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Brain endurance training improves sedentary older adults' cognitive and physical performance when fresh and fatigued

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ABSTRACT

Objectives: Cognitive and physical performance is impaired by aging and fatigue. Cognitive and exercise training may mitigate such impairments. Accordingly, we investigated the effect of Brain Endurance Training (BET) – combined cognitive and exercise training – on cognitive and physical performance when fresh and fatigued in older adults.

Design: Twenty-four healthy sedentary women (65–78 years) were randomly allocated to one of three training groups: BET, exercise training, and control (no training). The BET and exercise training groups completed the same physical training protocol comprising three 45-min exercise sessions (20-min resistance exercise plus 25-min endurance exercise) per week for eight weeks. The BET group completed a 20-min cognitive task prior to exercise tasks. Cognitive (tasks: psychomotor vigilance, Stroop) and physical (tests: walk, chair-stand, arm curl) performance was tested when fresh and fatigued (before and after a 30-min cognitive task) at weeks 0 (pre-test), 4 (mid-test), 8 (post-test), and 12 (follow-up test).

Results: Cognitive and physical and performance was generally superior when fresh and fatigued at mid-test and post-test for both BET and exercise training groups compared to the control group. The BET group outperformed the exercise group when fatigued at mid-test and post-test both cognitively (always) and physically (sometimes). The pre-to-post changes in cognitive performance when fresh and fatigued averaged 3.7 % and 7.8 % for BET, 3.6 % and 4.5 % for exercise, and −0.4 % and 0.3 % for control groups. The corresponding changes in physical performance averaged 16.5 % and 29.9 % for BET, 13.8 % and 22.4 % for exercise, and 10.8 % and 7.1 % for control groups.

Conclusion: These findings show that BET can improve cognitive and physical performance in older adults.

1. Introduction

Mental fatigue, a psychobiological state elicited by prolonged and demanding cognitive activities, can impair cognitive and physical performance (Van Cutsem et al., 2017, 2022). For instance, mental fatigue can compromise balance control and thereby increase the risk of falls and accidents (Pitts & Bhatt, 2023). Accordingly, the cognitive demands of activities of daily life can create a heighted state of mental fatigue with the potential for negative health consequences (Chen et al., 2023).

Aging is characterized by declines in both cognitive and physical performance (Pellegrini-Laplagne et al., 2023). Mental fatigue has the potential to exacerbate age-related impairments in cognitive and physical performance. For instance, previous studies in older adults have shown that experimentally-induced mental fatigue impairs subsequent cognition (Zhang et al., 2023) and postural stability (Nikooharf Salehi et al., 2023; Varas-Díaz et al., 2020). This effect could negatively impact individual healthspan (i.e., period of life when individual is healthy) in older adults and increase societal healthcare system costs (Li et al., 2018). Accordingly, it is important to determine the effect of mental fatigue on cognitive and physical performance in older adults and to explore potential mental fatigue countermeasures in this vulnerable population.

To address these issues and thereby reduce the incidence of falls and accidents, non-pharmacological interventions, such as cognitive and exercise training, have been advocated (Pellegrini-Laplagne et al., 2023). Indeed, there is good evidence that both cognitive and exercise training can benefit older adults' cognitive and physical performance (Gavelin et al, 2021; Mowszowski et al., 2016; Sadeghi et al., 2021). For

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instance, cognitive training aided walking and reduced the risk of falling in adults with (Lipardo & Tsang, 2018) and without (Raichlen et al., 2020) cognitive impairment.

Evidence suggests that combined cognitive and physical training improves cognitive performance more than separate cognitive or physical training alone. Pellegrini-Laplagne et al. (2023) reported that combined training for two 30-min sessions per week for 24 weeks improved cognitive function (response inhibition during Stroop task) more than separate training in older adults. Montero-Odasso et al (2023) showed that combined training for three 90-min sessions per week for 20 weeks improved cognitive function (attention, memory, orientation), with the extent of these improvements better than those accompanying exercise training alone. Neither of these studies reported benefits for physical performance outcomes, whereas Phirom et al. (2020) found that interactive physical-cognitive game-based training improved cognitive performance and reduced fall risk in older adults. Evidence in young physically active adults has established that combined cognitive and physical training (i.e., Brain Endurance Training, BET) benefits cognitive (Dallaway et al., 2021; Staiano et al., 2022, 2023) and exercise (e.g., Barzegarpoor et al., 2021; Dallaway et al., 2021, 2023; Díaz-García et al, 2024; Staiano et al., 2022, 2023) performance more than standard physical training alone. Building on these literatures, the present study was designed to examine the effects of BET on cognitive and physical performance in older adults.

Cognitive (tasks: psychomotor vigilance, Stroop) and exercise (tests: walk, chair-stand, arm curl) performance was tested when fresh and fatigued both before and after eight weeks of BET, physical training, or no training (control). We operationally define these states as follows: a fresh state is a participant's condition at the start of a session before completing any demanding cognitive and physical tasks, whereas a fatigued state is a participant's condition after completing demanding cognitive and physical tasks. In the current study, we operationally define mental fatigue as a decline in response speed and accuracy during cognitive probe tasks. All the exercise tasks used in our study were selected based on their positive application to the daily life activity of older adults. With regard to the squats, improving leg strength can have positive benefits for older women, including longer walking distances and less fatigue after walking. The same benefits are associated with walking exercise training. With regard the biceps curls, improving arm strength can benefit daily life activities, such carrying shopping and cleaning.

