Pupillary Responses Reveal Differential Mental Effort After Aerobic, Functional, and Brain Functional Training in Breast Cancer Survivors: A Randomized Crossover Trial

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ONLINE RESOURCE 1. SUPPLEMENTARY MATERIAL

Supplementary Chart 1. Structure of the Experimental Sessions

Block	Duration / Density	Functional Training (FT)	Brain Functional Training (BFT)	Aerobic Training (AT)
Movement preparation / Warm-up	FT/BFT: 10 min AT: 5 min	Mobility: cervical region, shoulders, hips, knees, and ankles. Muscle activation: squat.	Mobility: cervical region, shoulders, hips, knees, and ankles. Muscle activation: dynamic opposite “Sit down/Stand up” task (IC).	Treadmill walking (30–40% MAS) for cardiorespiratory adaptation.
Neuromuscular 1	FT/BFT: 12 min Density 1:2 (20″/40″) 2 rounds AT: -	Sprint Wallball throw against the wall Coordination on the agility ladder Wallball throw to the floor Horizontal jump Alternating battle rope	Sprint with auditory stop & go (IC) Wallball throw against the wall with 1-back task (WM) Coordination on the agility ladder with pattern change on command (CF) Wallball throw to the floor opposite to the command (IC) Horizontal jump with color sequence memorization (WM) Battle rope with pattern change to auditory cue (CF)	-

Neuromuscular 2	FT/BFT: 12 min Density 1:1 (30″/30″) 2 rounds AT: -	Neutral pull on suspension straps Squat with Bulgarian bag Box push-up Kettlebell deadlift Elastic band row Suitcase carry with kettlebell	Neutral pull on suspension straps with subtraction by 2 (CF) Squat with aquabag + step (MOT/MOT) Box push-up with opposite command “up/down” (IC) Kettlebell deadlift + lateral step (MOT/MOT) Elastic band row with 1-back task (WM) Suitcase carry with aquaball + squat and hand switch every 5 m (MOT/MOT)	-
Cardiometabolic	FT/BFT: 5 min Density 1:2 (10″/20″) 10 work intervals AT: 30 min	Interval running (HIIT)	Interval running (HIIT) with color memorization (WM)	Continuous main phase (60–70% MAS)
Cool-down	FT/BFT/AT: 5 min	-	-	Gradual speed reduction to light walking (30–40% MAS)

Note: Cognitive-motor task focused on: IC = inhibitory control; WM = working memory; CF = cognitive flexibility; MOT/MOT = simultaneous motor-motor task; MAS = maximal aerobic speed. The cardiometabolic block consisted of 10 work intervals, each comprising 10 s of interval running followed by 20 s of passive recovery. During each work interval, participants completed as many 10-m lengths as possible. Cardiometabolic volume was expressed as the total number of 10-m lengths completed, and total distance was calculated by multiplying this number by 10 m. The wallball used in throws weighed 2 kg. In FT, the squat was performed with a 10-kg Bulgarian bag, the deadlift with a 12-kg kettlebell, and the suitcase carry with a 10-kg kettlebell. In BFT, the squat was performed with a 10-kg aquabag, the deadlift with a 12-kg aquaball, and the suitcase carry with a 10-kg aquaball. The row was performed with a medium-resistance elastic band, and the push-up was performed on a 74-cm-high box.

Supplementary Table 1. External Load Performed During the Experimental Sessions

Training component	Variable	AT	FT	BFT	p-value FT vs BFT
General structure	Total duration, min	40	43-45	43-45	-
Aerobic training dose	Main intensity	70% MAS	-	-	-

Training component	Variable	AT	FT	BFT	p-value FT vs BFT
	Main-phase speed, km/h	4.9 ± 0.6	-	-	-
	Estimated main-phase distance, km	2.47 ± 0.30	-	-	-
FT and BFT density	Neuromuscular I density	-	20/40	20/40	-
	Neuromuscular II density	-	30/30	30/30	-
	Cardiometabolic density	-	10/20	10/20	-
Neuromuscular volume	Neuro I volume, repetitions/rounds	-	196.9 ± 26.0	149.9 ± 18.8	<0.001*
	Neuro II volume, repetitions/rounds	-	132.3 ± 23.2	112.1 ± 22.3	0.006*
Cardiometabolic volume	Cardiometabolic volume, 10-m lengths completed	-	19.6 ± 4.4	21.6 ± 3.0	0.109
	Total cardiometabolic distance, m	-	195.6 ± 43.5	215.6 ± 29.9	0.109
Total external volume	Total volume, repetitions/rounds	-	348.8 ± 44.9	283.6 ± 32.7	<0.001*
Concurrent-task performance	Mean task accuracy, %	-	-	77.7 ± 10.9	-

