Aerobic Exercise Improves Episodic Memory in Late Adulthood: A systematic review and meta-analysis

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Supplementary Tables
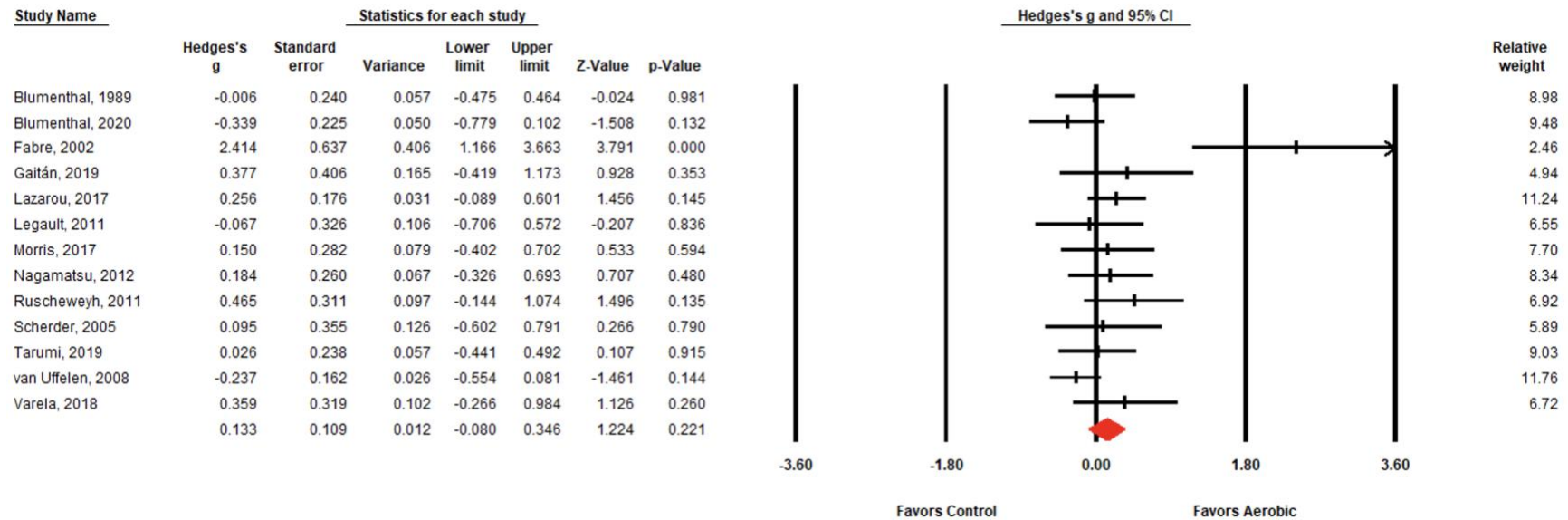
Supplementary Table 1. List of Coded Variables

Article Information	Sample Demographics
Reference	Age (M, SD, young-old, old-old)
Publication year	Sample size (N)
Quality of study	Sex distribution (low, high)
	Cognitive status (normal, impaired)
Intervention Characteristics	
Control group type (no-contact, inactive, physically active)	Episodic Memory
	Task (word list, story recall, face recognition, paired associates, object memory)
Intensity reporting (reported, not reported)	
Intervention length (short, medium, long)	Condition (learning, immediate-recall, delayed-recall, recognition)
Session duration (short, long)	
Session frequency (low, medium, high)	Pre-intervention score (M, SD)
Intervention volume (low, medium, high)	Post-intervention score (M, SD)
	Standardized mean difference (M, SD)

