Geriatric Nursing 53 (2023) 175–180

Contents lists available at ScienceDirect

Geriatric Nursing

journal homepage: www.gnjournal.com

Featured Article

The effect of Brain Gym on cognitive function in older people: A systematic review and meta-analysis

Silvia Varela, PhD[a,b], Carlos Ayán, PhD[a,b,c], Iraia Bidaurrazaga-Letona, PhD[c,d], José Carlos Diz, PhD[b,e], Iratxe Duñabeitia, PhD[c,d,*]

[a] Department of Special Didactics, University of Vigo, Vigo, Spain
[b] Well-Move Research Group, Galicia Sur Health Research Institute (IIS Galicia Sur), SERGAS-UVIGO, Vigo, Spain
[c] RIDEAIDI, Research Network on People with Disability: Exercise, Physical Activity and Inclusive Sport, Consejo Superior de Deportes (CSD), Spain
[d] Department of Physiology, Faculty of Medicine and Nursing, University of the Basque Country (UPV/EHU), Leioa, Spain
[e] Departamento de Bioloxía Funcional e Ciencias da Saúde, Universidade de Vigo, Vigo, Spain

ARTICLE INFO

Article history:
Received 22 May 2023
Received in revised form 14 July 2023
Accepted 18 July 2023
Available online 2 August 2023

Keywords:
Brain gym
Elderly
Cognitive function
Exercise
Systematic review

ABSTRACT

This review aimed to systematically evaluate and meta-analyze the available data on the effects of Brain Gym (BG) on cognitive function in older people. Six electronic databases were searched systematically using: “Brain Gym” AND “elderly, “Brain Gym” AND “older people”. The PEDro and MINORS scales were used to evaluate methodological quality. For the meta-analysis, inverse variance or generic inverse variance was used and heterogeneity was assessed with the Chi2 test and I2 test. Ten research studies with a high to low quality. Significant changes intra- and inter-group were observed for neurocognitive outcomes in the BG groups. Findings from the metaanalysis indicated changes in the BG groups, on cognitive function by means of the Mini–Mental State Examination, were not greater than those reported in the control/comparison groups. BG will not lead to improvements in cognitive function in people with and without cognitive impairment, supported by low to high evidence.

Introduction

Preserving physical and cognitive function is the main focus of geriatric and gerontological research.[1] Cognitive health is a major factor in ensuring the quality of life of older people and preserving independence. In an aging population with increasing incidence of dementia and cognitive impairment, strategies are needed to slow age-related decline in order to preserve cognitive function as long as possible. Among said strategies, physical exercise plays a prominent role.[2]

Several scientific reviews have provided robust evidence suggesting that various exercise training interventions, such as aerobic, strength training, or multi-component activities, can lead to cognitive improvements in older adults.[3-5] However, there is limited knowledge regarding the effectiveness of other exercise modalities that have traditionally been assumed to have potential benefits on cognitive function, such as Brain Gym (BG).

Brain Gym is an academic kinesiological program that was initially developed for children with learning disabilities. It involves the performance of specific movement patterns that incorporate the head, eyes, and extremities, focusing on three dimensions: laterality, attention, and centering.[6] During a typical BG session, participants engage in a wide variety of tasks that engage different aspects of cognitive and physical functioning. These tasks include dynamic movements involving coordination and balance such as crossing the midline of the body by touching the opposite knee with the opposite while walking (“Cross Crawl), and hand-eye coordination activities such as visualizing a figure and tracing its shape with the finger (“Lazy 8s”) or pressing the points located below the collarbone on either side of the sternum with the thumbs (“Brain Buttons”). Additionally, BG incorporates activities aimed at promoting relaxation, such as the "Energy Yawn." This involves taking a deep breath and audibly exhaling to create a calming and grounding effect.

According to its founders, BG practice stimulates various brain regions, with a particular emphasis on the corpus callosum, facilitating inter-hemisphere communication.[7] Additionally, Brain Gym is believed to enhance perception and reasoning abilities through neural remodeling.[8] Building upon these principles, BG has been suggested as a potentially beneficial physical therapy approach for enhancing brain functioning among older individuals.[9] Nevertheless, before considering BG as a therapeutic approach for enhancing

*Corresponding author at: Department of Physiology, Faculty of Medicine and Nursing, University of the Basque Country (UPV/EHU), Barrio Sarriena s/n, 48940, Leioa, Bizkaia, Basque Country, Spain.
E-mail address: iratxe.dunabeitia@ehu.eus (I. Duñabeitia).

https://doi.org/10.1016/j.gerinurse.2023.07.015
0197-4572/$ – see front matter

cognitive function in older people, quality and up-to-date information regarding its potential benefits should be made available to health and rehabilitation professionals working in the fields of psychogeriatric and psychogerontology. This goal can be achieved by conducting systematic reviews that synthesize and summarize the scientific evidence on the subject. To the very best of the author's knowledge, no systematic review focused on the effects of BG in older people has been published to date. In the light of this gap, the purpose of this study is to conduct a systematic review and meta-analysis in order to identify and critically analyze the best available evidence concerning the effects of BG on cognitive function in older people.