Our study purposes were threefold. First, we investigated whether BET improved exercise performance compared to physical training alone and no training. We hypothesized that BET would improve exercise performance compared to physical training alone and no training. Second, we explored changes in performance of cognitive tasks as a function of training. We hypothesized that BET would improve cognitive performance compared to physical training alone and no training. Third, we determined the effect of mental fatigue, following exercise and cognitive tasks, on subsequent performance. We hypothesized that participants would perform worse when fatigued than when fresh, and that this impairment would be moderated by training. Crucially, we expected that the cognitive task would elicit less mental fatigue and exert less impact on subsequent performance following BET than physical training alone and no training.

2. Method

2.1. Participants

Twenty-four healthy older women (range 65–78, $M = 71.42$, $SD = 4.02$ years) were recruited from the community (a small town in rural Spain) and gave informed consent to participate. They reported that they did not perform any regular physical activity. The inclusion criteria were age (over 65 years) and sex (women only). The exclusion criteria were engagement in physical or cognitive training in the last three years and presence of mental or physical medical conditions that interfered with performing the cognitive and exercise tasks. We encouraged participants to maintain their diet but avoid alcohol ingestion. The protocol was approved by the Ethics Committee at the University of Extremadura in accordance with the Declaration of Helsinki. Power calculations focused on the group by test interaction effects associated with our 3 group by 4 test experimental design and analysis. Specifically, GPower (Faul et al., 2007) indicated that with a sample size of 24, our study was powered at 80 % to detect significant ($p < .05$) between-within (i.e., group by test) interaction effects ($f = .28$, $\eta_p^2 = .07$) corresponding to a small-to-medium effect size by analysis of variance (Cohen, 1992). Previous studies have documented the performance benefits of BET compared to standard physical training with similar sample sizes: 20 (Barzegarpoor et al., 2021), 22 (Staiano et al., 2022), 24 (Dallaway et al., 2023), and 24–26 (Staiano et al., 2023), and young adult athletes. Accordingly, the current sample size was deemed adequate to explore the effects of BET on performance.

2.2. Tasks and measures

Chair-stand test. The 30-s chair-stand test (Jones et al., 1999) assessed lower body (leg) strength. Participants sat on a chair with arms crossed at the chest and hands over shoulders, stood up, and sat down again. This squat-stand sequence was repeated as many times as possible in 30 s. A successful repetition was counted for each complete knee extension. The number of repetitions was recorded.

Arm-curl test. The 30-s arm-curl test (Rikli & Jones, 2013) assessed upper body (arm) strength. Participants sat on a chair, held a 1 kg dumbbell in their dominant hand, curled the elbow until fully flexed to touch the shoulder, and slowly lowered the dumbbell to the starting position. This action was repeated as many times as possible in 30 s. A successful repetition was counted for each complete movement. The number of repetitions was recorded.

Walk test. The 6-min walk test (ATS, 2002) assessed aerobic exercise capacity. Participants walked up and down a flat 30 m corridor. They walked as far as possible in 6 min. The distance (m) covered was recorded. Upon completion, participants provided a rating of perceived exertion, on a scale anchored by 0 = minimal and 10 = maximal (Borg, 1982).

Brief Stroop Task. Response inhibition, an executive function and core cognitive operation, was assessed by a 45 s incongruent Stroop task performed on a smartphone (UMH-MEMTRAIN, Elche, Spain). The number of words that participants read out loud were recorded. A researcher told the participant when their answer was incorrect; they responded until correct. Performance was measured as the number of correct responses.

Brief Psychomotor Vigilance Task (PVT-B). A 3-min PVT-B was used to assess simple reaction time (Dinges & Powell, 1985) using a smartphone app (PVT Research Tool, The Texas A&M University). The interstimulus duration was random and ranged from 1 to 4 s. Participants were required to touch the screen of a smartphone as fast as possible after a visual stimulus appeared in the center of the screen. A "false start" message was displayed if they touched the screen before a stimulus appeared. Performance was measured as reaction time (ms).

2.3. Manipulation

A 30-min incongruent Stroop test (UMH-MEMTRAIN, Elche, Spain) was used to elicit mental fatigue. A word representing one of four colors (blue, green, red, yellow) was displayed on a 69 × 55 cm monitor in a different color on a black background. Participants were instructed to press a button to indicate the meaning of the words as quickly and accurately as possible. All words were displayed in a different color to their meaning (i.e., 100 % incongruent trials). The interstimulus interval was 1900 ms. A researcher sat behind the participant to check compliance.