Note. M = mean; SD = standard deviation; N = sample size

Supplementary Table 2. PEDro Template Used for Assessing Study Quality

#	Criteria	Score
1	Eligibility criteria were specified	
2	Subjects were randomly allocated to groups	
3	Allocation was concealed	
4	The groups were similar at baseline regarding the most important prognostic indicators	
5	There was blinding of all subjects	
6	There was blinding of all personnel who administered the intervention	
7	There was blinding of all assessors who measured at least one key outcome	
8	Measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups	
9	All subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analyzed by "intention to treat"	
10	The results of between-group statistical comparisons are reported for at least one key outcome	
11	The study provides both point measures and measures of variability for at least one key outcome	

Supplementary Figures

Study Name	Hedges's g	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value	Relative weight
Blumenthal, 1989	-0.006	0.240	0.057	-0.475	0.464	-0.024	0.981	8.98
Blumenthal, 2020	-0.339	0.225	0.050	-0.779	0.102	-1.508	0.132	9.48
Fabre, 2002	2.414	0.637	0.406	1.166	3.663	3.791	0.000	2.46
Gaitán, 2019	0.377	0.406	0.165	-0.419	1.173	0.928	0.353	4.94
Lazarou, 2017	0.256	0.176	0.031	-0.089	0.601	1.456	0.145	11.24
Legault, 2011	-0.067	0.326	0.106	-0.706	0.572	-0.207	0.836	6.55
Morris, 2017	0.150	0.282	0.079	-0.402	0.702	0.533	0.594	7.70
Nagamatsu, 2012	0.184	0.260	0.067	-0.326	0.693	0.707	0.480	8.34
Ruscheweyh, 2011	0.465	0.311	0.097	-0.144	1.074	1.496	0.135	6.92
Scherder, 2005	0.095	0.355	0.126	-0.602	0.791	0.266	0.790	5.89
Tarumi, 2019	0.026	0.238	0.057	-0.441	0.492	0.107	0.915	9.03
van Uffelen, 2008	-0.237	0.162	0.026	-0.554	0.081	-1.461	0.144	11.76
Varela, 2018	0.359	0.319	0.102	-0.266	0.984	1.126	0.260	6.72
	0.133	0.109	0.012	-0.080	0.346	1.224	0.221	

Hedges's g and 95% CI. X-axis: -3.60, -1.80, 0.00, 1.80, 3.60. Favors Control — Favors Aerobic.

Supplementary Figure 1. Forest Plot of Individual Studies and Pooled Effects of Aerobic Exercise Interventions on Learning
Positive values of Hedges' g reflect improvements in learning scores among those in the aerobic exercise group relative to the control group. A random-effects model was used. Results revealed a significant positive effect of aerobic exercise on learning scores.

Study Name	Hedges's g	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value	Hedges's g and 95% CI	Relative weight
Antunes, 2015a	1.071	0.336	0.113	0.414	1.729	3.193	0.001		5.09
Blumenthal, 1989	-0.144	0.239	0.057	-0.612	0.325	-0.601	0.548		5.64
Fabre, 2002	0.456	0.480	0.230	-0.484	1.396	0.952	0.341		4.22
Ferreira, 2015	-0.068	0.296	0.088	-0.649	0.512	-0.231	0.817		5.32
Hassmén, 1997	0.134	0.322	0.104	-0.497	0.766	0.416	0.677		5.17
Ijuin, 2013	0.081	0.245	0.060	-0.400	0.562	0.330	0.741		5.61
Jonasson, 2017	0.145	0.260	0.067	-0.363	0.654	0.560	0.575		5.53
Kramer, 2001	2.847	0.260	0.068	2.337	3.356	10.945	0.000		5.53
Lazarou, 2017	0.408	0.177	0.031	0.061	0.755	2.305	0.021		5.94
Legault, 2011	0.282	0.328	0.107	-0.360	0.924	0.862	0.389		5.14
Maass, 2015	-0.321	0.312	0.098	-0.934	0.291	-1.028	0.304		5.23
Matura, 2017	0.166	0.272	0.074	-0.368	0.700	0.609	0.543		5.46
Morris, 2017	-0.008	0.281	0.079	-0.559	0.543	-0.028	0.978		5.41
Mortimer, 2012	0.024	0.255	0.065	-0.475	0.524	0.095	0.924		5.56
Nagamatsu, 2012	0.288	0.261	0.068	-0.223	0.799	1.106	0.269		5.53
Perri, 1985	0.342	0.306	0.094	-0.259	0.943	1.116	0.265		5.27
Poinsatte, 2019	1.142	0.517	0.268	0.128	2.156	2.206	0.027		4.01
Yogev-Seligmann 2021	-0.098	0.374	0.140	-0.830	0.635	-0.262	0.794		4.86
Zhu, 2018	0.903	0.268	0.072	0.378	1.428	3.370	0.001		5.48
	0.395	0.171	0.029	0.061	0.730	2.318	0.020		

