Efficient and Innovative Physical Activity Interventions

Ben Singh, PhD Alliance for Research in Exercise Nutrition and Activity (ARENA), University of South Australia



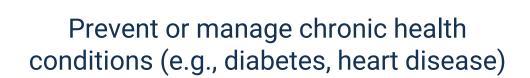
Reach or maintain a healthy weight



















Effectiveness of physical activity interventions for improving depression, anxiety and distress: an overview of systematic reviews

Ben Singh ⁽ⁱ⁾, ¹Timothy Olds, ¹Rachel Curtis, ¹Dorothea Dumuid ⁽ⁱ⁾, ¹Rosa Virgara, ¹ Amanda Watson, ¹Kimberley Szeto, ¹Edward O'Connor, ¹Ty Ferguson, ¹Emily Eglitis, ¹ Aaron Miatke, ¹Catherine EM Simpson, ¹Carol Maher²

ABSTRACT

Objective To synthesise the evidence on the effects of physical activity on symptoms of depression, anxiety and psychological distress in adult populations. Design Umbrella review.

Data sources Twelve electronic databases were searched for eligible studies published from inception to 1 January 2022.

Eligibility criteria for selecting studies Systematic reviews with meta-analyses of randomised controlled trials designed to increase physical activity in an adult population and that assessed depression, anxiety or psychological distress were eligible. Study selection was undertaken in duplicate by two independent reviewers. Results Ninety-seven reviews (1039 trials and 128 119 participants) were included. Populations included healthy adults, people with mental health disorders and people with various chronic diseases. Most reviews (n=77) had a critically low A MeaSurement Tool to Assess systematic Reviews score. Physical activity had medium effects on depression (median effect size=-0.43, IQR=-0.66 to -0.27), anxiety (median effect size=-0.42, IOR=-0.66 to -0.26) and psychological distress (effect size=-0.60, 95% CI -0.78 to -0.42), compared with usual care across all populations. The largest benefits were seen in people with depression, HIV and kidney disease, in pregnant and postpartum women, and in healthy individuals. Higher intensity physical activity was associated with greater improvements in symptoms. Effectiveness of physical activity interventions diminished with longer duration interventions.

Conclusion and relevance Physical activity is highly beneficial for improving symptoms of depression, anxiety and distress across a wide range of adult populations, including the general population, people with diagnosed mental health disorders and people with chronic disease. Physical activity should be a mainstay approach in the management of depression, anxiety and psychological distress.

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¹Allied Health & Human Performance, University of South Australia, Adelaide, South Australia, Australia ²Health and Use of Time (HUT) Group, University of South Australia, Adelaide, South Australia, Australia

exan Correspondence to Dr Ben Singh, University of South Australia, Adelaide, South Australia, Australia; ben.singh@unisa.edu.au

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> > distress. PROSPERO regis

which is projected to increase to \$6 trillion (USD) by 2030.⁵ Depression is the leading cause of mental health-related disease burden,⁶ while anxiety is the most prevalent mental health disorder.³ Additionally, the COVID-19 pandemic has been associated with increased rates of psychological distress, with prevalence ranging between 35% and 38% worldwide.⁷⁻⁹

The role of lifestyle management approaches, such as exercise, sleep hygiene and a healthy diet, varies between clinical practice guidelines, ¹⁰ psychotherapy or pharmacotherapy is recommended as the initial treatment approaches, with lifestyle approaches considered as 'complementary alternative treatments' where psychotherapy and pharmacotherapy are 'ineffective or unacceptable'. In other countries such as Australia, lifestyle management is recommended as the first-line treatment approach, ^{11 12} though in practice, pharmacotherapy is often provided first.

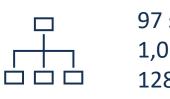
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There have been hundreds of research trials examining the effects of physical activity (PA) on depression, anxiety and psychological distress, many of which suggest that PA may have similar effects to psychotherapy and pharmacotherapy (and with numerous advantages over psychotherapy and pharmacotherapy, in terms of cost, side-effects and ancillary health benefits).¹³⁻¹⁸ Despite the evidence for the benefits of PA, it has not been widely adopted therapeutically. Patient resistance, the difficulty of prescribing and monitoring PA in clinical settings, as well as the huge volume of largely incommensurable studies, have probably impeded a wider take-up in practice. ^{13 14 17}

Meta-reviews are systematic reviews of systematic reviews, offering a way of synthesising a vast evidence base. While there have been several meta-reviews of PA for depression, anxiety and psychological distress,¹⁷ ^{19–24} they have focused on specific population subgroups, particular conditions (eg, depression only) or on particular forms of PA. We set out to undertake the most comprehensive synthesis to date



Umbrella review to summarise all existing systematic reviews on the effects of physical activity on depression and anxiety



97 systematic reviews 1,039 RCTs 128,119 participants



Cancer n=27 (28%) Depression n=11 (11%) Dementia n=5 (5%) Older adults n=5 (5%)



Various modes n=70 (72%) Specific modes (e.g., aerobic only, yoga only) n=27 (28%)

Depression (overall effect size): -0.43

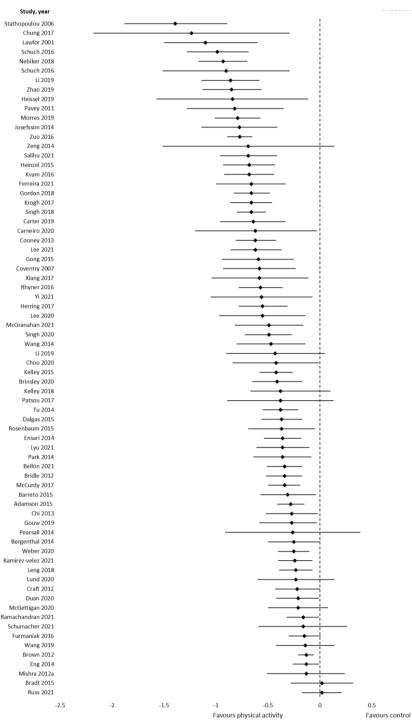


Kidney disease: -0.85 HIV/AIDS: -0.84 COPD: -0.72 Healthy adults: -0.69



Resistance: -0.64 Mixed-mode: -0.47 Yoga: -0.46 Aerobic: -0.45

Effect size interpretation: -0.2 = Small effect -0.5 = Medium Effect -0.8 = Large effect COPD: Chronic obstructive pulmonary disease.

