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Physical exercise on cortical brain activity in patients with mild cognitive impairment
A meta-analysis

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Abstract

Background: Physical exercise is recognized as a potential strategy to mitigate the cognitive decline associated with mild cognitive impairment (MCI). This systematic review aims to examine the specific effects of physical exercise on cortical brain activity in patients with MCI, an area that has not been thoroughly explored.

Methods: We conducted a search across 9 electronic databases for randomized controlled trials assessing the impact of physical exercise on the cortical activity of patients with MCI. The search covered the period from database inception to September 2023. Literature screening, data extraction, and quality assessments were carried out by 2 independent researchers. Meta-analyses were conducted using RevMan 5.3, and publication bias was evaluated using STATA 17.0. This study primarily assessed P300 latency and amplitude, alongside cognitive evaluations using the mini-mental state examination and Montreal Cognitive Assessment.

Results: Six high-quality randomized controlled trials, involving a total of 360 participants, were included. Compared to the control group, significant enhancements were observed in the amplitude of central midline electrode (mean difference [MD] = 1.64 [95% confidence interval [CI], 0.92–2.36]; $P < .00001$), frontal midline electrode (MD = 2.70 [95% CI, 2.02–3.38]; $P < .00001$), and parietal midline electrode (MD = 2.42 [95% CI, 0.44–4.41]; $P = .02$). Latency periods of the central midline electrode (MD = −32.40 [95% CI, −40.27 to −24.54]; $P < .00001$), frontal midline electrode (MD = −12.57 [95% CI, −30.83 to 5.69]; $P = .18$), and parietal midline electrode (MD = −12.57 [95% CI, −30.83 to 5.69]; $P = .81$) were also notably influenced. Moreover, overarching cognitive functions as measured by mini-mental state examination (MD = 1.02 [95% CI, 0.61–1.43]; $P < .00001$) and Montreal Cognitive Assessment (MD = 1.39 [95% CI, 0.67–2.12]; $P = .0002$) exhibited marked improvement.

Conclusion: This meta-analysis suggests that physical exercise can augment the P300 amplitude, reduce the P300 latency period, and, overall, enhance cognitive functionality in individuals with MCI.

Abbreviations: CI = confidence interval, CZ = central midline, EEG = electroencephalogram, FZ = frontal midline, MCI = mild cognitive impairment, MD = mean difference, MeSH = Medical Subject Headings, MMSE = mini-mental state examination, MoCA = Montreal Cognitive Assessment, PEDro = Physiotherapy Evidence Database, PZ = parietal midline, RCT = randomized controlled trial.

Keywords: cognitive dysfunction, EEG, electroencephalography, physical exercise, rehabilitation.

1. Introduction

Mild cognitive impairment (MCI) represents a prevalent clinical syndrome, often described as an intermediary stage nestled between the realms of normal aging and dementia. Clinically, MCI may manifest as impairments in linguistic comprehension, computational skills, and memory retention. Its trajectory is unpredictable—it may either stabilize, show improvements, or progress into full-blown dementia. Despite the ubiquity of dementia and MCI, there exists a conspicuous absence of effective pharmacological interventions. Under the overarching theme of healthy aging, the emphasis has been notably shifted towards exploring nonpharmacological treatments for MCI. Systematic reviews have demonstrated that nonpharmacological

XL and HC contributed to this article equally.

The authors have no conflicts of interest to disclose.

The data that support the findings of this study are available from a third party, but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are available from the authors upon reasonable request and with permission of the third party.

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interventions can indeed ameliorate cognitive deficits associated with MCI.[1,2] The World Health Organization posits that ≈50 million individuals globally are afflicted with dementia, with a new case emerging every 3 seconds. By 2050, this number is projected to triple.[3] The profound impact of severe dementia, both emotionally and economically, on families and societies cannot be understated. With the accelerating trend of global aging and increasing life expectancies, cognitive impairments are rapidly ascending to the forefront of global public health challenges.

Physical exercise is widely recognized as a modality that can enhance cerebral cognitive functions. An array of systematic reviews and meta-analyses has corroborated the notion that various forms of physical activity can augment cognitive capacities in individuals with MCI.[4–8] Physical engagement stands as a salient lifestyle determinant. Regular participation in such activities can attenuate risks associated with cognitive decline and dementia by 38% and 28%, respectively.[9] Natural aging invariably precipitates a decrement in cognitive prowess, hastening alterations in cerebral structures. For instance, white matter degeneration accompanies aging, subsequently impairing processing speeds, working memory, and executive functions.[10] Such cognitive detriments might also stem from anomalous alterations in cerebral structures, such as hippocampal atrophy and medial temporal gyrus changes, which are direct consequences of synaptic loss and neuronal attrition induced by neurofibrillary tangles and β-amyloid plaque accumulations. Moreover, reduced cerebral blood flow, compromised functional connectivity, and aberrant neural activations in specific brain regions have been associated with cognitive deficits.[11]

