration, BP level, gender and age). Finally, we included several studies[20,21,28] published after 2008.

CONCLUSIONS

In conclusion, TM may effectively decrease BP compared with a control group. The pooled meta-analysis showed TM is associated with a significant reduction in systolic and diastolic BP. Results from subgroup analysis suggested that TM had a greater effect on systolic BP among older participants, those with higher initial BP levels, and women. In terms of diastolic BP, it appears that TM might be more efficient in a short-term intervention and with individuals experiencing higher BP levels. However, these results need to be confirmed by more trials with improved study designs, including a focus on BP variability and ambulatory BP in the future.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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AUTHOR CONTRIBUTIONS

Zhenggang Bai and Jianbo Chang contributed equally.

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