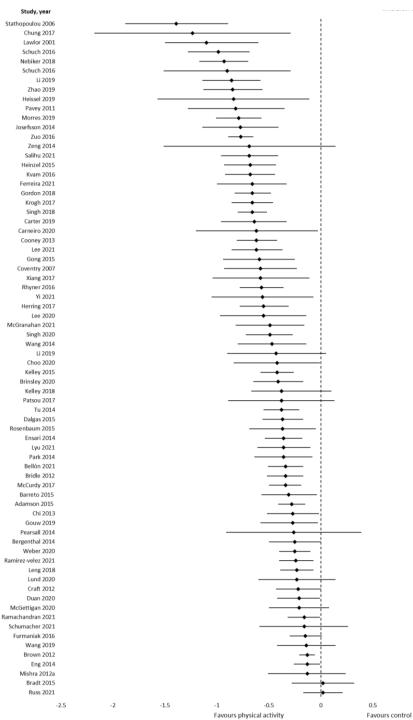




Exercise intensity High: -0.70 Moderate: -0.56 Low: -0.22

Exercise duration <12 weeks: -0.84 12-23 weeks: -0.46 ≥24 weeks: -0.28

Effect size interpretation: -0.2 = Small effect -0.5 = Medium Effect -0.8 = Large effect



Study, year

Gordon 2018

Adamson 2015

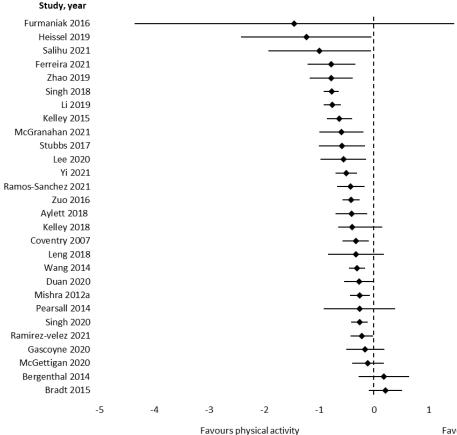
Furmaniak 2016

Anxiety (overall effect size): -0.42

HIV/AIDS: -1.23 Healthy adults: -0.85 Kidney disease: -0.78 Breast cancer: -0.53

Mixed-mode: -0.35 Aerobic: -0.29 Resistance: -0.23

Yoga & mind body: –0.42



Effect size interpretation: -0.2 = Small effect -0.5 = Medium Effect -0.8 = Large effect

Favours control



Exercise intensity Moderate: -0.47 High: -0.44 Low: -0.26

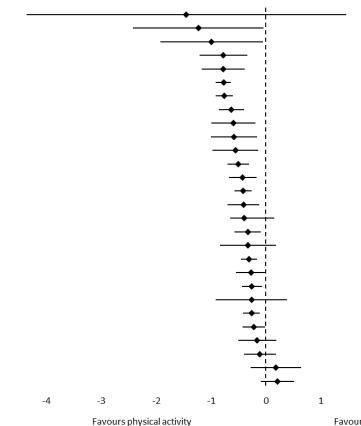
Exercise duration <12 weeks: -0.55 12-23 weeks: -0.47 ≥24 weeks: -0.15



Study, year Furmaniak 2016

Heissel 2019 Salihu 2021 Ferreira 2021 Zhao 2019 Singh 2018 Li 2019 Kelley 2015 McGranahan 2021 Stubbs 2017 Lee 2020 Yi 2021 Ramos-Sanchez 2021 Zuo 2016 Aylett 2018 Kelley 2018 Coventry 2007 Leng 2018 Wang 2014 Duan 2020 Mishra 2012a Pearsall 2014 Singh 2020 Ramirez-velez 2021 Gascoyne 2020 McGettigan 2020 Bergenthal 2014 Bradt 2015

-5



Effect size interpretation: -0.2 = Small effect -0.5 = Medium Effect -0.8 = Large effect

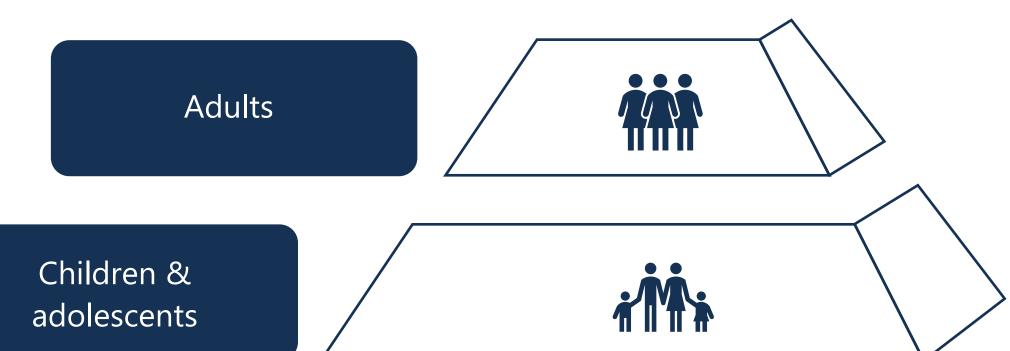
- All types of physical activity are beneficial.
- Greatest benefits in depression, healthy individuals, HIV & kidney disease.
- Higher intensity is more beneficial.
- Effects reduce over time.