The cerebral cortex's activity can be assayed using an array of instruments, including near-infrared spectroscopy, electroencephalogram (EEG), and magnetic resonance imaging.[12,13] Among these, the EEG, due to its noninvasive, cost-effective nature, and the ease with which it captures brain dynamics, is particularly favored by researchers and clinicians. As neurons engage in synaptic activities, electrical oscillations within the brain alter, which the EEG measures by amplifying these changes.[14] Studies have elucidated that an increase in low-frequency power bands and a decrease in high-frequency bands of resting-state EEGs can mirror cognitive degeneration.[15] The event-related potential P300 emerges as a sensitive marker for diagnosing and prognosticating the progression of MCI.[16] As cognitive capacities wane, there are discernible shifts in the EEG dynamics of individuals with MCI. Given that physical exercise is germane to cognitive enhancement, establishing the scientific evidence supporting the potential impact of exercise on the EEG activity of those with MCI is of paramount significance.

Currently, a paucity of systematic reviews encapsulates the effects of physical exercise on cortical activity in patients with MCI. Yet, due to various constraints, no meta-analyses exist. This review aggregates all extant literature concerning the influence of physical exercise on cortical activity in patients with MCI, as measured by EEG. The overarching aim of this systematic review is to address the research question: "What is the nature of the impact of physical exercise on cortical activity and cognition in patients with MCI?"

2. Materials and methods

2.1. Protocol and registration

This meta-analysis adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.[17] The methodological design aimed to search and analyze studies assessing the physical effects through EEG on the cortical activity of patients with MCI upon engaging in physical exercise. Ethical approval was not requisite, given that this study constitutes secondary research based on previously published articles. No conflicts of interest were present among the authors. This systematic review has been preregistered with PROSPERO (CRD42023467515).

2.2. Literature search strategy

To assess the impact of physical exercise on cortical activity in patients with MCI, we conducted an extensive search across 9 electronic databases: PubMed, Cochrane Library, Embase, Web of Science, PsycINFO, China National Knowledge Infrastructure, Chinese Biomedical Literature Database, China Science Journal Database, and Wanfang Database. The search encompassed studies published from the inception of these databases until September 25, 2023, exclusively considering randomized controlled trials (RCTs). To expand the search purview, we employed a combination of Medical Subject Headings and free-text terms, merging them using Boolean logic operators. These terms included "cognitive impairment," "mild cognitive impairment," "EEG," "electroencephalogram," "ERP," and "randomized controlled trial." Post search, articles were screened based on titles, abstracts, and full texts and assisted by checking the reference list and unpublished gray data, such as unpublished thesis, conference paper, etc. In addition, reference lists of chosen studies underwent manual screening to identify any other pertinent investigations that met inclusion criteria. Abstracts and full texts were assessed if titles pertained to MCI and physical exercise.

2.3. Literature inclusion and exclusion criteria

Inclusion criteria are given as follows.

1. Chinese or English literature.
2. The study population is patients with MCI.
3. Intervention methods include any form of physical exercise or physical activity.
4. EEG was employed to measure cortical activity.
5. Articles containing extractable primary outcome indicators.
6. The control group is a simple control group or a health education group without any intervention.

Exclusion criteria are given as follows.

1. Non-Chinese/English literature.
2. Duplicated studies.
3. Inaccessibility to full texts or required data.
4. Interventions not involving a control group for comparison.
5. Systematic reviews, meta-analyses, case reports, and abstracts were excluded.

2.4. Literature screening and data extraction

The article selection process was independently conducted by 2 researchers (HC and XL). Initially, the researchers scrutinized the titles and abstracts of all records. Full texts were analyzed if studies aligned with the selection criteria. In the event of disparities in opinions between the 2 researchers, face-to-face discussions were held to decide on the inclusion or exclusion of the study. If the 2 investigators held discordant views, a third researcher (MW) was solicited to arbitrate. All articles underwent evaluation in September 2023.

2.5. Outcome indicator

Primary outcome measures: P300 amplitude and P300 latency.

Secondary outcome measures: mini-mental state examination (MMSE) and Montreal Cognitive Assessment (MoCA).