Methods

The present study employed a systematic review approach in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[10] Furthermore, the study adhered to the PRISMA protocol checklist (Appendix 1) to ensure comprehensive reporting.

Search strategy

A systematic search was conducted across six electronic databases, namely MEDLINE/Web of Science, PubMed, PEDro, SPORTDiscus, Dialnet, and Scopus. The search encompassed the entire publication history of these databases up until October 2022. The search strategy involved the utilization of specific search terms, Boolean operators, and combinations, including "Brain Gym" AND "elderly" and "Brain Gym" AND "older people."

Eligibility criteria

Inclusion in this review was limited to intervention studies that provided relevant information on the effects of Brain Gym (BG) specifically among older adults. To be eligible, studies had to meet certain criteria. Studies were excluded if: a) they lacked a control or comparison group; b) BG was combined with other therapeutic approaches; c) cognitive function was not included as an outcome measure; d) the sample included individuals younger than 60 years old; e) the full-text of the study was unavailable.

Study selection

Two authors independently evaluated the titles and abstracts of the identified studies to determine their eligibility for inclusion. Following this initial screening, the selected studies underwent a thorough review by both authors to assess their suitability based on the predefined inclusion criteria. Any discrepancies that arose during this process were resolved through mutual agreement. In cases where the inclusion status of a study remained uncertain, a third author was consulted for guidance, and a consensus was reached based on the predetermined inclusion criteria. Additionally, the reference lists of the selected articles, as well as the citing studies, were examined to identify any potentially relevant articles that met the eligibility criteria for inclusion in this review.

Data extraction

Data extraction encompassed the retrieval of various key elements from the original reports, including study type, participants' characteristics, inclusion and exclusion criteria, interventions, neurocognitive outcomes (tests), results (including clinically meaningful changes), and completion rate. This process was performed by one researcher, and subsequently, a second investigator cross-checked the extracted data to ensure accuracy and consistency.

Quality appraisal

The methodological quality assessment of each randomized controlled trial (RCT) was conducted using the Physiotherapy Evidence Database (PEDro). In cases where a trial was not included in PEDro, two authors independently evaluated its quality, adhering to the PEDro evaluation guidelines. Any discrepancies that arose during this process were resolved through consensus. The suggested cut-off points for categorizing the studies based on their quality were as follows: excellent (9-10), good (6-8), fair (4-5), and poor (<3).[11]

For comparative studies, the methodological quality assessment was performed using the Methodological Index for Non-Randomized Studies (MINORS).[12] The MINORS instrument comprises 12 items, each representing a quality criterion for comparative studies. Each item was scored as 0 (not reported), 1 (reported but inadequate), or 2 (reported and adequate). The maximum total score achievable for comparative studies was 24 points. One author evaluated the methodological quality of the comparative studies, which was then reviewed by a second author. In the event of any discrepancies, the input of a third author was sought to reach a consensus. To classify the quality of comparative studies, a total MINORS score of 17 or higher was considered indicative of high quality, while a total score below 17 indicated low quality.[12]

Statistical analysis

The extracted data from the articles were organized and processed using an Excel spreadsheet. For the purpose of conducting the meta-analysis, the RevMan v5.4.1 software was employed. Mean differences for continuous data, along with their corresponding 95% confidence intervals (CIs), were reported using the inverse variance method. Heterogeneity among the included studies was assessed using both the Chi2 test and the I2 test.

Results

Design and samples

Out of the initial set of 44 references, a total of 12 references were selected for full-text reading from various databases and registers. Additionally, an additional 4 references were identified through citation searching of the selected articles. Ultimately, a total of 10 investigations were included in the study, with 9 identified through databases and registries, and one through citation searching. The flow diagram illustrating the search and selection process can be seen in Fig. 1.

Among the 10 included studies, six were randomized controlled trials,[13-18] while four were comparative studies.[19-22] A summary of the characteristics of these 10 reviewed studies can be found in the supplementary table.