2.4. Design

Participants completed four testing sessions at weeks 0 (pre-test), 4 (mid-test), 8 (post-test), and 12 (follow-up test). Sessions took place at the same time of day. They were encouraged to sleep at least 7 h the previous night and to refrain from caffeine and alcohol for 12 h before each session. In each testing session, participants completed a series of performance tests (chair-stand test, arm-curl test, walk test, rating of perceived exertion on a 0 (minimal) to 10 (maximal) scale (Borg, 1998), PVT-B, and brief Stroop) before and after a 30-min Stroop task.

Before the start of the study, participants were randomly allocated to one of three groups: BET ($n = 8$), exercise training ($n = 8$), or no training control ($n = 8$). Both the BET and exercise groups completed the same training sessions, comprising 20-min resistance training (1-min squat, 1.5-min rest, 1-min biceps curl, 1.5-min rest; repeated 4 times) and 25-min walking outside. Researchers encouraged participants to train at an intensity ranging between 7 and 8 of their perceived exertion. The BET group performed a 20-min Stroop task prior to exercise training (see Dallaway et al., 2023). More details about the intervention is provided in Table S1 (Supplementary Materials). The study protocol is depicted in Figure S1 (Supplementary Materials).

2.5. Data analysis

A series of mixed factorial ANOVAs, with group (BET, Exercise, Control) as the between-participants factor and with test (pre-, mid-, post-, follow-up) and fatigue state (before Stroop, after Stroop) as the within-participants factors, were performed on the measures of physical

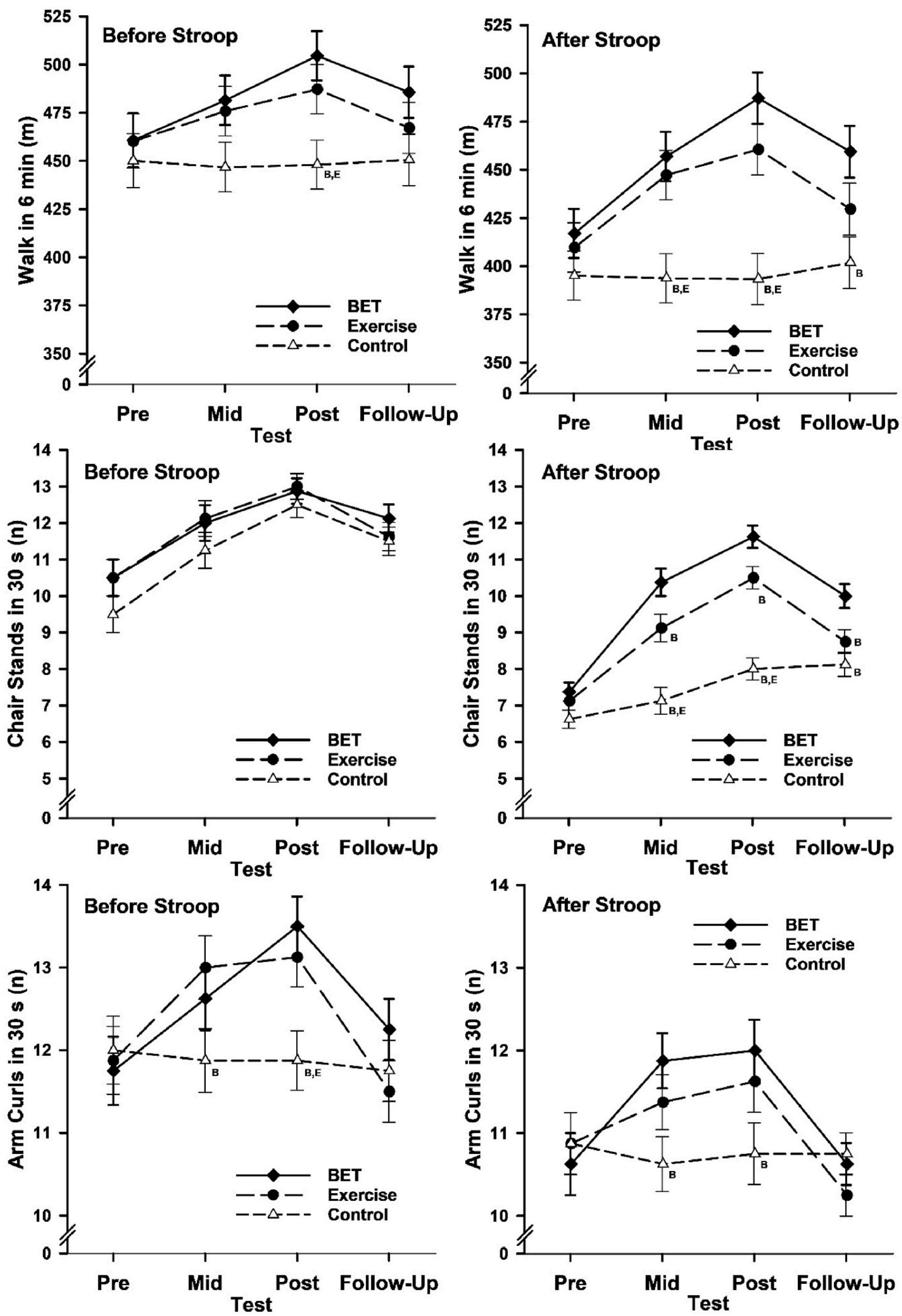

Figure 1. Mean (*SE*) walk, chair-stand, and arm curl exercise performance as a function of group (BET, Exercise, Control), test (pre-, mid-, post-, follow-up) and state (before Stroop, after Stroop). *T* tests: B = different from BET group, E = different from Exercise group.