- Aim for at least 150 minutes of moderate-intensity or 75 minutes of vigorous-intensity activity each week.
- Even a small amount of physical activity is better than none.
- Any type of physical activity is better than none.
- Find an activity that you enjoy and that fits into your lifestyle.







Children aged 3-17 years

- 4.4% have depression¹
- 9.4% have anxiety¹
- Prevalence increased by 24% and 27% between 2016-2020²

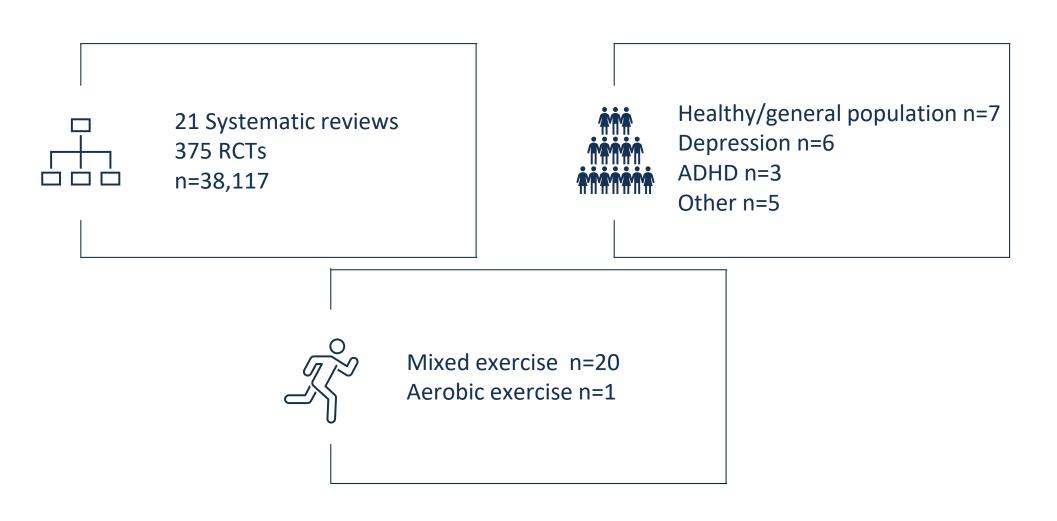


¹Centres for Disease Control and Prevention (2023). ² Lebrun-Harris, JAMA Pediatrics (2023)



Evaluate the effects of exercise on depression and anxiety symptoms in children and adolescents and identify the most effective exercise-based approaches





Overall effect size: -0.45, p<0.01

ADHD: -1.09 Mental illness: -1.07 Other clinical: -0.43 Overweight/obese: -0.39 Healthy/general population: -0.11

Study					Effect size Weigh with 95% CI (%)	
Sun 2024				-	-1.67 [-2.87, -0.47] 1.16	
Barahona-Fuentes 2021 (Resistance exercise)	_				-1.61 [-2.54, -0.68] 1.76	
Barahona-Fuentes 2021 (Mixed-mode exercise)	_				-1.33 [-2.55, -0.11] 1.12	
Sun 2022		-	-		-0.72 [-1.55, 0.11] 2.12	
Peng 2022			-	-	-0.68 [-0.98, -0.38] 6.24	
Wang 2022				-	-0.67 [-1.01, -0.34] 5.82	
Larun 2006			·		-0.66 [-1.25, -0.08] 3.43	
Zhang 2022				_	-0.65 [-1.03, -0.27] 5.30	
Radovic 2017				<u> </u>	-0.61 [-1.06, -0.16] 4.57	
Bailey 2018				⊢	-0.59 [-1.07, -0.10] 4.24	
Axelsdóttir 2021				—	-0.59 [-1.08, -0.10] 4.19	
Wang 2022				F	-0.57 [-0.90, -0.24] 5.82	
Carter 2016				-	-0.48 [-0.86, -0.09] 5.25	
Oberste 2020			-	-	-0.47 [-0.70, -0.24] 7.04	
Chen 2024					-0.39 [-0.51, -0.26] 8.23	
Recchia 2023				-	-0.29 [-0.47, -0.10] 7.62	
Brown 2013				-	-0.26 [-0.43, -0.08] 7.73	
Andermo 2020				-	-0.01 [-0.20, 0.19] 7.47	
Zang 2023				-	0.06 [-0.38, 0.50] 4.67	
Neill 2020					0.10 [-0.20, 0.40] 6.24	
Overall					-0.45 [-0.59, -0.31]	
Heterogeneity: $\tau^2 = 0.06$, $I^2 = 71.37\%$, $H^2 = 3.49$						
Test of $\theta_i = \theta_j$: Q(19) = 57.89, p = 0.00						
Test of θ = 0: z = -6.38, p = 0.00						
	-3	-2	-1	0	1	

Effect size interpretation: -0.2 = Small effect -0.5 = Medium Effect -0.8 = Large effect ADHD: Attention deficit hyperactivity disorder