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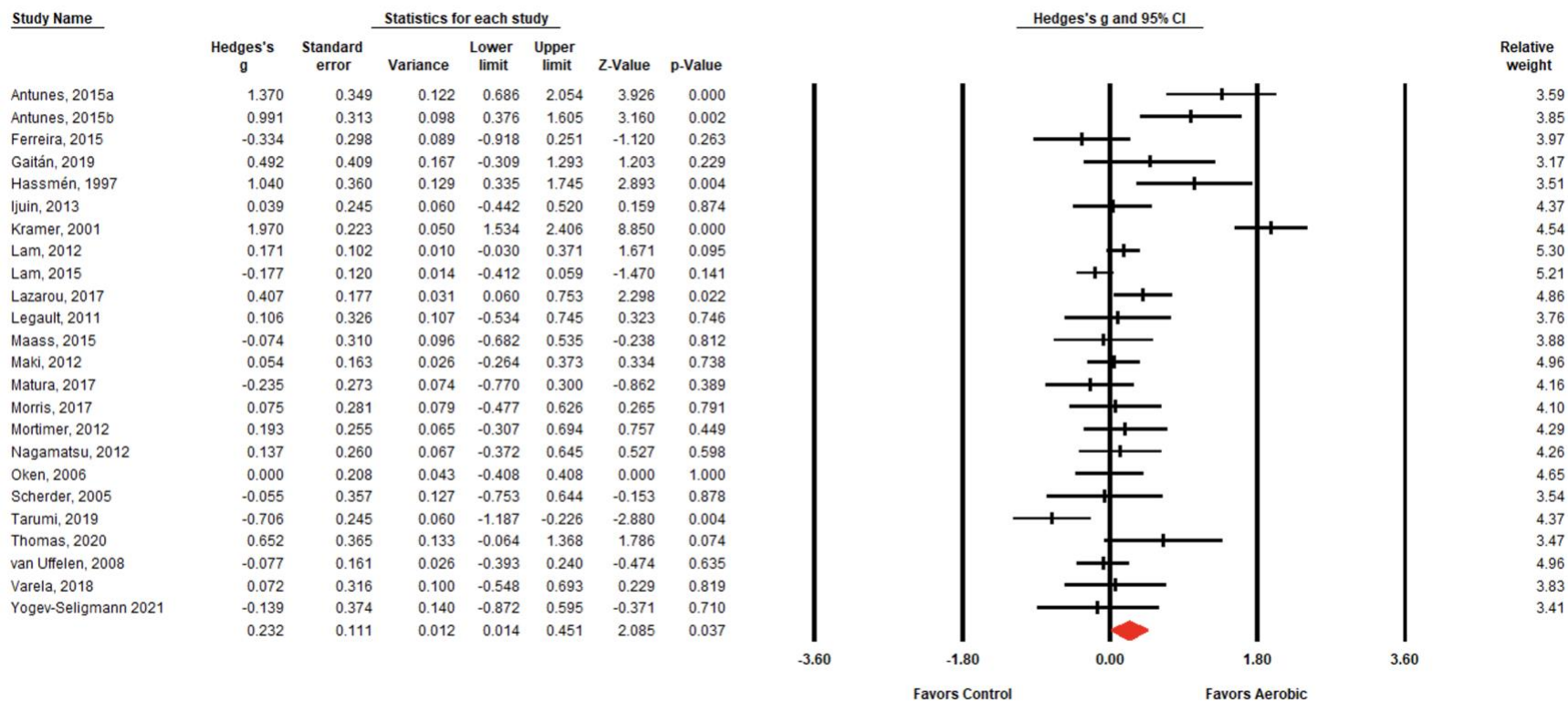**Supplementary Figure 2. Forest Plot of Individual Studies and Pooled Effects of Aerobic Exercise Interventions on Immediate Recall**
Positive values of Hedges' *g* reflect improvements in immediate recall scores among those in the aerobic exercise group relative to the control group. A random-effects model was used. Results revealed a significant positive effect of aerobic exercise on immediate recall scores.