and cognitive performance. We report the multivariate solution to minimize the risk of violating sphericity and compound symmetry assumptions in ANOVA designs (Vasey & Thayer, 1987). Partial eta-squared ($\eta^2 p$) was reported as a measure of effect size, with values of .02, .13 and .26 indicating small, medium, and large effect sizes, respectively (Cohen, 1992). Significance was set at $p < .05$. *T*-tests were used to directly compare groups following significant group by test (by state) interactions. Analyses were conducted using the Statistical Package for the Social Sciences (SPSS) software (IBM, United States).

3. Results

A series of 3 group (BET, Exercise, Control) by 4 test (pre-, mid-, post-, follow-up) by 2 state (before Stroop, after Stroop) ANOVAs on exercise performance yielded large main effects for test and state for all three forms of exercise (see Figure 1 and Table 1), whereby performance improved with training and then fell back after training as well as performance being worse after compared to before the 30-min Stroop task. Importantly, large group by test, group by state, and/or group by test by state interaction effects were found for each exercise task. Post hoc comparisons directly compared the exercise performance of the three groups at each test and state (Figure 1). At the mid-test, the BET group performed better than the Control group for one exercise in the fresh state (before Stroop) and three exercises in the fatigued state (after Stroop). At the post-test, the BET group performed better than the Control group for two exercises in the fresh state and three exercises in the fatigued state. At the follow-up test, the BET group performed better than the Control group for two exercises in the fatigued state. Moreover, at the post-test, the Exercise group performed better than the Control group for two exercises in the fresh and fatigued states. Finally, the BET group performed more chair stands in the fatigued state than the Exercise group at mid-, post- and follow-up tests.

The 3 group by 4 test by 2 state ANOVA on ratings of perceived exertion yielded large effects for test (decreased progressively with training before partly increasing after training), state (increased after Stroop task), and group by test (see Figure 2 and Table 1). Perceived exertion remained stable across tests for the Control group. Perceived exertion was lower during mid-test and post-test than pre-test and follow-up test for the Exercise group. Perceived exertion fell from pre-test to mid-test to post-test, and, remained at this low point at follow-up for the BET group. Post hoc comparisons exploring the group by test interaction confirmed that perceived exertion was lower for the Exercise group than Control group at mid-test, lower for the BET and Exercise groups than Control group at post-test, and lower for the BET group than Exercise and Control groups at follow-up test.

The 3 group by 4 test by 2 state ANOVAs on cognitive performance yielded large main effects for test and state for both cognitive tasks (see Figure 2 and Table 1), with performance improving with training and then falling back after training as well as performance being worse after compared to before the 30-min Stroop task. Importantly, large group by test and group by test by state interaction effects were found for both cognitive task measures. Post hoc comparisons directly compared the cognitive performance of the three groups at each test and state (Figure 2). At mid-, post-, and follow-up tests, the BET and Exercise groups responded faster and more accurately than the Control group in both tasks in both fresh and fatigued states. Finally, the BET group performed better than the Exercise group in the fatigued state at both mid-test and post-test.

4. Discussion

Our study determined the effects of BET on older women's cognitive and physical performance when initially in a relatively fresh state and later in a more fatigued state. We compared the effectiveness of BET against standard exercise only training and no training groups, and found evidence that BET is the most effective training method to improve the cognitive and physical performance of older adults. We also found that BET improved fatigue resilience and performance when the tasks were performed following a long and demanding cognitive task.

Aging is characterized by a decline in both cognitive and physical performance (Pellegrini-Laplagne et al., 2023). This age-related decline can reduce independence, well-being, and quality of life (Mendonca et al., 2016). Regular physical activity can tackle the detrimental effects of age on performance and improve independence and health (Roberts et al., 2017). A systematic review and meta-analysis (Salzman et al., 2022) coupled with recent intervention studies provide preliminary evidence that combined cognitive and physical training produces greater benefits than separate cognitive or physical training for cognition in older adults (e.g., Montero-Odasso et al., 2023; Pellegrini-Laplagne et al., 2023; Phirom et al., 2020). In line with our first and second study hypotheses, the findings confirm that BET, a form of combined cognitive and exercise training, can improve the cognitive and physical performance of healthy older adults more than no training or exercise training alone. Specifically, an 8-week *prior* BET intervention enhanced upper (arm curls) and lower (squats) body resistance exercise as well as aerobic (walking) exercise performance. These BET-related enhancements (expressed as pre-test to post-test changes for curls, squats, and walking) averaged 15.4 %, 24.4 %, and 9.6 % (when fresh) and 13.4 %, 59.4 %, and 16.9 % (when fatigued). By comparison, the corresponding exercise training only changes in exercise performance were 11.2 %, 24.3 %, and 6.0 % (when fresh) and 7.2 %, 47.5 %, and 12.5 % (when fatigued). Notably, this combined *prior* BET intervention also made walking feel easier – a similar finding to that observed in previous BET studies (see Dallaway et al., 2021; Staiano et al., 2022, 2023) – and reduced symptoms of fatigue.