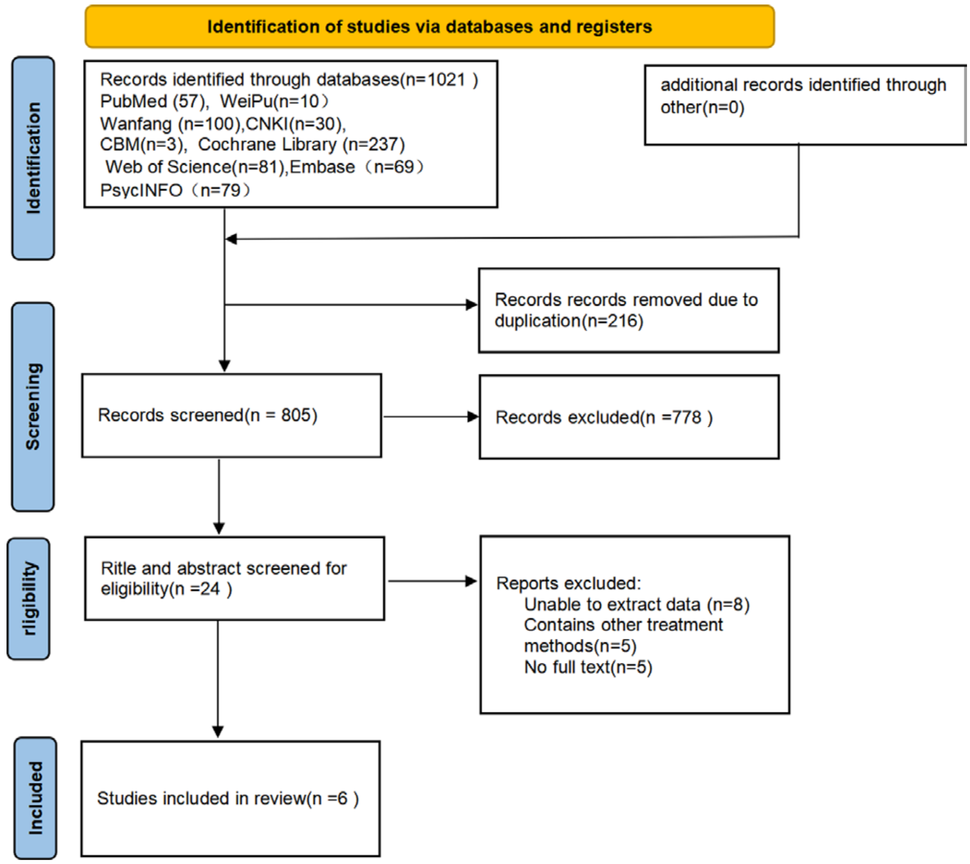

Figure 1. Study selection represented by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses flowchart. CBM = China Biology Medicine disc, CNKI = China National Knowledge Infrastructure.

2.6. Quality and risk assessment for bias

The methodological quality of the included studies was evaluated using the Physiotherapy Evidence Database (PEDro) scale. The PEDro scale comprises 11 questions, corresponding to 11 quality criteria, with a total possible score of 10 (each criterion met earns 1 point, unmet criteria earn 0 points, and the first question is not included in the total score). The assessment was conducted by 2 reviewers (HC and XL) in a double-blinded, independent manner over 2 rounds. Scores were categorized as 9 to 10 for high-quality studies, 6 to 8 for moderately high-quality studies, 4 to 5 for average-quality studies, and below 4 for low-quality studies (Maher et al, 2003).[18]

2.7. Statistical analysis

Statistical analyses were performed using RevMan 5.3 software and Stata 17. The data types included in this study were continuous. When the unit of the effect size and measurement method differed, the standardized mean difference was adopted. Standardized mean difference values neutralize the impact of different measurement units and are suitable for pooled analysis with varying units or scales. If the unit of the effect size and the measurement method were the same, the mean difference (MD) was adopted, and the confidence interval (set at a 95% confidence interval [CI]) was calculated. The heterogeneity of the results of the included studies was analyzed with the $\chi 2$ test (test level $\alpha = 0.1$), complemented by the I^2 statistic to quantify the magnitude of heterogeneity. If $P > .1$ and $I^2 < 50\%$, it indicates low heterogeneity, and the fixed-effects model can be used. Otherwise, a high level of heterogeneity is suggested, prompting sensitivity and subgroup analyses to explore the sources of heterogeneity. If the source of heterogeneity is unclear, the random-effects model is employed. Moreover, potential publication bias was evaluated using Egger and Begg tests.

3. Results

3.1. Literature search results

An initial search identified 1021 articles. After importing these into Endnote 9.1 software, 216 duplicates were removed. By reading the titles and abstracts, unrelated articles were excluded. After a full-text reading and screening of 24 articles, 6 were ultimately included. The detailed process of literature selection is shown in Figure 1.