The total sample size across all studies consisted of 440 participants, with the smallest and largest study samples including 26[20] and 85[21] participants, respectively. The sex of the participants was reported in all studies except for three.[13,15,20] Based on the available data, it was found that more than half of the participants were women (68%). The characteristics of the participants varied across the samples, with a wide age range observed (mean $\pm$ SD: 74.23 $\pm$ 6.29 years, range: 60-95 years). However, Parellangi et al.[22] did not report the mean age $\pm$ SD of the sample.

Regarding cognitive status, three studies focused on individuals without cognitive complaints.[13,20,21] Three investigations included participants with mild cognitive impairment (MCI),[14,19,22] with Cano-

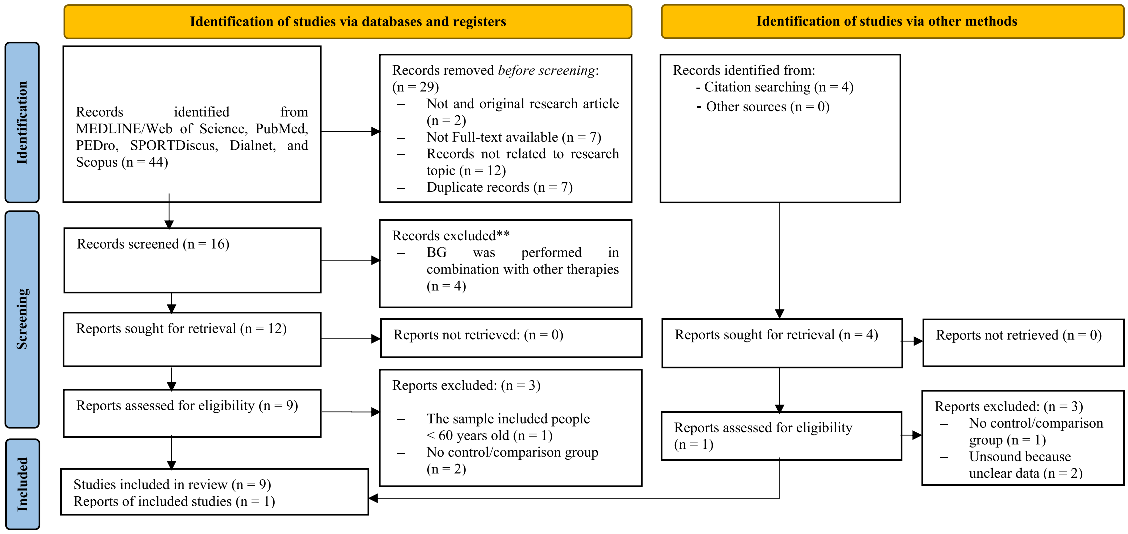

Fig. 1. Flow diagram of the search and selection process for the inclusion of articles.

Estrada et al.[19] reporting 9 out of 15 participants in the intervention group and 14 out of 15 older adults with MCI. Ayán et al.[16] included participants with moderate cognitive impairment. One study included a mixed sample of participants with and without cognitive impairment,[15] while two studies focused on individuals with dementia.[17,18] Notably, there was considerable heterogeneity in terms of the measurement tools used to assess the impact of Brain Gym (BG) on cognitive outcomes.

Quality appraisal

The methodological quality assessment of the six reviewed randomized controlled trials (RCTs) resulted in a range of ratings from "fair"[13,17,18] to "good"[14-16] according to Table 1. In the examined studies[13-18], all of them provided point estimates and variability (item 10), but did not blind subjects (item 4) and therapists (item 5). Four studies lacked intention-to-treat analysis (item 8),[13,15,17,18] while three studies failed to blind assessors (item 6).[13,17,18] Additionally, three studies did not adequately conceal allocation (item 2),[13,15,18] and two studies lacked baseline comparability (item 3).[13,14,18] Yagüez et al.[18] employed random allocation (item 1), whereas Morgenstern et al.[18] did not conduct sufficient follow-up (item 7) and failed to compare outcomes between groups (item 9).