BET enhanced cognition, assessed here by response speed during the PVT-B task and response accuracy during the brief Stroop task indicative of greater readiness to respond and inhibitory control, respectively. The BET-related enhancements (from pre-test to post-test for speed and accuracy) averaged 1.7 % and 5.7 % (when fresh) and 3.4 % and 12.1 % (when fatigued). By comparison, the corresponding exercise-training improvements in cognition were 1.6 % and 5.5 % (when fresh) and 2.0 %, and 6.9 % (when fatigued). These BET-related enhancements in cognition exceed those found for physical training alone when in a state of fatigue. We speculate that these enhancements in cognitive and physical functioning should increase healthspan and lower risk of

Table 1
Summary of the 3 group (BET, Exercise, Control) by 4 test (pre-, mid-, post-, follow-up) by 2 state (before Stroop, after Stroop) ANOVAs on exercise performance, perceived exertion, and cognitive performance.

	Group	Test	State	Group x Test	Group x State	Test x State	Group x Test x State
Measures	$F(2, 21)$ η^2_p	$F(3, 19)$ η^2_p	$F(1, 21)$ η^2_p	$F(6, 38)$ η^2_p	$F(2, 21)$ η^2_p	$F(3, 19)$ η^2_p	$F(6, 38)$ η^2_p
Walk Distance	3.44* .25	60.32*** .91	473.16*** .96	16.13*** .72	16.85*** .62	20.76*** .77	5.98*** .49
Chair Stands	6.45** .38	180.98*** .97	586.76*** .97	5.11*** .45	16.64*** .61	.86 .12	8.35*** .57
Arm Curls	1.63 .14	14.14*** .69	108.81*** .84	3.03** .34	.28 .03	.41 .06	1.81 .22
RPE	1.67 .14	24.52*** .80	595.59*** .97	5.74*** .48	1.31 .11	4.82* .43	1.50 .19
PVT-B RT	26.31*** .72	67.34*** .91	945.11*** .98	21.29*** .77	1.38 .11	18.26*** .74	3.54** .36
Stroop Words	10.09*** .49	40.77*** .87	1163.01*** .98	7.76*** .55	36.43*** .78	7.08** .53	3.82** .38

Note: $^*p < .05$, $^{**}p < .01$, $^{***}p < .001$.