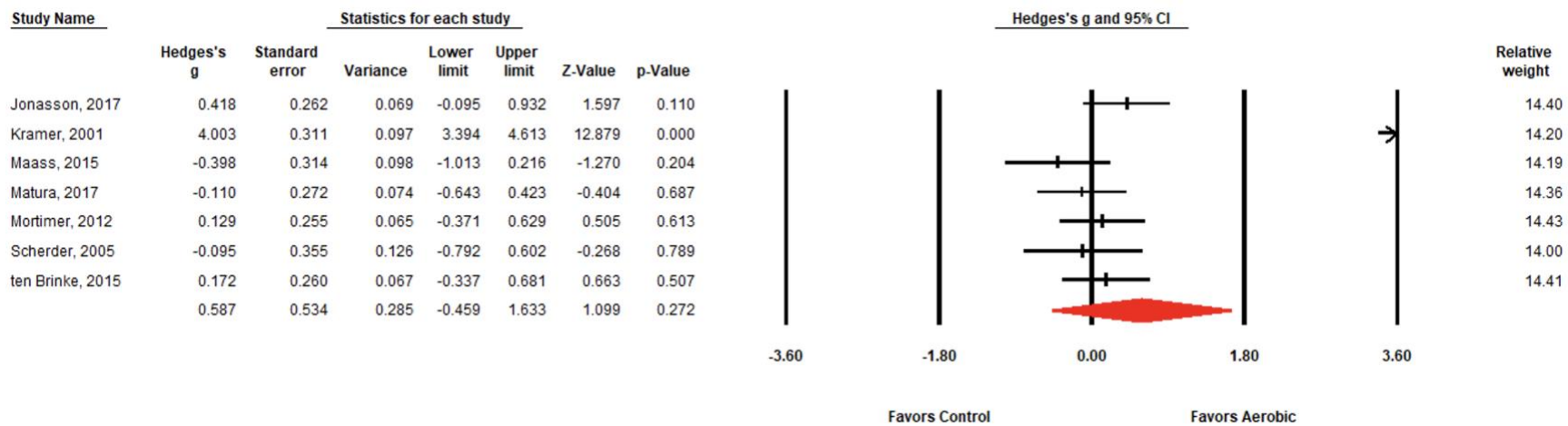| Study Name	Hedges's g	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value		Relative weight
Antunes, 2015a	1.370	0.349	0.122	0.686	2.054	3.926	0.000		3.59
Antunes, 2015b	0.991	0.313	0.098	0.376	1.605	3.160	0.002		3.85
Ferreira, 2015	-0.334	0.298	0.089	-0.918	0.251	-1.120	0.263		3.97
Gaitán, 2019	0.492	0.409	0.167	-0.309	1.293	1.203	0.229		3.17
Hassmén, 1997	1.040	0.360	0.129	0.335	1.745	2.893	0.004		3.51
Ijuin, 2013	0.039	0.245	0.060	-0.442	0.520	0.159	0.874		4.37
Kramer, 2001	1.970	0.223	0.050	1.534	2.406	8.850	0.000		4.54
Lam, 2012	0.171	0.102	0.010	-0.030	0.371	1.671	0.095		5.30
Lam, 2015	-0.177	0.120	0.014	-0.412	0.059	-1.470	0.141		5.21
Lazarou, 2017	0.407	0.177	0.031	0.060	0.753	2.298	0.022		4.86
Legault, 2011	0.106	0.326	0.107	-0.534	0.745	0.323	0.746		3.76
Maass, 2015	-0.074	0.310	0.096	-0.682	0.535	-0.238	0.812		3.88
Maki, 2012	0.054	0.163	0.026	-0.264	0.373	0.334	0.738		4.96
Matura, 2017	-0.235	0.273	0.074	-0.770	0.300	-0.862	0.389		4.16
Morris, 2017	0.075	0.281	0.079	-0.477	0.626	0.265	0.791		4.10
Mortimer, 2012	0.193	0.255	0.065	-0.307	0.694	0.757	0.449		4.29
Nagamatsu, 2012	0.137	0.260	0.067	-0.372	0.645	0.527	0.598		4.26
Oken, 2006	0.000	0.208	0.043	-0.408	0.408	0.000	1.000		4.65
Scherder, 2005	-0.055	0.357	0.127	-0.753	0.644	-0.153	0.878		3.54
Tarumi, 2019	-0.706	0.245	0.060	-1.187	-0.226	-2.880	0.004		4.37
Thomas, 2020	0.652	0.365	0.133	-0.064	1.368	1.786	0.074		3.47
van Uffelen, 2008	-0.077	0.161	0.026	-0.393	0.240	-0.474	0.635		4.96
Varela, 2018	0.072	0.316	0.100	-0.548	0.693	0.229	0.819		3.83
Yogev-Seligmann 2021	-0.139	0.374	0.140	-0.872	0.595	-0.371	0.710		3.41
	0.232	0.111	0.012	0.014	0.451	2.085	0.037		