Regarding the four comparative studies, three were classified as having low methodological quality based on the MINORS scale,[20-22] while the study conducted by Cano-Estrada et al.[19] demonstrated high methodological quality (Table 2). All of the studies analyzed[19-22] included consecutive patients (item 2), conducted prospective data collection (item 3), defined appropriate endpoints (item 4), and employed a follow-up period that aligned with the study's objectives (item 6). Additionally, these studies maintained contemporary comparison groups (item 10). However, none of them performed an unbiased assessment of the study endpoint (item 5). With the exception of Parellangi et al.,[22] all studies experienced a follow-up loss of more than 5% (item 7) but had an adequate control group (item 9). Only Imran et al.[20] prospectively calculated the sample size (item 8), while Cano-Estrada et al.[19] achieved baseline equivalence between groups (item 11). Imran et al.[20] failed to clearly state the aim of the study (item 1), and Cancela et al.[21] demonstrated very good adequacy in their statistical analyses (item 12).

Intervention characteristics

The selected studies carried out different exercise interventions, based on the BG performance. Five studies detailed the number of BG movements performed in each session; 19 movements,[16] 15 movements,[18,21] 13 movements,[19,22] and 6 movements[14]. Six studies performed a structured intervention with a warm-up, the main part of BG exercises and a time for cool-down.[14-16,19-21] Two studies did a standard intervention,[13,17] performing always similar exercises in the same order and sequence.

Four investigations compared the efficacy of BG against different exercise modalities,[14,16,21,22] proposed the performance of two BG programs of different frequency and duration. The remainig investigations compared BG against standard care,[18] occupational therapy,[17] or educational talks on cognitive impairment.[19] In three studies, participants in the non-BG group maintained their usual activity.[14,15,20,21]

Table 1
PEDro result of the methodological quality evaluation of the RCTs.

First author (year)	PEDro items										Score
	1	2	3	4	5	6	7	8	9	10	
Ayán et al. (2018)	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	8/10
Cancela et al. (2020)	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	7/10
Adriani et al. (2020)	Yes	No	Yes	No	No	Yes	Yes	No	Yes	Yes	6/10
Morgenstern et al. (2017)	Yes	Yes	Yes	No	No	No	No	No	No	Yes	4/10
Tootak et al. (2021)	Yes	No	No	No	No	No	Yes	No	Yes	Yes	4/10
Yagüez et al. (2010)	No	No	Yes	No	No	No	Yes	No	Yes	Yes	4/10

Items: 1 = random allocation; 2 = concealed allocation; 3 = baseline comparability; 4 = blind subjects; 5 = blind therapists; 6 = blind assessors; 7 = adequate follow-up; 8 = intention-to-treat analysis; 9 = between-group comparisons; 10 = point estimates and variability.

Table 2
Methodological quality of the included non-randomized comparative studies.

First author (year)	MINORS items												Score
	1	2	3	4	5	6	7	8	9	10	11	12	
Cano-Estrada et al. (2022)	2	2	2	2	0	2	0	0	2	2	2	1	17/24
Imran et al. (2020)	1	2	2	2	0	2	0	2	2	2	0	1	16/24
Cancela et al. (2015)	2	2	2	2	0	2	0	0	2	2	0	2	16/24
Parellangi et al. (2018)	2	2	2	2	0	2	2	0	0	2	0	1	15/24

Items: 1 = a clearly stated aim; 2 = inclusion of consecutive patients; 3 = prospective collection of data; 4 = endpoints appropriate to the aim of the study; 5 = unbiased assessment of the study endpoint; 6 = follow-up period appropriate to the aim of the study; 7 = loss to follow up less than 5%; 8 = prospective calculation of the study size; 9 = an adequate control group; 10 = contemporary groups; 11 = baseline equivalence of groups; 12 = adequate statistical analyses. The items are scored 0 (not reported), 1 (reported but inadequate) or 2 (reported and adequate).

The interventions lasted from 6 to 18 weeks, while BG sessions were usually performed twice per week.[13-16,19,20] Nevertheles, other studies proposed one[18] or three sessions[22] per week. In the study by Morgenstern et al.,[17] daily sessions were conducted. The duration of the sessions ranged between 10[22] and 240 minutes,[18] being the most frequent session duration 60 minutes.[14,15,20,21]

Main outcomes

Global cognitive function

The impact of Brain Gym (BG) on global cognitive function was analyzed in eight studies.[14-16,18-22] Four of these studies utilized the Mini-Mental State Examination (MMSE) as a measure of cognitive functioning.[14,15,19,22] Other tests were employed in the remaining studies to assess cognitive function. Adriani et al.[15] measured serum Brain-Derived Neurotrophic Factor (BDNF) concentration, Ayán et al.[16] used the Cognitive Mini-Test (MEC) and Phototest, Yagüez et al.[18] employed the Cambridge Neuropsychological Test Automated Battery, Imran et al.[20] utilized the Montreal Cognitive Assessment for Indonesian subjects (MoCA-INA), and Cancela et al.[21] used the Symbol Digit Modality Test (SDMT).