3.2. Clinical characteristics of the included studies

A total of 6 RCTs were ultimately included,[19–24] comprising 360 participants. All studies originated in China. All subjects in the studies were elderly individuals. The intervention in the experimental groups was physical exercise or combined with health education. The control groups generally continued their regular daily routines or received health education. The intervention duration ranged from 6 weeks to 6 months. The outcome measures included the P300 amplitude and latency under the central midline (CZ), parietal midline (PZ), and frontal midline (FZ) leads, MMSE, and MoCA. The basic characteristics of the included studies are presented in Table 1.

3.3. Quality assessment of the included literature

The quality of the included literature was assessed using the PEDro scale. Among the 6 studies included, all were of relatively high quality, with no studies being of the highest quality. This could be due to the minimal use of allocation concealment and blinding in these studies, likely because such experiments find it challenging to maintain strict allocation concealment and blinding. Overall, the methodological quality of the included studies was high. The results can be seen in Table 2.

3.4. P300 amplitude

Included studies reported on the P300 amplitude for the CZ, PZ, and FZ electrode placements.

3.4.1. CZ electrode. A total of 260 participants were included in 5 studies on the CZ electrode.[20–24] Heterogeneity tests revealed low heterogeneity ($I^2 = 45\%$; $P = .12$), so a fixed-effects model was used for meta-analysis. The meta-analysis results showed a statistically significant difference between the 2 groups in terms of P300 amplitude (MD = 1.64 [95% CI, 0.92–2.36]; $P < .00001$), suggesting that exercise can enhance the amplitude of P300. Details can be seen in Figure 2.

3.4.2. FZ electrode. A total of 92 participants were included in 2studies on the FZ electrode.[21,24] Heterogeneity tests showed low heterogeneity ($I^2 = 4\%$; $P = .31$), so a fixed-effects model was used for meta-analysis. The meta-analysis results showed a statistically significant difference between the 2 groups in terms of P300 latency (MD = 2.70 [95% CI, 2.02–3.38]; $P < .00001$), indicating that exercise can reduce the amplitude of P300 at the FZ point. Details can be found in Figure 3.

3.4.3. PZ electrode. A total of 92 participants were included in 5 studies on the PZ electrode.[21,24] Heterogeneity tests indicated higher heterogeneity ($I^2 = 72\%$; $P = .06$), so a random-effects model was used for meta-analysis. The meta-analysis results showed a statistically significant difference between the 2 groups in terms of P300 latency (MD = 2.42 [95% CI, 0.44–4.41]; $P = .02$), suggesting that exercise can reduce the amplitude of P300 at the CZ point. Details can be seen in Figure 4.

3.5. P300 latency

Included studies reported on the P300 latency for the CZ, PZ, and FZ electrode placements.

3.5.1. CZ electrode. A total of 260 participants were included in 5 studies on the CZ electrode.[20–24] Heterogeneity tests revealed high heterogeneity ($I^2 = 71\%$; $P = .007$). A sensitivity analysis, after excluding the study by Wu 2019, showed a decrease in heterogeneity ($I^2 = 38\%$; $P = .19$). A fixed-effects model was used for the meta-analysis. The results showed a statistically significant difference between the 2 groups in terms of P300 latency (MD = −32.40 [95% CI, −40.27 to −24.54]; $P < .00001$), suggesting that exercise can reduce the latency of P300 at the CZ point. Detailed results are available in Figure 5.

3.5.2. FZ electrode. A total of 92 participants were included in 2 studies on the FZ electrode.[21,24] Heterogeneity tests indicated high heterogeneity ($I^2 = 79\%$; $P < .03$). A random-effects model was employed for the meta-analysis. The results showed no statistically significant difference between the 2 groups in terms of P300 latency (MD = −12.57 [95% CI, −30.83 to 5.69]; $P = .18$). Details can be seen in Figure 6.

3.5.3. PZ electrode. A total of 92 participants were included in 2 studies on the PZ electrode.[21,24] Heterogeneity tests revealed low heterogeneity ($I^2 = 36\%$; $P = .21$). A fixed-effects model was used for the meta-analysis. The results showed a statistically

Table 1

The details of research characteristics.