Random-effects REML model

Exercise mode Mixed mode: -1.20 Resistance: -1.05 Aerobic: -0.43 Yoga: -0.12

Exercise intensity MVPA: -1.06 Moderate: -0.91 Vigorous : -0.38 Low: -0.20

Study						ect size 95% CI	Weight (%)
Sun 2024					-1.67 [-	2.87, -0.47]	1.16
Barahona-Fuentes 2021 (Resistance exercise)					-1.61 [-	2.54, -0.68]	1.76
Barahona-Fuentes 2021 (Mixed-mode exercise)				—	-1.33 [-	2.55, -0.11]	1.12
Sun 2022		-			-0.72 [-	1.55, 0.11]	2.12
Peng 2022				-	-0.68 [-	0.98, -0.38]	6.24
Wang 2022				-	-0.67 [-	1.01, -0.34]	5.82
Larun 2006					-0.66 [-	1.25, -0.08]	3.43
Zhang 2022				_	-0.65 [-	1.03, -0.27]	5.30
Radovic 2017				—	-0.61 [-	1.06, -0.16]	4.57
Bailey 2018					-0.59 [-	1.07, -0.10]	4.24
Axelsdóttir 2021					-0.59 [-	1.08, -0.10]	4.19
Wang 2022				F	-0.57 [-	0.90, -0.24]	5.82
Carter 2016				-	-0.48 [-	0.86, -0.09]	5.25
Oberste 2020			-	-	-0.47 [-	0.70, -0.24]	7.04
Chen 2024					-0.39 [-	0.51, -0.26]	8.23
Recchia 2023				-	-0.29 [-	0.47, -0.10]	7.62
Brown 2013				-	-0.26 [-	0.43, -0.08]	7.73
Andermo 2020				-	-0.01 [-	0.20, 0.19]	7.47
Zang 2023					- 0.06 [-	0.38, 0.50]	4.67
Neill 2020				-	- 0.10 [-	0.20, 0.40]	6.24
Overall					-0.45 [-	0.59, -0.31]	
Heterogeneity: $\tau^2 = 0.06$, $I^2 = 71.37\%$, $H^2 = 3.49$							
Test of $\theta_i = \theta_j$: Q(19) = 57.89, p = 0.00							
Test of θ = 0: z = -6.38, p = 0.00							
	-3	-2	-1	0	 1		
	U	~	•	U	I		

Effect size interpretation: -0.2 = Small effect -0.5 = Medium Effect -0.8 = Large effect Random-effects REML model

Overall effect size: -0.39, p=0.01

Mental illness: -0.55 ADHD: -0.42 Obese/overweight: -0.30

Study				Effect size with 95% CI	Weight (%)
Barahona-Fuentes 2021			-1.7	75 [-3.02, -0.48]	2.58
Zhang 2022			-0.7	75 [-1.15, -0.35]	12.65
Cerrillo-Urbina 2015			-0.6	66 [-1.19, -0.14]	9.74
Larun 2006			-0.4	48 [-0.97, 0.01]	10.51
Andermo 2020			-0.3	35 [-0.62, -0.07]	16.55
Chen 2024			-0.3	30 [-0.43, -0.18]	20.96
Sun 2024			-0.2	22 [-0.76, 0.32]	9.33
Neill 2020		-	- 0.0	04 [-0.20, 0.28]	17.68
Overall		•	-0.3	39 [-0.61, -0.17]	
Heterogeneity: $\tau^2 = 0.05$, $I^2 = 68.08\%$, $H^2 = 3.13$					
Test of $\theta_i = \theta_j$: Q(7) = 19.94, p = 0.01					
Test of θ = 0: z = -3.50, p = 0.00					
	-3 -2	-1 0	1		

Random-effects REML model

Effect size interpretation: -0.2 = Small effect -0.5 = Medium Effect -0.8 = Large effect

Exercise mode Resistance: -0.90 Aerobic: -0.19

Intervention duration >8 weeks: -1.87 ≤8 weeks: -0.64

Session duration > 30 mins: -1.21 ≤ 30 mins: -0.15

Frequency >3/week: -1.35 1-3/week: -0.70

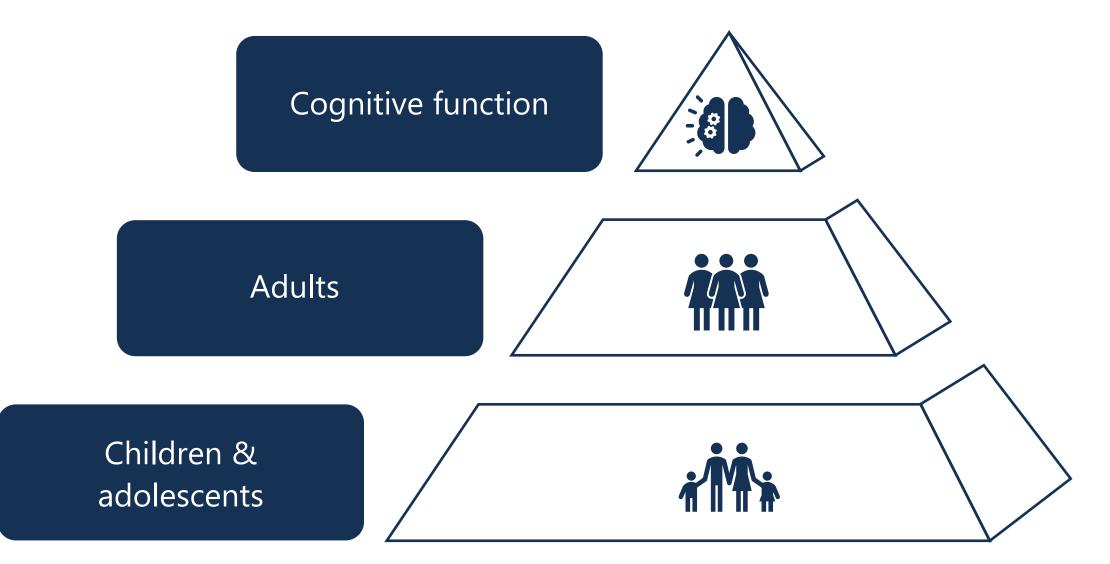
Study			Effect size Weig with 95% CI (%)	
Barahona-Fuentes 2021		•	-1.75 [-3.02, -0.48] 2.58	8
Zhang 2022			-0.75 [-1.15, -0.35] 12.65	5
Cerrillo-Urbina 2015		B	-0.66 [-1.19, -0.14] 9.74	4
Larun 2006			-0.48 [-0.97, 0.01] 10.5 ²	1
Andermo 2020			-0.35 [-0.62, -0.07] 16.55	5
Chen 2024			-0.30 [-0.43, -0.18] 20.96	6
Sun 2024			0.22 [-0.76, 0.32] 9.33	3
Neill 2020		- -	0.04 [-0.20, 0.28] 17.68	8
Overall		•	-0.39 [-0.61, -0.17]	
Heterogeneity: $\tau^2 = 0.05$, $I^2 = 68.08\%$, $H^2 = 3.13$	5			
Test of $\theta_i = \theta_j$: Q(7) = 19.94, p = 0.01				
Test of θ = 0: z = -3.50, p = 0.00	rr			
	-3 -2	2 -1 0	1	