Significant statistical effects were observed in five of the studies.[15,16,19-22] Imran et al.[20] found significant improvements in cognitive function among participants in the Brain Gym (BG) group compared to the control group in the post-test, specifically in healthy subjects. Adriani et al.[15] reported significant improvements in the BG group compared to the control group in the post-test among individuals with a mixed sample. Yagüez et al.[18] observed significant improvements in sustained attention, visual memory, and working memory among individuals with Alzheimer's type dementia who performed BG in the post-test. Cano-Estrada et al.[19] demonstrated significant improvements in the BG group compared to the effects of educational talks (control group) among individuals with mild cognitive impairment. Parellangi et al.[22] found significant improvements in both groups, with greater improvements observed in the light intensity BG group compared to the medium intensity group among individuals with mild cognitive impairment.

Three of the four studies that utilized the Mini-Mental State Examination (MMSE) to evaluate the impact of Brain Gym (BG) on cognitive function[14,15,19] were included in the meta-analysis (Fig. 2). The pooled analysis of the data revealed that the observed changes in the BG groups were not significantly different from those reported in the control or comparison groups, with a mean difference of 0.67 points (95% CI -1.58, 2.92, p=0.56). Furthermore, when considering only randomized controlled trials (RCTs), the effect size was even smaller, with a mean difference of -0.28 points (95% CI -1.25, 0.68).

Executive function

Two studies assessed executive function using different tests: the Wisconsin Card Sorting Test[13] and the Trail Making Test (TMT).[16] Tootak et al.[13] reported statistically significant improvements in executive function among participants who performed Brain Gym (BG) compared to the control group, all of whom did not have cognitive impairment. However, in the study by Ayán et al.,[16] no significant effects on executive function were found in individuals with moderate cognitive impairment.

Dementia severity

In the study conducted by Morgenstern et al.,[17] which assessed the impact of Brain Gym (BG) on dementia severity, no significant changes were observed after the performance of BG.

Completion rate

The completion rates reported in the five studies that provided information on this outcome varied from 80% to 100%.[14-16,18,20]

Discussion

The purpose of this review was to examine and critically review the existing scientific evidence on the effects of BG on the cognitive function in older people. The information provided here could be useful for health professionals and researchers aiming to design rehabilitation programs that enhance the cognitive health of this population. To ensure the credibility and reliability of the study's findings, a rigorous and thorough search strategy was employed, resulting in a substantial number of studies that investigated BG as an intervention. However, some studies were initially excluded due to unreliable or flawed data, while others were excluded because they lacked a comparison group. This careful selection process was necessary to maintain the integrity of the study. It is important to note that the majority of the included studies exhibited low to fair methodological

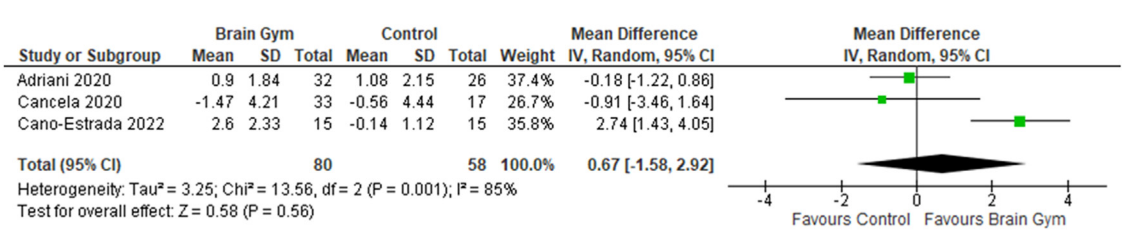

Fig. 2. Forest plot for the Brain Gym group *vs.* control on MMSE.

quality, which may limit the generalizability of the findings. However, the assessment tools used in these studies have been validated as sensitive measures for detecting changes in cognitive functioning over time These tests have been validated and demonstrated sensitivity in detecting changes in cognitive function over time and identifying cognitive function decline.[23-28] Therefore, specific findings derived from the analysis of these studies merit further discussion as they provide valuable insights.

For instance, BG was shown to be a viable therapy for people with MCI or dementia, as the completion rate was high, according to the studies that provided this information. However, the results regarding the beneficial effects of BG were mixed, as approximately half of the studies reported a lack of improvement in the cognitive function of the participants. Moreover, out of the reviewed investigations only one study demonstrated the presence of a clinically meaningful benefit, which raises doubt about the overall impact of BG as a therapy in producing effects that have clinical or practical importance.