Supplementary Figure 3. Forest Plot of Individual Studies and Pooled Effects of Aerobic Exercise Interventions on Delayed Recall
Positive values of Hedges' *g* reflect improvements in delayed recall scores among those in the aerobic exercise group relative to the control group. A random-effects model was used. Results revealed a significant positive effect of aerobic exercise on delayed recall scores.
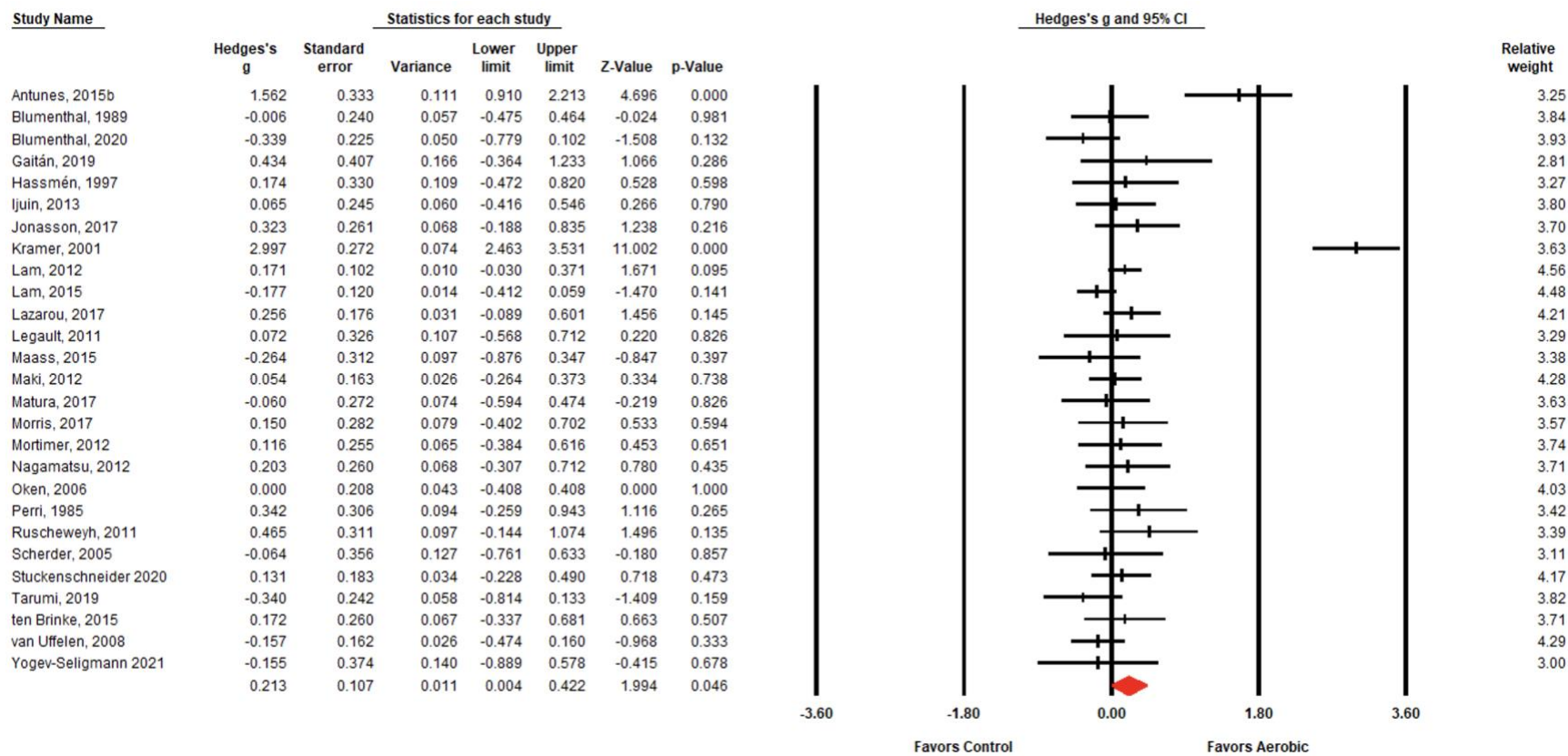
Study Name	Statistics for each study							Hedges's g and 95% CI	Relative weight
	Hedges's g	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value		
Jonasson, 2017	0.418	0.262	0.069	-0.095	0.932	1.597	0.110		14.40
Kramer, 2001	4.003	0.311	0.097	3.394	4.613	12.879	0.000		14.20
Maass, 2015	-0.398	0.314	0.098	-1.013	0.216	-1.270	0.204		14.19
Matura, 2017	-0.110	0.272	0.074	-0.643	0.423	-0.404	0.687		14.36
Mortimer, 2012	0.129	0.255	0.065	-0.371	0.629	0.505	0.613		14.43
Scherder, 2005	-0.095	0.355	0.126	-0.792	0.602	-0.268	0.789		14.00
ten Brinke, 2015	0.172	0.260	0.067	-0.337	0.681	0.663	0.507		14.41
	0.587	0.534	0.285	-0.459	1.633	1.099	0.272		