Study	country	Sample size T	Sample size C	Mean age, yr T	Mean age, yr C	Description of intervention T	Description of intervention C	Dosage	Outcome
Bao and Liu[23]	China	31	31	65.62 ± 9.34	68.22 ± 9.84	Health education + taiji	Health education	30 min each time, twice a day, 3× a week, for 6 mo	①, ②, ④, ⑤
Cai and Zhang[22]	China	28	30	67.5 ± 6.33	66.75 ± 5.27	Qigong	No intervention	90 min each time, 5× a week, for 6 mo	①, ②, ④, ⑤
Chen et al[21]	China	32	33	>60	>60	Health education + finger exercise	Finger exercise	Twice a day, for a total of 12 wk.	①, ②, ④
Guo and Li[24]	China	13	14	65.46 ± 2.76	64.86 ± 2.88	Baduanjin	No intervention	Four times a week, for a total of 9 mo	①, ②, ④, ⑤
Wu 2019[20]	China	29	31	70.3 ± 6.7	69.0 ± 7.3	Aerobic dance	health education	35 min per session, 3× a wk, for 3 mo	①, ②, ④, ⑤
Zheng et al[19]	China	45	43	65.31 ± 5.34	64.22 ± 5.41	Six-character formula	No intervention	Twice a day, 30 min each time, practice ≥ 5 days a wk, for 6 mo	③, ④, ⑤

① = P300 amplitude; ② = P300 latency; ③ = EEG; ④ = mini-mental state examination; ⑤ = Montreal Cognitive Assessment.

Table 2

Quality assessment (PEDro scale) of included studies.

PEDro scale questions	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Total score
Bao and Liu[23]	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	7
Cai and Zhang[22]	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	7
Chen et al[21]	Y	Y	N	Y	N	N	N	N	Y	Y	Y	6
Guo and Li[24]	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	7
Wu 2019[20]	Y	Y	N	Y	N	N	Y	Y	Y	Y	Y	8
Zheng et al[19]	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	7

N = no, PEDro = Physiotherapy Evidence Database, Q1 = eligibility criteria and source, Q2 = random allocation, Q3 = concealed allocation, Q4 = baseline comparability, Q5 = participants, Q6 = blinding of therapists, Q7 = blinding of assessors, Q8 = adequate follow-up (85%), Q9 = intention-to-treat analysis, Q10 = intergroup statistical comparisons, and Q 11 = = reporting of point measures and measures of variability, Y = yes.

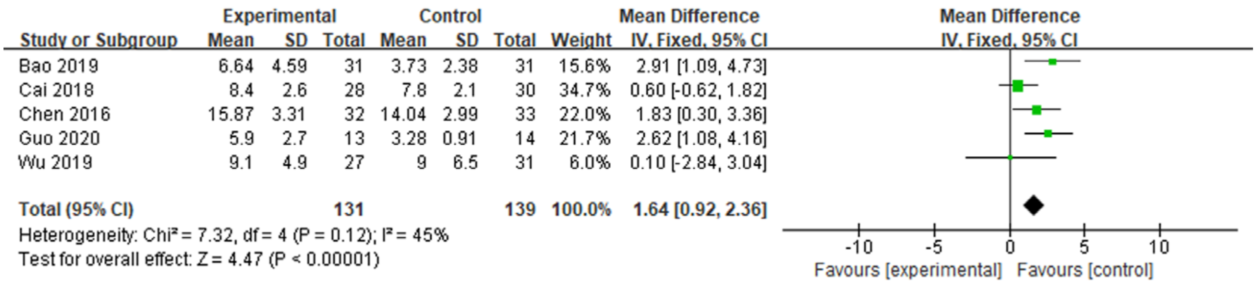

Figure 2. Forest plot of the meta-analysis on P300 amplitude (central midline electrode). CI, confidence interval; SD, standard deviation.

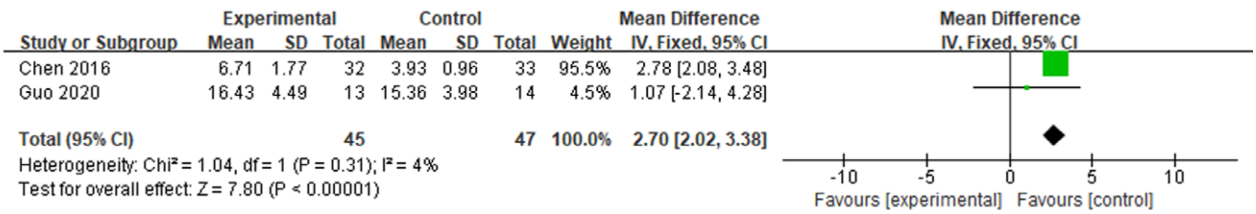

Figure 3. Forest plot of the meta-analysis on P300 amplitude (frontal midline electrode). CI, confidence interval; SD, standard deviation.