These conflicting findings appear to be consistent with existing research on the efficacy of exercise in people with dementia. On one hand, previous studies in this population showed that high intensity functional exercise or attention activities had no effects on global cognition.[29] On the other hand, a comprehensive analysis Demurtas et al.,[30] which synthesized evidence from multiple existing reviews on the subject, determined that aerobic or muscular resistance exercises were effective in improving global cognition, although no significant effect on attention or executive function was observed.

On the contrary, systematic reviews and meta-analyses have reported the positive effects of various exercise types, including resistance training and mind-body exercises, on the cognitive function of individuals with MCI.[30-32] In any case, it is important to acknowledge that the beneficial effect of BG in this population is supported by evidence of very low certainty. While two comparative studies reported positive results, two RCTs indicated a lack of effectiveness. In light of these findings, it appears that incorporating BG as a cognitive training strategy and combining it with other exercise modalities may be more effective, rather than using BG as a standalone therapy. This approach could lead to improvements in the cognitive function of people with MCI and dementia.[33]

Scientific evidence has shown that both aerobic and resistance exercise can help preserve or improve cognitive function in healthy older adults.[5] However, based on our review, the effects of BG on cognitive function are limited, with a greater impact on executive function. Furthermore, when the pooled data was analyzed, it was found that the practice of BG did not result in significant changes in cognition. Additionally, the changes observed in the BG groups were not significantly different from those reported in the control or comparison groups.

Aerobic exercise is often considered as an effective form of exercise for improving cognitive function, primarly due to its effects on cerebral blood flow and related markers (i.e. cerebral perfusion, cerebrovascular tone).[34] Resistance exercise, on the other hand, has been suggested to enhance cognitive function by affecting basal concentrations of neurotrophic factors (i.e. BDNF, IG-1) as well as on corticospinal excitability.[35] The effects of both exercise training modalities have been associated with exercise intensity.[35-36] While BG is considered a cognitively demand task that could increase the number of dendritic branches and the level of synaptic plasticity,[14] its practice does not typically involve high physical exertion and is also performed at a low intensity. As a result, it is unlikely that the aforementioned neurophysiological mechanisms are triggered by the practice of BG.

This review provides useful information on the effectiveness of BG as therapeutic approach for improving cognitive function. Nevertheless, there are some limitations that should be acknowledged. First, although a meta-analysis could be performed, few studies with a considerable heterogeneity were finally included. For instance, it should be noted that some investigations included individuals without cognitive impairment, while others focused specifically on individuals with cognitive impairment. Additionally, the duration of BG interventions varied considerably across studies, ranging from a few weeks to several months.

Second, we only found three studies comparing BG versus other exercise interventions. Therefore, it was not possible to conduct a detailed analysis to determine whether BG is superior to other training programs. Finally, there are limitations related to the fact that we did not review the gray literature, and to the publication bias to the publication bias, which may have conditioned the results showed here.

Conclusion

The findings of this review suggest that there is no evidence to support the idea that the practice BG enhances cognitive and executive function in individuals with and without cognitive impairment. Moreover, the available information regarding whether BG provides greater cognitive benefits compared to other exercise modalities is derived from a limited number of studies with very low-to-moderate certainty of evidence. It is recommended to conduct RCTs with larger samples in order to obtain more solid conclusions in this regard.

Declaration of Competing Interest

The authors report that this study has been conducted without funding and that they have no competing interests to declare.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.gerinurse.2023.07.015.