-3.60   -1.80   0.00   1.80   3.60

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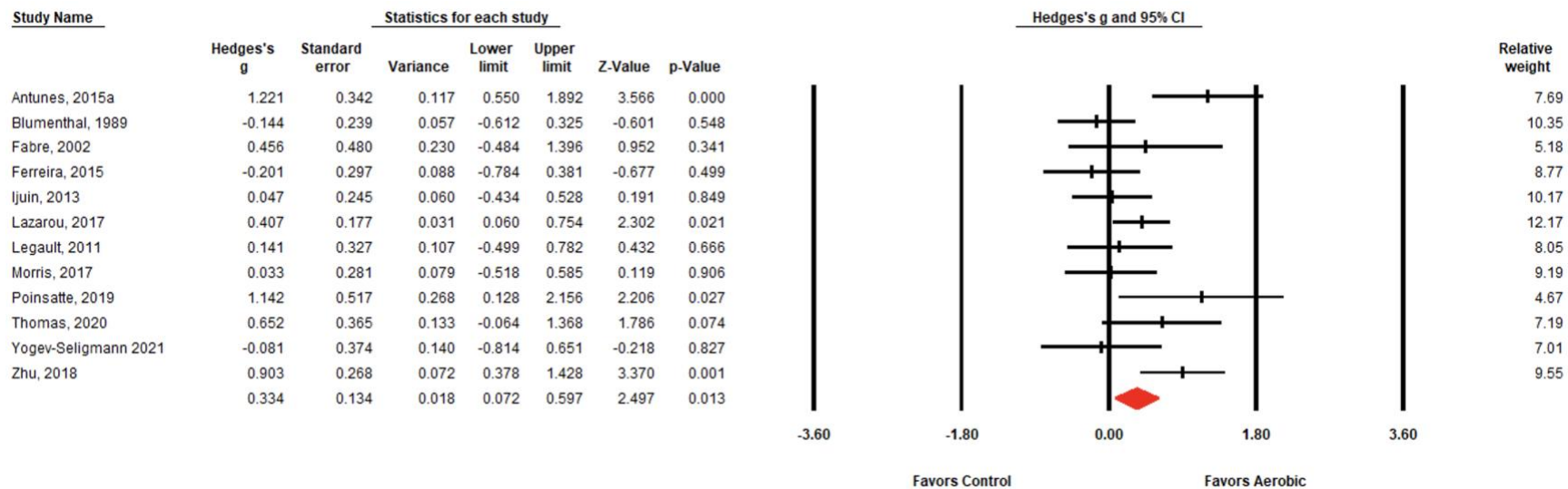
Supplementary Figure 4. Forest Plot of Individual Studies and Pooled Effects of Aerobic Exercise Interventions on Recognition
Positive values of Hedges' *g* reflect improvements in recognition scores among those in the aerobic exercise group relative to the control group.
A random-effects model was used. Results did not reveal a significant effect of aerobic exercise on recognition scores.

Study Name	Hedges's g	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value		Relative weight
Antunes, 2015b	1.562	0.333	0.111	0.910	2.213	4.696	0.000		3.25
Blumenthal, 1989	-0.006	0.240	0.057	-0.475	0.464	-0.024	0.981		3.84
Blumenthal, 2020	-0.339	0.225	0.050	-0.779	0.102	-1.508	0.132		3.93
Gaitán, 2019	0.434	0.407	0.166	-0.364	1.233	1.066	0.286		2.81
Hassmén, 1997	0.174	0.330	0.109	-0.472	0.820	0.528	0.598		3.27
Ijuin, 2013	0.065	0.245	0.060	-0.416	0.546	0.266	0.790		3.80
Jonasson, 2017	0.323	0.261	0.068	-0.188	0.835	1.238	0.216		3.70
Kramer, 2001	2.997	0.272	0.074	2.463	3.531	11.002	0.000		3.63
Lam, 2012	0.171	0.102	0.010	-0.030	0.371	1.671	0.095		4.56