Random-effects REML model

Depression & anxiety

- Mixed mode & resistance exercise
- ADHD & mental illness
- Moderate & MVPA
- >8 weeks, >30 minutes & >3x per week



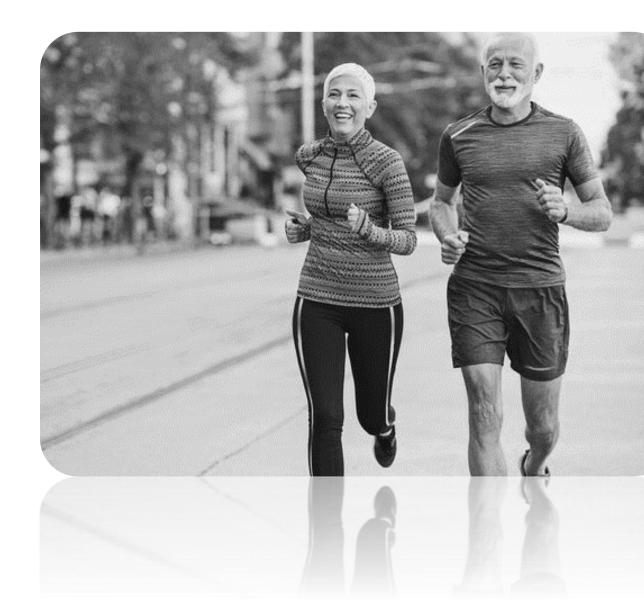






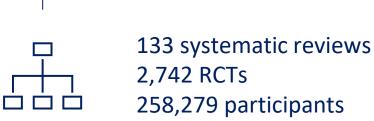
Median prevalence of 19% in adults aged 50+ globally¹.

Global prevalence of dementia is projected to reach 82 million by 2030 and 152 million by 2050¹.





Umbrella review to summarise all existing systematic reviews on the effects of exercise on general cognition & memory. Exercise & cognition





Older adults n=72 Adults n=47 Children n=11 Children & adults n=3



Various modes n=103 Aerobic n=7, resistance n=5, Tai Chi n=5, dance n=5, exergames n=4, Yoga n=2, Baduanjin n=2

Cognitive function (overall effect size): 0.42



Population Healthy adults: 0.47 Dementia: 0.44 Chronic diseases: 0.41



Age group Older adults: 0.42 Adults: 0.40 Children: 0.28

Effect size interpretation: 0.2 = Small effect 0.5 = Medium Effect 0.8 = Large effect