References

1. Bektas A, Schurman SH, Sen R, Ferrucci L. Aging, inflammation and the environment. *Exp Gerontol*. 2018;105:10–18. https://doi.org/10.1016/j.exger.2017.12.015.
2. Kirk-Sanchez NJ, McGough EL. Physical exercise and cognitive performance in the elderly: current perspectives. *Clin Interv Aging*. 2014;9:51. https://doi.org/10.2147/CIA.S39506.
3. Cadore EL, Sáez de Asteasu ML, Izquierdo M. Multicomponent exercise and the hallmarks of frailty: considerations on cognitive impairment and acute hospitalization. *Exp Gerontol*. 2019;122:10–14. https://doi.org/10.1016/j.exger.2019.04.007.
4. Falck RS, Davis JC, Best JR, Crockett RA, Liu-Ambrose T. Impact of exercise training on physical and cognitive function among older adults: a systematic review and meta-analysis. *Neurobiol Aging*. 2019;79:119–130. https://doi.org/10.1016/j.neurobiolaging.2019.03.007.
5. Northey JM, Cherbuin N, Pumpa KL, Smee DJ, Rattray B. Exercise interventions for cognitive function in adults older than 50: a systematic review with meta-analysis. *Br J Sports Med*. 2018;52(3):154–160. https://doi.org/10.1136/bjsports-2016-096587.
6. Dennison G, Dennison P. *Brain Gym®: Teacher's edition revised*. Ventura, CA: Edu-Kinesthetics; 1994.
7. Dennison P. *Whole brain learning for the whole person*. Ventura, CA: Edu-Kinesthetics Inc; 1985.
8. Siroya VV, Naqvi WM, Kulkarni CA. Importance of Brain Gym as exercise in physiotherapy and rehabilitation. *Int J Res Pharm Sci*. 2020;11:1386–1389. https://doi.org/10.26452/ijrps.v10i4.
9. Drabben-Thiemann G, Hedwig D, Kenklies M, et al. The effect of Brain Gym on the cognitive performance of Alzheimer's patients. *Brain Gym J*. 2002;16(1):10.
10. Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *Syst Rev*. 2021;10(1):1–11. https://doi.org/10.1136/bmj.n71.
11. Silverman SR, Schertz LA, Yuen HK, Lowman JD, Bickel CS. Systematic review of the methodological quality and outcome measures utilized in exercise interventions for adults with spinal cord injury. *Spinal Cord*. 2012;50(10):718–727. https://doi.org/10.1038/sc.2012.78.
12. Slim K, Nini E, Forestier D, Kwiatkowski F, Panis Y, Chipponi J. Methodological index for non-randomized studies (MINORS): development and validation of a new instrument. *ANZ J Surg*. 2003;73(9):712–716. https://doi.org/10.1046/j.1445-2197.2003.02748.x.