Lam, 2015	-0.177	0.120	0.014	-0.412	0.059	-1.470	0.141		4.48
Lazarou, 2017	0.256	0.176	0.031	-0.089	0.601	1.456	0.145		4.21
Legault, 2011	0.072	0.326	0.107	-0.568	0.712	0.220	0.826		3.29
Maass, 2015	-0.264	0.312	0.097	-0.876	0.347	-0.847	0.397		3.38
Maki, 2012	0.054	0.163	0.026	-0.264	0.373	0.334	0.738		4.28
Matura, 2017	-0.060	0.272	0.074	-0.594	0.474	-0.219	0.826		3.63
Morris, 2017	0.150	0.282	0.079	-0.402	0.702	0.533	0.594		3.57
Mortimer, 2012	0.116	0.255	0.065	-0.384	0.616	0.453	0.651		3.74
Nagamatsu, 2012	0.203	0.260	0.068	-0.307	0.712	0.780	0.435		3.71
Oken, 2006	0.000	0.208	0.043	-0.408	0.408	0.000	1.000		4.03
Perri, 1985	0.342	0.306	0.094	-0.259	0.943	1.116	0.265		3.42
Ruscheweyh, 2011	0.465	0.311	0.097	-0.144	1.074	1.496	0.135		3.39
Scherder, 2005	-0.064	0.356	0.127	-0.761	0.633	-0.180	0.857		3.11
Stuckenschneider 2020	0.131	0.183	0.034	-0.228	0.490	0.718	0.473		4.17
Tarumi, 2019	-0.340	0.242	0.058	-0.814	0.133	-1.409	0.159		3.82
ten Brinke, 2015	0.172	0.260	0.067	-0.337	0.681	0.663	0.507		3.71
van Uffelen, 2008	-0.157	0.162	0.026	-0.474	0.160	-0.968	0.333		4.29
Yogev-Seligmann 2021	-0.155	0.374	0.140	-0.889	0.578	-0.415	0.678		3.00
	0.213	0.107	0.011	0.004	0.422	1.994	0.046		