Note: Values are presented as mean ± standard deviation. AT: aerobic training; FT: functional training; BFT: Brain Functional Training; MAS: maximal aerobic speed. In AT, main-phase speed was calculated as 70% of each participant's individual MAS, and distance was estimated from speed and main-phase duration. In FT and BFT, volume was calculated as the sum of repetitions/rounds performed in the Neuro I, Neuro II, and cardiometabolic blocks. Cardiometabolic distance was estimated considering 10 m per round. In BFT, accuracy represents mean performance in tasks with concurrent demands. *Statistically significant difference between FT and BFT ($p < 0.05$).

Supplementary Table 2. Behavioral Performance During the Stroop Color and Word Test

Variable	Baseline	FT	BFT	AT
Congruent RT, ms	885.3 ± 198.9	806.4 ± 212.9	840.9 ± 153.1	812.5 ± 122.1
Incongruent RT, ms	955.8 ± 267.5	851.4 ± 294.7	899.6 ± 218.6	872.4 ± 129.0
Congruent accuracy, %	97.2 ± 4.5	97.6 ± 2.9	96.9 ± 4.0	98.3 ± 3.3
Incongruent accuracy, %	95.6 ± 5.7	96.5 ± 5.1	95.9 ± 5.8	96.9 ± 4.1
Stroop effect, ms	70.6 ± 112.6	45.0 ± 119.5	58.7 ± 124.5	59.8 ± 69.0

Note: Values are presented as mean ± standard deviation. RT: reaction time; FT: functional training; BFT: Brain Functional Training; AT: aerobic training. The Stroop effect was calculated as incongruent RT − congruent RT. The Baseline condition is presented only as a descriptive reference and was not included in the inferential models.

Supplementary Table 3. Behavioral Performance During the N-back Task

Variable	Baseline	FT	BFT	AT
d' 0-back	2.61 ± 0.90	2.87 ± 1.00	2.89 ± 0.76	2.55 ± 1.10
d' 1-back	1.61 ± 1.10	1.79 ± 1.19	1.82 ± 1.04	1.80 ± 1.17
d' 2-back	0.72 ± 0.59	0.90 ± 0.61	0.83 ± 0.59	0.90 ± 0.50
d' 3-back	0.44 ± 0.36	0.64 ± 0.32	0.56 ± 0.41	0.76 ± 0.56
RT 0-back, ms	431.4 ± 32.9	427.6 ± 24.7	429.8 ± 34.7	430.6 ± 26.9
RT 1-back, ms	403.2 ± 82.9	421.3 ± 36.7	424.1 ± 44.5	415.3 ± 39.7
RT 2-back, ms	393.1 ± 127.8	423.2 ± 45.0	413.3 ± 45.1	423.8 ± 40.9
RT 3-back, ms	389.1 ± 83.1	422.6 ± 53.5	426.3 ± 52.9	416.2 ± 58.5

Note: Values are presented as mean ± standard deviation. FT: functional training; BFT: Brain Functional Training; AT: aerobic training; RT: reaction time for correct responses. The baseline assessment was presented only descriptively and was not included in the inferential models.

Supplementary Table 4. Signal Yield and Preprocessing Quality of Pupillometry Data

Task	Recordings		Samples			Temporal coverage	Preprocessing	
	Acquired, n	Included, n	Raw, n	Confidence ≥ 0.75, n (%)	Per recording, mean ± SD		Artifacts removed, %	Interpolated, %
SCWT	48	47	663,625	580,252 (87.44)	12,346 ± 4,657	150.19 ± 50.90	17.22	15.41
N-back	48	47	2,157,011	1,937,480 (89.82)	41,223 ± 7,788	485.55 ± 73.90	14.88	13.65

Note: Each series represents one participant-condition recording for a given task. Values are presented as absolute number, percentage, or mean ± standard deviation, as appropriate. Artifacts include samples masked because of low tracking confidence, blink windows, or invalid/extreme values. Linearly interpolated samples represent short internal gaps reconstructed during preprocessing and constitute a subset of previously artifacts removed observations. SCWT: Stroop Color and Word Test; AT: aerobic training; FT: functional training; BFT: Brain Functional Training.