Cognitive function

The second s		E	ffect size th 95% C
Study Sarha 2017 (Resistance)			
Somez 2023		0.01	[-2.88, - [-0.55,
J 2023C			.0.09
Sehn 2020	+		[-0.16,
Buckenschneider 2019 (Aerobic) Jin 2023	t		(-0.38, (-0.21,
in 2023 Nang 2022B (M-ACE)	T		[-0.21, [-0.41,
J 2023A (Cognitive speed)	-		1-0.07.
Irondino 2017		0.08	-0.09,
Ingevaren 2008			-0.16,
Ju 2022 (3MSE)		0.1	-0.96,
Sanders 2019 Ju 20238 (ADAS- Cog)		0.1 0.1	-0.04,
shu 20208 (HDHS= Cog) Shu 2020		0.1	-0.09,
Pattab 2021	-	0.1	0.00,
Celly 2014		0.1	-0.13,
Clifford 2023		0.1	-0.27,
Belbim 2022 Nardat 2022	•	0.1 0.1	0.05,
J 2023A		0.2	0.06,
Jin 2022		0.2	0.12,
Vang 2022B (MMSE)	•	0.2	-0.02,
Jang 2022 /eldema 2020	•	0.2	0.06,
		0.2	-0.50,
udyga 2020		0.2	0.17, 0.15,
Falck 2019 (Cognitive function) fermoso 2020		0.2	0.15,
Cai 2017		0.2	0.11,
ki 2023A		0.2	0.08,
iorthey 2018		0.2	0.17,
Dauwan 2021	-	0.3	-0.03,
Oberlin 2017 Jong 2018		0.3	0.14, 0.11,
long 2018 Balbim 2022		0.3	0.11, 0.05,
Cai 2020 (Cognitive function)		0.1	0.28.
Jan 2020 (MMSE)	-	0.3	0.06,
ian 2020 (Overall cognitive function)	•	0.3	0.10,
Stuckenschneider 2019 (Mixed-mode)		0.3	-0.57,
ian 2020 (MoCA) falck 2019 (Global cognition)		0.2	-0.09, 0.15,
lanabria 2022		0.3	0.08
Sehn 2020		0.3	0.17,
ang 2020		0.3	0.12,
Park 2023	•	0.3	0.20,
Pensoon 2013	•	0.3	0.13,
.iu 2022 (Overall cognitive function) Shohani 2020	•	0.1	0.13,
Cai 2020 (Global cognition)		0.4	0.34,
5hou 2022		0.4	0.24
Garamacoska 2023	+	0.4	0.14,
iroot 2016	-	0.4	0.22,
orbes 2013		0.4	-0.06,
Stanmore 2017 .aw 2020	1 () () () () () () () () () (0.4	0.19, 0.27,
J 2019		0.4	-0.21,
Nang 2022A (Multi-mode exercise)		0.4	0.11,
Jan 2020 (ADAS-Cog) Rey 2023	-	0.4	0.08,
Roy 2023	+	0.4	0.07,
Jang 2022 Ji 20238	•	0.4	0.29.
a 20236 Aa 2023		0.4	-0.01, 0.04,
Sanders 2019	+	0.4	0.19
Chan 2020	-	0.4	0.21,
Aartins 2022 (FAB)		0.4	-0.09.
Cardona 2021	-	0.4	0.19,
J 20228 Wu 2021 (MMSE)		0.5	0.08, 0.19,
0un 2020 (MMISE) Dun 2020	-	0.5	0.19,
Ju 2022 (MoCA)		0.5	0.00,
J 2022A	+	0.5	0.16,
thang 2020		0.5	0.02,
Nu 2021 (Overall cognitive function)	-	0.5	0.24,
la Silva 2023 (MMSE) re 202	-	0.5	0.24, 0.34,
tevn 2004		0.5	0.34,
la Silva 2023 (Overall cognitive function)		0.5	0.34,
Nu 2021 (MoCA)		0.5	0.02_
la Silva 2023 (MoCA)		0.6	0.11.
Dang 2019 Ju 2023B (Overall cognitive function)		0.8 0.8	0.39, 0.36.
Nang 2023B (Overall cognitive function)	-	0.6	0.36,
/in 2023		0.6	0.21,
Ann 20238	+	0.8	0.39,
Song 2022	+	0.6	0.34,
5hang 2023	-	0.8	0.31, 0.43,
Almeida 2020 Jandrigan 2020	-	0.7	0.43, 0.30,
Sarreto 2018		0.7	0.30,
iu 2023B (MoCA)		0.7	0.32,
iu 2023B (MMSE)	+	0.7	0.35,
Nhn 2023A	-	0.7	0.37,
iu 2022 (MMSE) Nang 2022B (MoCA)		8.0 8.0	0.07, 0.50,
Wang 20228 (MoCA) Wang 2022A (Single-mode exercise)		0.8	0.50,
Barha 2017 (Aerobic)		5.0	0.24,
.ee 2020		8.0	0.11,
chen 2023	-	0.5	0.61,
Martins 2022 (Overall cognitive function)		0.5	0.20,
Tam 2022 Yan 2023		0.5	0.31,
fan 2023 Farina 2014		0.9	0.30, 0.37,
la 2019	-	ŝ.	0.57,
Sexton 2019		1.2	0.25,
Dai 2022		1.3	0.24,
Aartins 2022 (MMSE)	a second second	14	0.24,
fin 2023 Barha 2017 (Mixed-mode)		1.8 1.8	0.82, 1.41,
Sama 2017 (Miked-mode) Overall		0.4	0.37,
seterogeneity: τ ² = 0.05, i ² = 82.73%, H ² =		-	w.dr.
fest of 8, = 8; Q(106) = 402.50, p = 0.00			
fest of 0 = 0: z = 15.89, p = 0.00			·
	3 2 1 0 1 2	£	



Exergames: 0.61 Yoga: 0.44 Dance: 0.43 Mixed mode: 0.42 Resistance: 0.30 Aerobic: 0.20

Exercise intensity No significant differences between low, moderate, MVPA and vigorous intensity.

Effect size interpretation: 0.2 = Small effect 0.5 = Medium Effect 0.8 = Large effect



-3

Memory (overall effect size): 0.26

***1.**

Population Healthy adults: 0.38 Neurological disorders: 0.29 Dementia: 0.20



Age group Children: 0.85 Older adults: 0.27 Adults: 0.20

Effect size interpretation: 0.2 = Small effect 0.5 = Medium Effect 0.8 = Large effect