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Supplementary Figure 5. Forest Plot of Individual Studies and Pooled Effects of Aerobic Exercise Interventions on Word-List Task Performance
Positive values of Hedges' *g* reflect improvements in word-list scores among those in the aerobic exercise group relative to the control group. A random-effects model was used. Results revealed a significant positive effect of aerobic exercise on word-list task performance.

Study Name	Hedges's g	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Antunes, 2015a	1.221	0.342	0.117	0.550	1.892	3.566	0.000
Blumenthal, 1989	-0.144	0.239	0.057	-0.612	0.325	-0.601	0.548
Fabre, 2002	0.456	0.480	0.230	-0.484	1.396	0.952	0.341
Ferreira, 2015	-0.201	0.297	0.088	-0.784	0.381	-0.677	0.499
Ijuin, 2013	0.047	0.245	0.060	-0.434	0.528	0.191	0.849
Lazarou, 2017	0.407	0.177	0.031	0.060	0.754	2.302	0.021
Legault, 2011	0.141	0.327	0.107	-0.499	0.782	0.432	0.666
Morris, 2017	0.033	0.281	0.079	-0.518	0.585	0.119	0.906
Poinsatte, 2019	1.142	0.517	0.268	0.128	2.156	2.206	0.027
Thomas, 2020	0.652	0.365	0.133	-0.064	1.368	1.786	0.074
Yogev-Seligmann 2021	-0.081	0.374	0.140	-0.814	0.651	-0.218	0.827
Zhu, 2018	0.903	0.268	0.072	0.378	1.428	3.370	0.001
	0.334	0.134	0.018	0.072	0.597	2.497	0.013

Study Name	Hedges's g and 95% CI	Relative weight
Antunes, 2015a		7.69
Blumenthal, 1989		10.35
Fabre, 2002		5.18
Ferreira, 2015		8.77
Ijuin, 2013		10.17
Lazarou, 2017		12.17
Legault, 2011		8.05
Morris, 2017		9.19
Poinsatte, 2019		4.67
Thomas, 2020		7.19
Yogev-Seligmann 2021		7.01
Zhu, 2018		9.55

-3.60   -1.80   0.00   1.80   3.60

Favors Control   Favors Aerobic

Supplementary Figure 6. Forest Plot of Individual Studies and Pooled Effects of Aerobic Exercise Interventions on Story-Recall Task Performance
Positive values of Hedges' *g* reflect improvements in story-recall scores among those in the aerobic exercise group relative to the control group. A random-effects model was used. Results revealed a significant positive effect of aerobic exercise on story-recall task performance.