13. Tootak M, Abedanzadeh R. Effectiveness of Brain Gym exercise on cognitive flexibility of male elderly. *Adv Cogn Sci*. 2021;22(4):65–74. https://doi.org/10.30514/icss.22.4.65.
14. Cancela JM, Casal Á, Sánchez-Lastra MA, Ayán C. Brain Gym exercises versus standard exercises for institutionalised older people with cognitive impairment: A randomised controlled study. *Asian J Gerontol Geriatr*. 2020;15(1):1–7. https://doi.org/10.12809/ajgg-2019-383-oa.
15. Adriani D, Imran Y, Mawi M, Amani P, Ilyas EI. Effect of Brain Gym® exercises on cognitive function and brain-derived neurotrophic factor plasma level in elderly: a randomized controlled trial. *Univ Med*. 2020;39(1):34–41. https://doi.org/10.18051/UnivMed.2020.v39.34-41.
16. Ayán C, Sánchez-Lastra MA, Cabanelas P, Cancela JM. Effects of Brain Gym® Exercises on institutionalized older adults with cognitive impairment. *Rev Int Med Cienc Act Fis Deporte*. 2018;18(72). https://doi.org/10.15366/rimcafd2018.72.011.
17. Morgenstern U, Ketelhut K, Rösler D. Konzentrationssteigerung zum Erhalt der Alltagskompetenz bei Demenz. *Zeitschrift fur Gerontologie und Geriatrie*. 2021;50(1):28–34. https://doi.org/10.1007/s00391-015-0982-0.
18. Yágüez L, Shaw KN, Morris R, Matthews D. The effects on cognitive functions of a movement-based intervention in patients with Alzheimer's type dementia: a pilot study. *Int J Geriatr Psychiatry*. 2011;26(2):173–181. https://doi.org/10.1002/gps.2510.
19. Cano-Estrada A, Jimenez-Mendoza A, Contreras-Guerrero D, Hernandes-Alejandro M, Salas-Casas A. The effect of Brain Gym on global cognitive function of institutionalized older people. *Int J Ment Health Promot*. 2022;24(3):375–383. https://doi.org/10.32604/ijmhp.2022.018857.
20. Imran Y, Adriani D, Amani P, Rachmiyani I, Prawiroharjo P. Association between Brain Gym and cognitive function in postmenopausal women. *Int J Sci Technol Res*. 2020;9(3):1405–1408.
21. Cancela JM, Suárez MHV, Vasconcelos J, Lima A, Ayán C. Efficacy of Brain Gym training on the cognitive performance and fitness level of active older adults: a preliminary study. *J Aging Phys Act*. 2015;23(4):653–658. https://doi.org/10.1123/japa.2014-0044.
22. Parellangi P, Loriana R, Firdaus R. Effect of light and medium intensity brain gymnastics on the improvement of cognitive function in elderly. *Belitung Nurs J*. 2018;4(5):518–523. https://doi.org/10.33546/bnj.497.
23. Bargalló EV, Domènech JV, Pallàs JA, Boquet JE, Pueyo TA, Ramírez EL. Concordancia entre el Mini-Examen Cognoscitivo y el Mini-Mental State Examination en el cribado del déficit cognitivo. *Atención primaria*. 2002;30(1):5–13. https://doi.org/10.1016/S0212-6567(02)78956-7.
24. Feeney J, Savva GM, O'Regan C, King-Kallimanis B, Cronin H, Kenny RA. Measurement error, reliability, and minimum detectable change in the Mini-Mental State Examination, Montreal Cognitive Assessment, and Color Trails Test among community living middle-aged and older adults. *J Alzheimers Dis*. 2016;53(3):1107–1114. https://doi.org/10.3233/JAD-160248.
25. Hörnsten C, Littbrand H, Boström G, et al. Measurement error of the Mini-Mental State Examination among individuals with dementia that reside in nursing homes. *Eur J Ageing*. 2021;18:109–115. https://doi.org/10.1007/s10433-020-00572-9.
26. Caldichoury N, Soto-Añari M, Camargo L, et al. Clinical utility of Phototest via teleneuropsychology in Chilean rural older adults. *Dement Neuropsychol*. 2022;16:316–323. https://doi.org/10.1590/1980-5764-DN-2021-0082.
27. Karlsen RH, Karr JJ, Saksvik SB, et al. Examining 3-month test-retest reliability and reliable change using the Cambridge Neuropsychological Test Automated Battery. *Appl Neuropsychol Adult*. 2022;29(2):146–154. https://doi.org/10.1080/23279095.2020.1722126.
28. Strober LB, Bruce JM, Arnett PA, et al. A much needed metric: defining reliable and statistically meaningful change of the oral version symbol digit modalities test (SDMT). *Mult Scler Relat Disord*. 2022;57: 103405. https://doi.org/10.1016/j.msard.2021.103405.
29. Toots A, Littbrand H, Boström G, et al. Effects of exercise on cognitive function in older people with dementia: a randomized controlled trial. *J Alzheimers Dis*. 2017;60(1):323–332. https://doi.org/10.3233/JAD-170014.
30. Demurtas J, Schoene D, Torbahn G, et al. Physical activity and exercise in mild cognitive impairment and dementia: an umbrella review of intervention and observational studies. *J Am Med Dir Assoc*. 2020;21(10):1415–1422. https://doi.org/10.1016/j.jamda.2020.08.031.
31. Wang S, Yin H, Wang X, et al. Efficacy of different types of exercises on global cognition in adults with mild cognitive impairment: a network meta-analysis. *Aging Clin Exp Res*. 2019;31(10):1391–1400. https://doi.org/10.1007/s40520-019-01142-5.
32. Biazus-Sehn LF, Schuch FB, Firth J, de Souza Stigger F. Effects of physical exercise on cognitive function of older adults with mild cognitive impairment: a systematic review and meta-analysis. *Arch Gerontol Geriatr*. 2020;89: 104048. https://doi.org/10.1016/j.archger.2020.104048.
33. Karssemeijer E, Aaronson J, Bossers W, Smits T, Kessels R. Positive effects of combined cognitive and physical exercise training on cognitive function in older adults with mild cognitive impairment or dementia: a meta-analysis. *Ageing Res Rev*. 2017;40:75–83. https://doi.org/10.1016/j.arr.2017.09.003.
34. Guadagni V, Drogos LL, Tyndall AV, et al. Aerobic exercise improves cognition and cerebrovascular regulation in older adults. *Neurology*. 2020;94(21):e2245–e2257. https://doi.org/10.1212/WNL.0000000000009478.
35. Chow ZS, Moreland AT, Macpherson H, Teo WP. The central mechanisms of resistance training and its effects on cognitive function. *Sports Med*. 2021;51(12):2483–2506. https://doi.org/10.1007/s40279-021-01535-5.
36. Kovacevic A, Fenesi B, Paolucci E, Heisz JJ. The effects of aerobic exercise intensity on memory in older adults. *Appl Physiol Nutr Metab*. 2020;45(6):591–600. https://doi.org/10.1139/apnm-2019-0495.