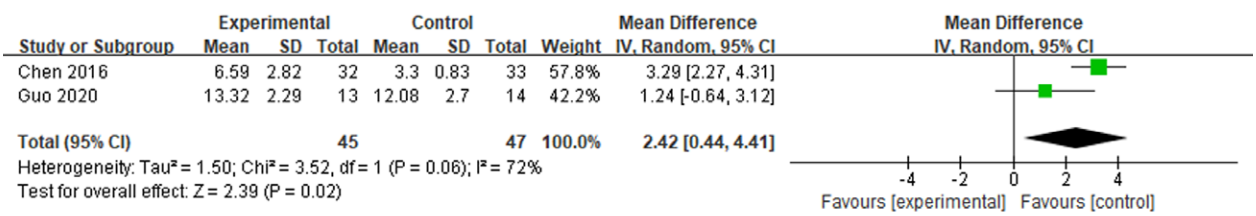

Figure 4. Forest plot of the meta-analysis on P300 amplitude (parietal midline electrode). CI, confidence interval; SD, standard deviation.

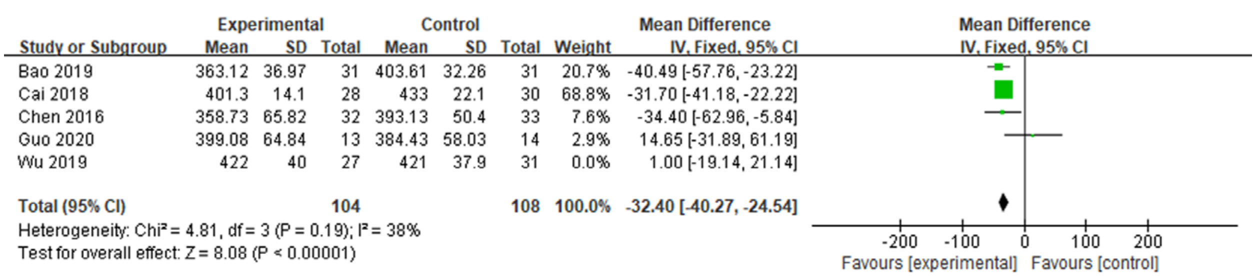

Figure 5. Forest plot of the meta-analysis on P300 latency (central midline electrode). CI, confidence interval; SD, standard deviation.

significant difference between the 2 groups in terms of P300 latency (MD = –12.57 [95% CI, –30.83 to 5.69]; $P = .81$), suggesting that exercise can reduce the latency of P300 at the PZ point. Detailed findings can be found in Figure 7.

3.6. MMSE

A total of 269 participants were included in 5 studies on MMSE.[19–23] Heterogeneity tests indicated high heterogeneity ($I^2 = 85\%$; $P < .0001$). Sensitivity analysis, after excluding the Bao study, revealed very low heterogeneity ($I^2 = 0\%$; $P = .49$). Thus, a fixed-effects model was employed for meta-analysis. Results showed a statistically significant difference between the 2 groups in MMSE scores (MD = 1.02 [95% CI, 0.61–1.43]; $P < .00001$), suggesting that exercise can enhance overall cognitive function. Detailed results are presented in Figure 8.

3.7. MoCA

A total of 204 participants were included in 5 studies on MoCA.[19,20,22,23] Heterogeneity tests revealed high heterogeneity ($I^2 = 89\%$; $P < .0001$). Sensitivity analysis, after excluding the Bao study, indicated very low heterogeneity ($I^2 = 0\%$; $P = .42$). Thus, a fixed-effects model was used for meta-analysis. The results demonstrated a significant difference between the 2 groups in MoCA scores (MD = 1.39 [95% CI, 0.67–2.12]; $P = .0002$], suggesting that exercise can improve overall cognitive function. Details can be seen in Figure 9.

3.8. Sensitivity analysis

Sensitivity analysis was conducted by sequentially omitting each individual study. It was found that the results of Bao 2019 noticeably changed the overall findings. After its exclusion, the results of this study became more stable.

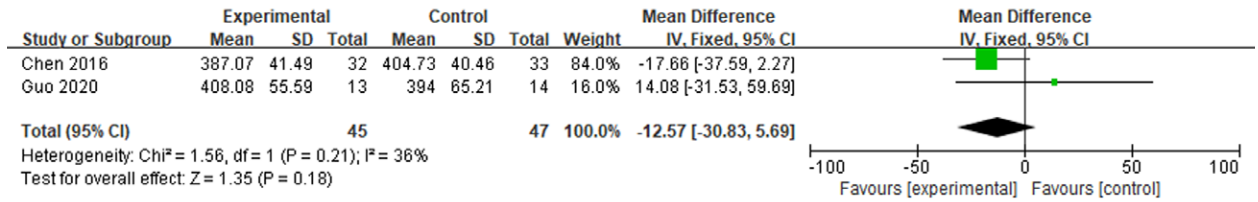

Figure 6. Forest plot of the meta-analysis on P300 latency (frontal midline electrode). CI, confidence interval; SD, standard deviation.