Memory

Study		with 95% CI	(%)
Angevaren 2008 (Memory functions, delayed)		-0.55 [-2.10, 1.00]	0.14
Stuckenschneider 2019 (Mixed mode)		-0.49 [-0.80, -0.18]	1.50
Angevaren 2008 (Visual functions, immediate)		-0.15 [-0.58, 0.28]	1.07
Gates 2013	+	-0.01 [-0.16, 0.14]	2.20
Song 2018 (Delayed recall)	+	0.00 [-0.14, 0.14]	2.24
Wu 2021A (Delayed memory)		0.01 [-0.39, 0.41]	
Barha 2017 (Aerobic)		0.04 [-0.37, 0.45]	1.16
Song 2018	•	0.04 [-0.07, 0.15]	2.37
Brondino 2017 (Verbal)	-	0.05 [-0.13, 0.23]	
Ye 2021 (Semantic, neurological diseases)	-	0.05 [-0.13, 0.23]	2.05
Angevaren 2008 (Verbal functions, immediate)	1	0.06 [-0.30, 0.42]	1.31
Barha 2017 (Resistance)	Ī	0.07 [-0.08, 0.22]	
Balbim 2022 Biazus-Sehn 2020 (Immediate recall)	T	0.09 [-0.08, 0.26] 0.09 [-0.08, 0.27]	2.11
Law 2020 (Memory recognition)		0.10 [-0.49, 0.69]	0.72
Song 2018 (Immediate recall test)		0.10 [-0.07, 0.27]	
Sanders 2019 (Adults with cognitive impairment)		0.11 [-0.07, 0.29]	
Dauwan 2021		0.12 [0.04, 0.20]	
Smith 2010		0.13 [0.02, 0.24]	
Zhang 2019	-	0.13 [-0.03, 0.28]	
Law 2020 (Delayed memory)	-	0.15 [0.00, 0.30]	
Wu 2021A (Verbal memory)		0.15 [-0.40, 0.70]	
Li 2023		0.17 [0.01, 0.33]	
Biazus-Sehn 2020 (Delayed recall)	-	0.18 [0.00, 0.36]	
Falck 2019	-	0.21 [0.04, 0.38]	2.11
Ludyga 2020	-	0.22 [0.12, 0.32]	2.37
Khattab 2021	+	0.24 [0.03, 0.45]	1.93
Wu 2019 (Learning and memory)		0.24 [0.10, 0.38]	2.22
Brondino 2017 (Visual)		0.24 [0.00, 0.47]	1.82
Zheng 2016 (Delayed recall ability)	-	0.25 [0.05, 0.45]	1.98
Zheng 2016 (Immediately recall ability)		0.26 [0.00, 0.52]	1.71
Kelly 2014 (Aerobic, delayed recall)		0.27 [-0.08, 0.62]	1.34
Wu 2021A (Immediate memory)		0.27 [0.00, 0.54]	1.69
Aghjayan 2022	-	0.28 [0.10, 0.46]	2.07
Xiang-Lian 2020 (Wechsler immediate recall)		0.28 [-0.06, 0.62]	1.40
Zhu 2020	-	0.28 [0.11, 0.45]	2.11
Kelly 2014 (Aerobic, immediate recall)		0.29 [-0.25, 0.83]	0.81
Cai 2020	•	0.31 [0.23, 0.39]	
Sanders 2019 (Healthy adults)		0.31 [0.10, 0.52]	1.91
Chan 2020 (Delayed recall)	-	0.33 [0.02, 0.65]	1.48
Wu 2021B	•	0.33 [0.17, 0.49]	
Northey 2018	• •	0.36 [0.22, 0.50]	
Xiang-Lian 2020 (Wechsler immediate and delayed recall)	-	0.37 [0.14, 0.60]	
Karamacoska 2023 Stuckenschneider 2019 (Aerobic)		0.41 [-0.00, 0.82] 0.45 [-0.76, 1.66]	1.14 0.22
Xiang-Lian 2020 (Wechsler delayed recall)		0.45 [0.11, 0.79]	1.38
Ye 2021 (Working memory, neurological diseases)		0.46 [0.25, 0.67]	1.93
Barha 2017 (Mixed-mode)		0.48 [0.33, 0.63]	2.18
Ye 2021 (Short term memory, healthy)		0.51 [0.09, 0.92]	
Stanmore 2017 (Verbal learning and memory)		0.53 [-0.07, 1.13]	
Chan 2020 (Immediate recall)		0.54 [0.38, 0.71]	
Ye 2021 (Semantic memory, healthy)		0.59 [0.20, 0.98]	1.20
Wu 2021C		0.68 [0.23, 1.13]	
Ye 2021 (Short term memory, neurological diseases)		0.68 [0.16, 1.20]	0.85
Ye 2021 (Episodic memory, healthy)		0.74 [0.44, 1.04]	1.52
Ye 2021 (Long-term memory, healthy)	-	0.78 [0.57, 0.99]	1.93
Ye 2021 (Long-term memory, neurological diseases)		0.80 [0.27, 1.34]	0.82
Hoffmann 2021		0.80 [0.13, 1.47]	0.60
Ferreira-Vorkapic 2015		0.85 [0.56, 1.15]	1.56
Ye 2021 (Episodic memory, neurological diseases)		0.91 [0.37, 1.45]	0.81
Stanmore 2017 (Spatial learning and memory)		- 1.23 [-0.93, 3.39]	0.07
Ye 2021 (General memory, healthy)		1.24 [0.39, 2.09]	0.40
Overall		0.26 [0.20, 0.32]	
Heterogeneity: τ ² = 0.04, l ² = 78.16%, H ² = 4.58			



Exergames: 0.58 Yoga: 0.51 Dance: 0.41 Mixed mode: 0.42 Aerobic: 0.14 Resistance: 0.13

Exercise intensity Moderate: 0.41 Vigorous: 0.23 Low: 0.15

Effect size interpretation: 0.2 = Small effect 0.5 = Medium Effect 0.8 = Large effect