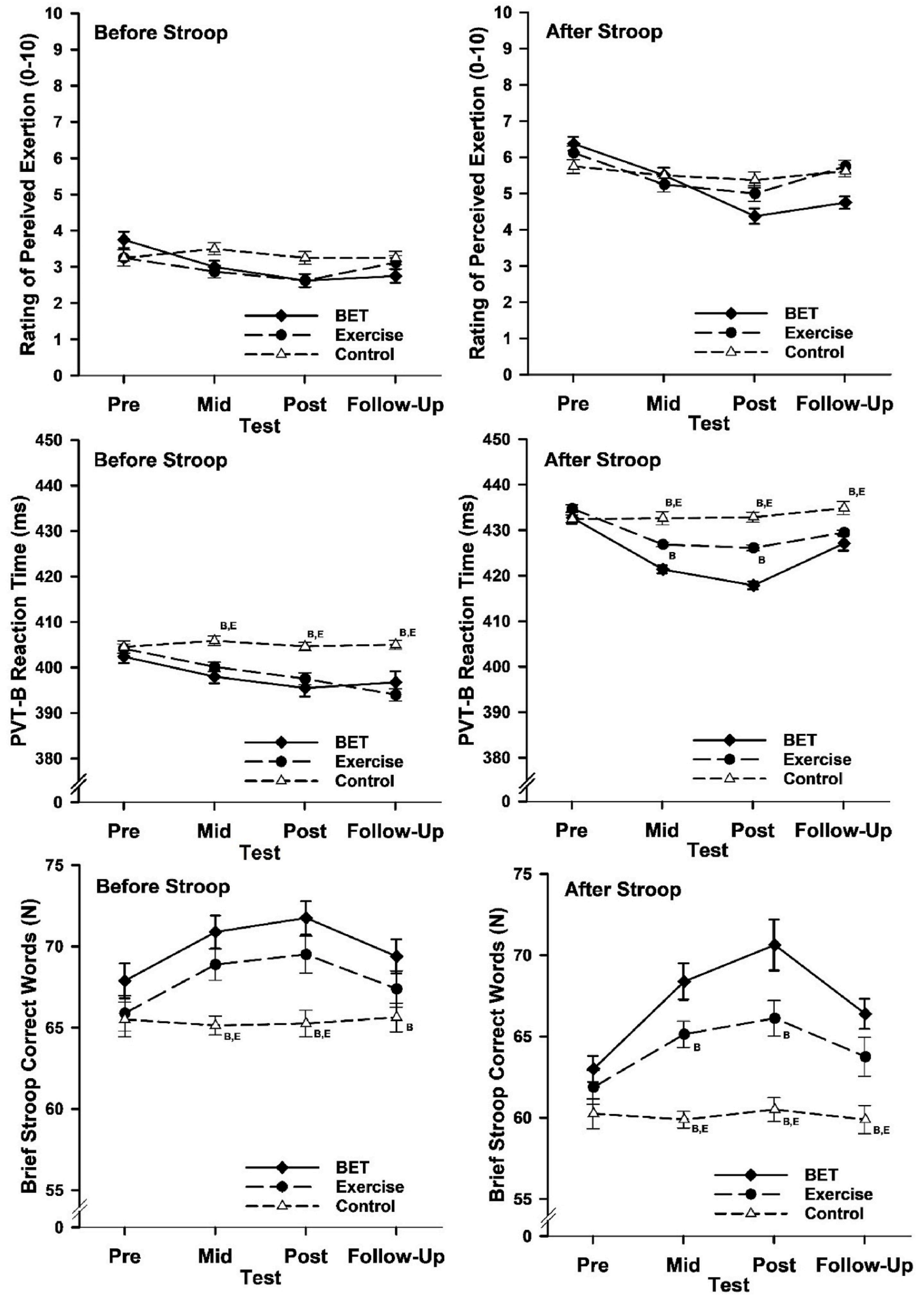

Figure 2. Mean (*SE*) RPE, PVT-B performance, and brief Stroop performance as a function of group (BET, Exercise, Control), test (pre-, mid-, post-, follow-up) and state (before Stroop, after Stroop). *T* tests: B = different from BET group, E = different from Exercise group.

accidents and falls.

In support of our third study hypothesis, the findings show, for the first time, that BET is an effective countermeasure against mental fatigue and its detrimental effects on performance in older adults. Our findings are in line with previous evidence that BET is an effective method to develop mental fatigue resilience in young adult athletes (e.g., Dallaway et al., 2021, 2023; Díaz-García et al., 2023; Staiano et al., 2022). Accordingly, BET can be recommended for use by older adults to improve performance and tackle the detrimental effects of mental fatigue on behavior, with the likely benefits being improved balance control and less incidence of falls and accidents (see Pitts & Bhatt, 2023).

4.1. Practical applications

The findings of the present study show that cognitive training prior to exercise training (i.e., *prior* BET) enhanced older women's cognitive and exercise performance. Notably, this method of combined training improved their mental fatigue resilience enabling them to perform better when fatigued by previous exercise and cognitive tasks. Although the exercise only group also generally improved their cognitive and physical performance compared to control (i.e., no training), our findings suggest that we should encourage older women and men to engage in BET. In sum, we show that the *prior* BET method was most beneficial for performance, however, a decision about the optimal training method must await confirmation (cf., Salzman et al., 2022).

4.2. Strengths, limitations and guidelines

Despite the present study yielding novel and important findings that can help improve older adults' cognition, fitness, and fatigue resilience, some limitations should be acknowledged. First, only women were tested. Future studies should replicate the findings in older sedentary men. Second, the sample size was relatively small. This can affect measurement error. Accordingly, future studies could recruit larger samples. Third, we only assessed mental fatigue via performance on a cognitive probe task, namely, the PVT-B. Future studies should include other markers of mental fatigue, such as subjective ratings and physiological responses (e.g., heart rate variability), to triangulate the measurement process and thereby better assess changes in mental fatigue associated with the experimental manipulations and interventions. Fourth, we examined a limited number and range of performance tasks. Studies should evaluate the extent to which BET benefits activities of everyday living and skill-based tasks in older adults (Díaz-García et al., 2023; Staiano et al., 2022). Finally, we only evaluated one BET method – *prior* BET (see Dallaway et al., 2023). Programmatic studies are needed that compare the benefits of different BET features, such as the dose (intensity and duration) of the individual training sessions as well as the entire intervention. This information will help identify the optimal BET method and program.

5. Conclusions

The present study demonstrated that BET, which combines cognitive and exercise training, enhanced cognitive and physical performance in older adults. These enhancements were observed for attention and executive function cognitive operations as well as endurance and resistance exercise activities. Importantly, these BET-related enhanced performances were seen relative to both no training (most of the time) and exercise training (sometimes). Finally, we confirmed that BET developed resilience to mental fatigue and recalibrated the relationship between exercise and perceived effort. Research studies with large samples are required to replicate and extend these findings to other groups (e.g., men, age cohorts, clinical diseases), exercise types (e.g., balance, flexibility, strength), cognitive operations (e.g., memory updating, switching), and activities of daily living.

CRediT authorship contribution statement

Jesús Díaz-García: Writing – review & editing, Writing – original draft, Visualization, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Tomás García-Calvo:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Christopher Ring:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Formal analysis, Conceptualization.

Declaration of competing interest

We have no conflicts of interest to declare.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.psychsport.2024.102757.