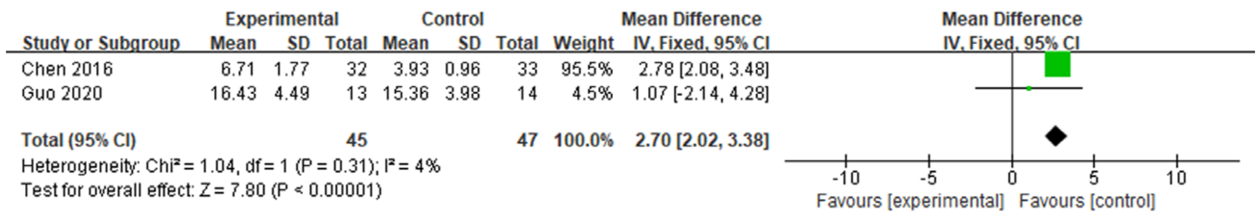

Figure 7. Forest plot of the meta-analysis on P300 latency (parietal midline electrode). CI, confidence interval; SD, standard deviation.

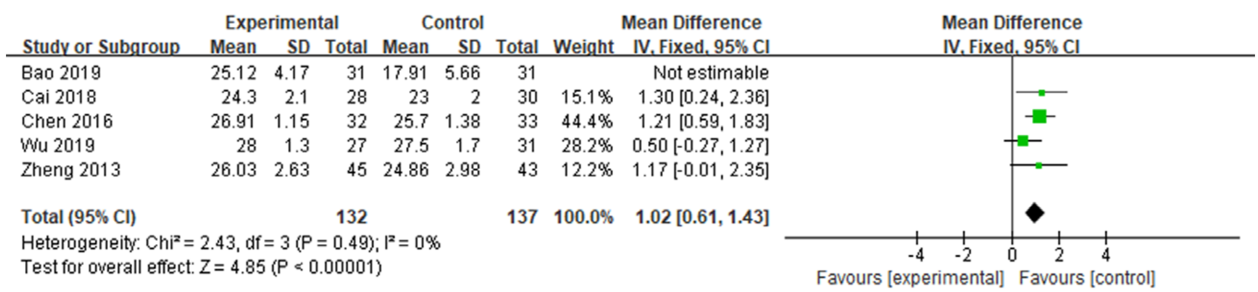

Figure 8. Forest plot of the meta-analysis on the mini-mental state examination. CI, confidence interval; SD, standard deviation.

3.9. Publication bias

Egger test and Begg test were utilized to quantitatively analyze the primary outcome measures for publication bias. The results indicated that there was not a noticeable publication bias among the included studies (Figs. 10 and 11).

4. Discussion

This study aimed to deeply investigate the impact of physical exercise on the electroencephalographic changes in patients with MCI. To our knowledge, this is the first meta-analysis concerning the effects of physical exercise on EEG activity in patients with MCI. All included studies indicated that physical exercise has a significant activating effect on the cortical activity of patients with MCI. This research provides valuable reference for those dedicated to formulating health strategies and exercise rehabilitation plans for patients with MCI, aiming to delay cognitive decline and enhance their cognitive function.

The results demonstrated that physical exercise can significantly enhance the amplitude and latency of P300, as well as improve overall cognitive function. The amplitude of P300 indicates the degree of effective resource mobilization during brain information processing, while its latency reflects the speed of the brain's cognitive processing of stimuli.[25] This implies that exercise can speed up cognitive processing and increase resource mobilization. Such effects may be attributed to neural and vascular regeneration and synaptic plasticity.[26] A meta-analysis by Cai et al[27] revealed a positive correlation between prolonged sitting and cognitive decline risk in the elderly. Prolonged sitting can lead to reduced cerebral blood flow in the medial temporal lobe, impair skeletal muscle contraction, and accelerate cell aging and brain atrophy, leading to MCI in the elderly. Dance has recently been studied as an intervention to improve cognition and increase brain volume in the elderly. Rehfeld et al[28] compared the effects of 6 months of dancing to traditional physical activities and found that while both improved cognition, dance led to an overall increase in brain volume, whereas traditional physical activities affected only the occipital and cerebellar areas. Dancing helps reduce sedentary behavior, allows interaction with others, and provides beneficial stimulation to the brain.