Memory

udy	1	Effect size with 95% CI	Weight (%)
ngevaren 2008 (Memory functions, delayed)		-0.55 [-2.10, 1.00]	0.14
tuckenschneider 2019 (Mixed mode)		-0.49 [-0.80, -0.18]	1.50
ngevaren 2008 (Visual functions, immediate)		-0.15 [-0.58, 0.28]	1.07
sates 2013	Ī	-0.01 [-0.16, 0.14]	2.20
ong 2018 (Delayed recall) /u 2021A (Delayed memory)	<u> </u>	0.00 [-0.14, 0.14] 0.01 [-0.39, 0.41]	2.24 1.16
arha 2017 (Aerobic)		0.04 [-0.37, 0.45]	1.16
ong 2018	_	0.04 [-0.07, 0.15]	2.37
rondino 2017 (Verbal)	+	0.05 [-0.13, 0.23]	2.07
e 2021 (Semantic, neurological diseases)	+	0.05 [-0.13, 0.23]	2.05
ngevaren 2008 (Verbal functions, immediate)	+-	0.06 [-0.30, 0.42]	1.31
arha 2017 (Resistance)	+	0.07 [-0.08, 0.22]	2.20
albim 2022	+	0.09 [-0.08, 0.26]	2.11
iazus-Sehn 2020 (Immediate recall)	*	0.09 [-0.08, 0.27]	2.09
aw 2020 (Memory recognition)		0.10 [-0.49, 0.69]	0.72
ong 2018 (Immediate recall test) anders 2019 (Adults with cognitive impairment)		0.10 [-0.07, 0.27] 0.11 [-0.07, 0.29]	2.13 2.09
auwan 2021		0.12 [0.04, 0.20]	2.43
mith 2010	-	0.13 [0.02, 0.24]	2.35
hang 2019		0.13 [-0.03, 0.28]	2.18
aw 2020 (Delayed memory)	-	0.15[0.00, 0.30]	2.20
/u 2021A (Verbal memory)	<u></u> →-	0.15 [-0.40, 0.70]	0.78
i 2023	•	0.17 [0.01, 0.33]	2.18
iazus-Sehn 2020 (Delayed recall)	+	0.18 [0.00, 0.36]	2.07
alck 2019	-	0.21 [0.04, 0.38]	2.11
udyga 2020	•	0.22 [0.12, 0.32]	2.37
hattab 2021 /u 2019 (Learning and memory)		0.24 [0.03, 0.45] 0.24 [0.10, 0.38]	1.93 2.22
rondino 2017 (Visual)	-	0.24 [0.00, 0.47]	1.82
heng 2016 (Delayed recall ability)		0.25 [0.05, 0.45]	1.98
heng 2016 (Immediately recall ability)		0.26 [0.00, 0.52]	1.71
elly 2014 (Aerobic, delayed recall)		0.27 [-0.08, 0.62]	1.34
/u 2021A (Immediate memory)		0.27 [0.00, 0.54]	1.69
ghjayan 2022		0.28 [0.10, 0.46]	2.07
iang-Lian 2020 (Wechsler immediate recall)		0.28 [-0.06, 0.62]	1.40
hu 2020	-	0.28 [0.11, 0.45]	2.11
elly 2014 (Aerobic, immediate recall)		0.29 [-0.25, 0.83]	0.81
ai 2020 anders 2019 (Healthy adults)		0.31 [0.23, 0.39] 0.31 [0.10, 0.52]	2.43 1.91
chan 2020 (Delayed recall)	- I	0.33 [0.02, 0.65]	1.48
/u 2021B		0.33 [0.17, 0.49]	2.16
lorthey 2018		0.36 [0.22, 0.50]	2.24
iang-Lian 2020 (Wechsler immediate and delayed recall)	-	0.37 [0.14, 0.60]	1.86
aramacoska 2023		0.41 [-0.00, 0.82]	1.14
tuckenschneider 2019 (Aerobic)		0.45 [-0.76, 1.66]	0.22
iang-Lian 2020 (Wechsler delayed recall)		0.45[0.11, 0.79]	1.38
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chan 2020 (Immediate recall)		0.54 [0.38, 0.71]	2.13
e 2021 (Semantic memory, healthy)		0.59 [0.20, 0.98]	1.20
Vu 2021C		0.68 [0.23, 1.13]	1.01
e 2021 (Short term memory, neurological diseases)		0.68 [0.16, 1.20]	0.85
e 2021 (Episodic memory, healthy)		0.74 [0.44, 1.04]	1.52
e 2021 (Long-term memory, healthy)	-	0.78 [0.57, 0.99]	1.93
e 2021 (Long-term memory, neurological diseases)		0.80 [0.27, 1.34]	0.82
offmann 2021		0.80 [0.13, 1.47]	0.60
erreira-Vorkapic 2015		0.85 [0.56, 1.15]	1.56
e 2021 (Episodic memory, neurological diseases) tanmore 2017 (Spatial learning and memory)		0.91 [0.37, 1.45] - 1.23 [-0.93, 3.39]	0.81 0.07
e 2021 (General memory, healthy)		1.24 [0.39, 2.09]	0.40
verall		0.26 [0.20, 0.32]	2.10
eterogeneity: τ ² = 0.04, I ² = 78.16%, H ² = 4.58	ľ	0.20[0.20, 0.32]	
est of $\theta_i = \theta_i$: $Q(61) = 222.18$, $p = 0.00$			
est of $\theta = 0$: z = 8.72, p = 0.00			
-	2 0 2	4	
ndom-effects REML model			

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- Improved cognition & memory across all ages & health conditions.
- Exergaming & mind-body exercise show particularly strong benefits.
- Even light-intensity can enhance cognitive function, making it accessible for diverse populations.



Thank you

Ben Singh, PhD Alliance for Research in Exercise Nutrition and Activity (ARENA), University of South Australia