References

ATS Committee on Proficiency Standards for Clinical Pulmonary Function Laboratories. (2002). ATS statement: Guidelines for the six-minute walk test. *American Journal of Respiratory and Critical Care Medicine, 166*(1), 111–117. https://doi.org/10.1164/ajrccm.166.1.at1102

Barzegarpoor, H., Rajabi, H., Button, D., & Fayazmilani, R. (2021). The effect of simultaneous physical and brain endurance training on fatigue and exercise tolerance inactive people. *Journal of Practical Studies of Biosciences in Sport, 9*(18), 72–83. https://doi.org/10.22077/jpsbs.2020.3110.1540

Borg, G. (1998). *Borg's perceived exertion and pain scales*. Human kinetics. https://psycnet.apa.org/PsycINFO/1998-07179-000.

Chen, R., Wang, R., Fei, J., Huang, L., & Wang, J. (2023). Quantitative identification of daily mental fatigue levels based on multimodal parameters. *Review of Scientific Instruments, 94*(9), Article 095106. https://doi.org/10.1063/5.0162312

Cohen, J. (1992). A power primer. *Psychological Bulletin, 112*(1), 155–159. http://www.ncbi.nlm.nih.gov/pubmed/19565683.

Dallaway, N., Lucas, S., Marks, J., & Ring, C. (2023). Prior Brain Endurance Training improves endurance exercise performance. *European Journal of Sport Science, 23*(7), 1269–1278. https://doi.org/10.1080/17461391.2022.2153231

Dallaway, N., Lucas, S. J. E., & Ring, C. (2021). Concurrent Brain Endurance Training improves endurance exercise performance. *Journal of Science and Medicine in Sport, 24*(4), 405–411. https://doi.org/10.1016/j.jsams.2020.10.008

Díaz-García, J., García-Calvo, T., Manzano-Rodríguez, D., López-Gajardo, M.Á., Parraca, J. A., & Ring, C. (2023). Brain Endurance Training improves shot speed and accuracy in grassroots padel players. *Journal of Science and Medicine in Sport, 26*(7), 386–393. https://doi.org/10.1016/j.jsams.2023.06.002

Díaz-García, J., López-Gajardo, M.Á., Parraca, J. A., Batalha, N., López-Rodríguez, R., & Ring, C. (2024). Brain endurance training improves and maintains chest press and squat jump performance when fatigued. *Journal of Strength and Conditioning Research, 38*(9), 1568–1575. https://doi.org/10.1519/JSC.0000000000004847

Dinges, D. F., & Powell, J. W. (1985). Microcomputer analyses of performance on a portable, simple visual RT task during sustained operations. *Behavior Research Methods, Instruments, & Computers, 17*, 652–655. https://doi.org/10.3758/BF03200977

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*, 175–191. https://doi.org/10.3758/BF03193146

Gavelin, H. M., Dong, C., Minkov, R., Bahar-Fuchs, A., Ellis, K. A., Lautenschlager, N. T., Mellow, M. L., Wade, A. T., Smith, A. E., Finke, C., Krohn, S., & Lampit, A. (2021). Combined physical and cognitive training for older adults with and without cognitive impairment: A systematic review and network meta-analysis of randomized controlled trials. *Ageing Research Review, 66*, Article 01232. https://doi.org/10.1016/j.arr.2020.101232

Jones, C. J., Rikli, R. E., & Beam, W. C. (1999). A 30-s chair-stand test as a measure of lower body strength in community-residing older adults. *Research Quarterly for Exercise & Sport, 70*(2), 113–119. https://doi.org/10.1080/02701367.1999.10608028

Li, K. Z. H., Bherer, L., Mirelman, A., Maidan, I., & Hausdorff, J. M. (2018). Cognitive involvement in balance, gait and dual-tasking in aging: A focused review from a neuroscience of aging perspective. *Frontiers in Neurology, 9*, 913. https://doi.org/10.3389/fneur.2018.00913

Lipardo, D. S., & Tsang, W. W. (2018). Falls prevention through physical and cognitive training (falls PACT) in older adults with mild cognitive impairment: A randomized controlled trial protocol. *BMC Geriatrics, 18*, 1–12. https://doi.org/10.1186/s12877-018-0868-2

Mendonca, G. V., Pezarat-Correia, P., Vaz, J. R., Silva, L., Almeida, I. D., & Heffernan, K. S. (2016). Impact of exercise training on physiological measures of physical fitness in the elderly. *Current Aging Science, 9*(4), 240–259. https://doi.org/10.2174/1874609809666160426120600

Montero-Odasso, M., Zou, G., Speechley, M., Almeida, Q. J., Liu-Ambrose, T., Middleton, L. E., … McGibbon, C. (2023). Effects of exercise alone or combined with cognitive training and vitamin D supplementation to improve cognition in adults with mild cognitive impairment: A randomized clinical trial. *JAMA Network Open, 6*(7), Article e2324465. https://doi:10.1001/jamanetworkopen.2023.24465.