Traditional Chinese mind-body exercises such as Tai Chi, Ba Duan Jin, Liu Zi Jue, and Qigong, accompanied by rhythmic breathing, can improve cardiopulmonary function and enhance cerebral blood circulation and oxygen supply, benefiting cognitive function. Research confirms that these exercises increase bioelectrical activity, improve the nervous system's function, synchronize brainwaves across regions, and accelerate neural transmission.[29] Concentrated intent, continuous adjustments of movement directions, amplitude, and timing during these exercises activate brain regions associated with motor functions, thus enhancing central nervous system coordination and precision and improving memory in the elderly. A network meta-analysis showed that at least 150 minutes of moderate-intensity exercise per week promote cerebral blood flow, and metabolic and cardiovascular health.[30] Patients with MCI require adequate exercise duration and intensity to activate the cerebral cortex optimally.

Concerning different EEG frequency bands, only the study by Zheng et al[19] investigated the results, so it is regrettable that a meta-analysis could not be conducted. Their study showed significant reductions in the δ frequency and increases in the $\alpha1$ frequency, consistent with the findings of complexity analysis of

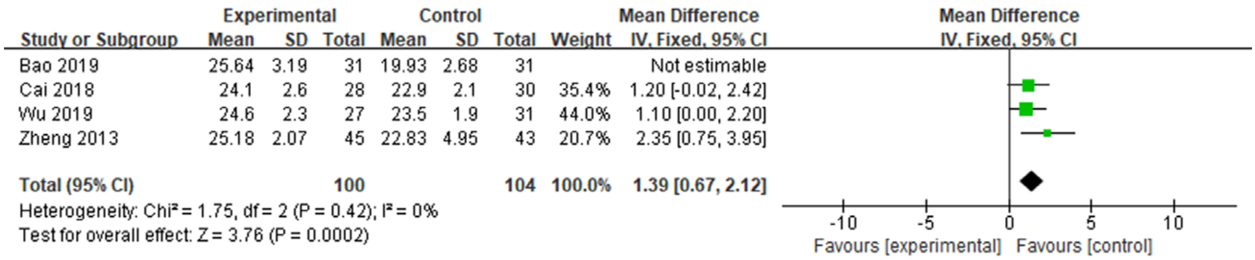

Figure 9. Forest plot of the meta-analysis on the Montreal Cognitive Assessment. CI, confidence interval; SD, standard deviation.

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Begg's Test

  adj. Kendall's Score (P-Q) =       2
          Std. Dev. of Score =    2.94
           Number of Studies =       4
                           z =    0.68
                    Pr > |z| =   0.497
                           z =    0.34 (continuity corrected)
                    Pr > |z| =   0.734 (continuity corrected)
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Egger's test

Std_Eff	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
slope	-1.19847	.928598	-1.29	0.326	-5.193904	2.796965
bias	5.758082	3.277104	1.76	0.221	-8.342158	19.85832

Figure 10. Egger test and Begg test of P300 amplitude outcomes.

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Begg's Test

  adj. Kendall's Score (P-Q) =       2
          Std. Dev. of Score =    2.94
           Number of Studies =       4
                           z =    0.68
                    Pr > |z| =   0.497
                           z =    0.34 (continuity corrected)
                    Pr > |z| =   0.734 (continuity corrected)
```

Egger's test

Std_Eff	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
slope	-1.417718	2.786667	-0.51	0.661	-13.40778	10.57234
bias	2.635519	9.547867	0.28	0.808	-38.44564	43.71667

Figure 11. Egger test and Begg test of P300 latency outcomes.

brainwaves by Imran Amjad.[31] In another study by Imran Amjad, aerobic exercise was found to be superior to anaerobic exercise.[32]

Physical exercise can improve functional brain activity and cognitive function, thereby preventing further cognitive decline, and is a safe and inexpensive means of treatment and prevention.

5. Conclusion

Our meta-analysis confirms that physical exercise induces positive changes in cortical activity and cognitive abilities in patients with MCI, making it a promising approach to enhance cognitive function in these patients.

6. Limitation

Only Chinese RCTs were included in this study. Despite extensive searching, we could not identify any English articles that met our criteria. Further primary research is needed to achieve more reliable and consistent results.

Author contributions

Investigation: Xiaomei Li.
Project administration: Xiaomei Li, Hejia Cai, Fangcun Li.
Software: Xiaomei Li.
Supervision: Xiaomei Li, Fangcun Li, Gangjian Tang.

Validation: Xiaomei Li, Hejia Cai.
Writing – original draft: Xiaomei Li, Hejia Cai, Fangcun Li.
Resources: Hejia Cai.
Methodology: Fangcun Li.
Data curation: Ke Tang.
Formal analysis: Ke Tang.
Writing – review & editing: Gangjian Tang.

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