Mowszowski, L., Lampit, A., Walton, C. C., & Naismith, S. L. (2016). Strategy-based cognitive training for improving executive functions in older adults: A systematic review. *Neuropsychology Review, 26*(3), 252–270. https://doi.org/10.1007/s11065-016-9329-x

Nikooharf Salehi, E., Jaydari Fard, S., & Jaberzadeh, S. (2023). Mental fatigue impairs postural stability in older adults. *Research Quarterly for Exercise & Sport, 94*(2), 401–408. https://doi.org/10.1080/02701367.2021.1999892

Pellegrini-Laplagne, M., Dupuy, O., Sosner, P., & Bosquet, L. (2023). Effect of simultaneous exercise and cognitive training on executive functions, baroreflex sensitivity, and pre-frontal cortex oxygenation in healthy older adults: A pilot study. *GeroScience, 45*(1), 119–140. https://doi.org/10.1007/s11357-022-00595-3

Phirom, K., Kamnardsiri, T., & Sungkarat, S. (2020). Beneficial effects of interactive physical-cognitive game-based training on fall risk and cognitive performance of older adults. *International Journal of Environmental Research and Public Health, 17*(17), 6079. https://doi.org/10.3390/ijerph17176079

Pitts, J., & Bhatt, T. (2023). Effects of mentally induced fatigue on balance control: A systematic review. *Experimental Brain Research, 241*(1), 13–30. https://doi.org/10.1007/s00221-022-06464-x

Raichlen, D. A., Bharadwaj, P. K., Nguyen, L. A., Franchetti, M. K., Zigman, E. K., Solorio, A. R., & Alexander, G. E. (2020). Effects of simultaneous cognitive and aerobic exercise training on dual-task walking performance in healthy older adults: Results from a pilot randomized controlled trial. *BMC Geriatrics, 20*(1), 83. https://doi.org/10.1186/s12877-020-1484-5

Rikli, R. E., & Jones, C. J. (2013). Development and validation of criterion-referenced clinically relevant fitness standards for maintaining physical independence in later years. *The Gerontologist, 53*(2), 255–267. https://doi.org/10.1093/geront/gns071

Roberts, C. E., Phillips, L. H., Cooper, C. L., Gray, S., & Allan, J. L. (2017). Effect of different types of physical activity on activities of daily living in older adults: Systematic review and meta-analysis. *Journal of Aging and Physical Activity, 25*(4), 653–670. https://doi.org/10.1123/japa.2016-0201

Sadeghi, H., Jehu, D. A., Daneshjoo, A., Shakoor, E., Razeghi, M., Amani, A., Hakim, M. N., & Yusof, A. (2021). Effects of 8 Weeks of balance training, virtual reality training, and combined exercise on lower limb muscle strength, balance, and functional mobility among older men: A randomized controlled trial. *Sports Health, 13*(6), 606–612. https://doi.org/10.1177/1941738120986803

Salzman, T., Sarquis-Adamson, Y., Son, S., Montero-Odasso, M., & Fraser, S. (2022). Associations of multidomain interventions with improvements in cognition in mild cognitive impairment: A systematic review and meta-analysis. *JAMA Network Open, 5*(5), Article e226744. https://doi.org/10.1001/jamanetworkopen.2022.6744

Staiano, W., Marcora, S., Romagnoli, M., Kirk, U., & Ring, C. (2023). Brain Endurance Training improves endurance and cognitive performance in road cyclists. *Journal of Science and Medicine in Sport, 26*, 375–385. https://doi.org/10.1016/j.jsams.2023.05.008

Staiano, W., Merlini, M., Romagnoli, M., Kirk, U., Ring, C., & Marcora, S. (2022). Brain Endurance Training improves physical, cognitive, and multitasking performance in professional football players. *International Journal of Sports Physiology and Performance, 17*(12), 1732–1740. https://doi.org/10.1123/ijspp.2022-0144

Van Cutsem, J., Marcora, S., De Pauw, K., Bailey, S., Meeusen, R., & Roelands, B. (2017). The effects of mental fatigue on physical performance: A systematic review. *Sports Medicine, 47*(8), 1569–1588. https://doi.org/10.1007/s40279-016-0672-0

Van Cutsem, J., Van Schuerbeek, P., Pattyn, N., Raeymaekers, H., De Mey, J., Meeusen, R., & Roelands, B. (2022). A drop in cognitive performance, whodunit? Subjective mental fatigue, brain deactivation or increased parasympathetic activity? It's complicated. *Cortex, 155*, 30–45. https://doi.org/10.1016/j.cortex.2022.06.006

Varas-Diaz, G., Kannan, L., & Bhatt, T. (2020). Effect of mental fatigue on postural sway in healthy older adults and stroke populations. *Brain Sciences, 10*(6), 388. https://doi.org/10.3390/brainsci10060388

Vasey, M. W., & Thayer, J. F. (1987). The continuing problem of false positives in repeated measures ANOVA in psychophysiology: A multivariate solution. *Psychophysiology, 24*, 479–486. https://doi.org/10.1111/j.1469-8986.1987.tb00324.x

Zhang, Q., Sun, M. A., Sun, Q., Mei, H., Rao, H., & Liu, J. (2023). Mental fatigue is associated with subjective cognitive decline among older adults. *Brain Sciences, 13*, 376. https://doi.org/10.3390/brainsci13030376