Mass General Brigham
Spaulding Rehabilitation

Cardiovascular Health after Traumatic Brain Injury (TBI)

Shanti M. Pinto, MD, MSCS

November 2026

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HARVARD MEDICAL SCHOOL
TEACHING HOSPITAL

Disclosures

- Funding Sources
  - NIDILRR (90DPTB0023; 90DPTB0027; 90IFRE0115; 90DPKT0026)
  - NIH/NINDS (1R01NS133245)

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Outline

- Epidemiology of Cardiovascular Disease after TBI
- Impact of Poor Cardiovascular Health after TBI
- Potential Pathophysiologic Mechanisms Leading to Adverse Cardiovascular Outcomes after TBI
- Initial Thoughts on Management

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Outline

- **Epidemiology of Cardiovascular Disease after TBI**
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TBI as a Chronic Health Condition

ACRM
AMERICAN CONGRESS OF REHABILITATION MEDICINE

Archives of Physical Medicine and Rehabilitation

journal homepage: www.archives-pmr.org

Archives of Physical Medicine and Rehabilitation 2013;94:1199-201



SPECIAL COMMUNIC

Traumatic Br

John D. Corrigan,

Traumatic brain injury as a chronic disease: insights from the United States Traumatic Brain Injury Model Systems Research Program

Kristen Dams-O'Connor, Shannon B Juengst, Jennifer Bogner, Nancy D Chiaravalloti, John D Corrigan, Joseph T Giacino, Cynthia L Harrison-Felix, Jeanne M Hoffman, Jessica M Ketchum, Anthony H Lequerica, Jennifer H Marwitz, A Cate Miller, Risa Nakase-Richardson, Amanda R Rabinowitz, Angelle M Sander, Ross Zafonte, Flora M Hammond

Traumatic brain injury (TBI) is a global health priority, associated with substantial burden. Historically conceptualised as an injury event with finite recovery, TBI is now recognised as a chronic condition that can affect multiple domains of health and function, some of which might deteriorate over time. Many people who have had a TBI remain moderately to severely disabled at 5 years, are rehospitalised up to 10 years post-injury, and have a reduced lifespan relative to the general population. Understanding TBI as a chronic disease process can be highly informative for

Lancet Neurol 2023; 22: 517–28

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S1474-4422(23)00065-0

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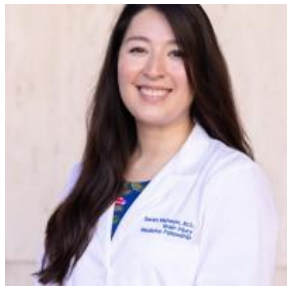
TBI Associated with Increased Risk of Mortality

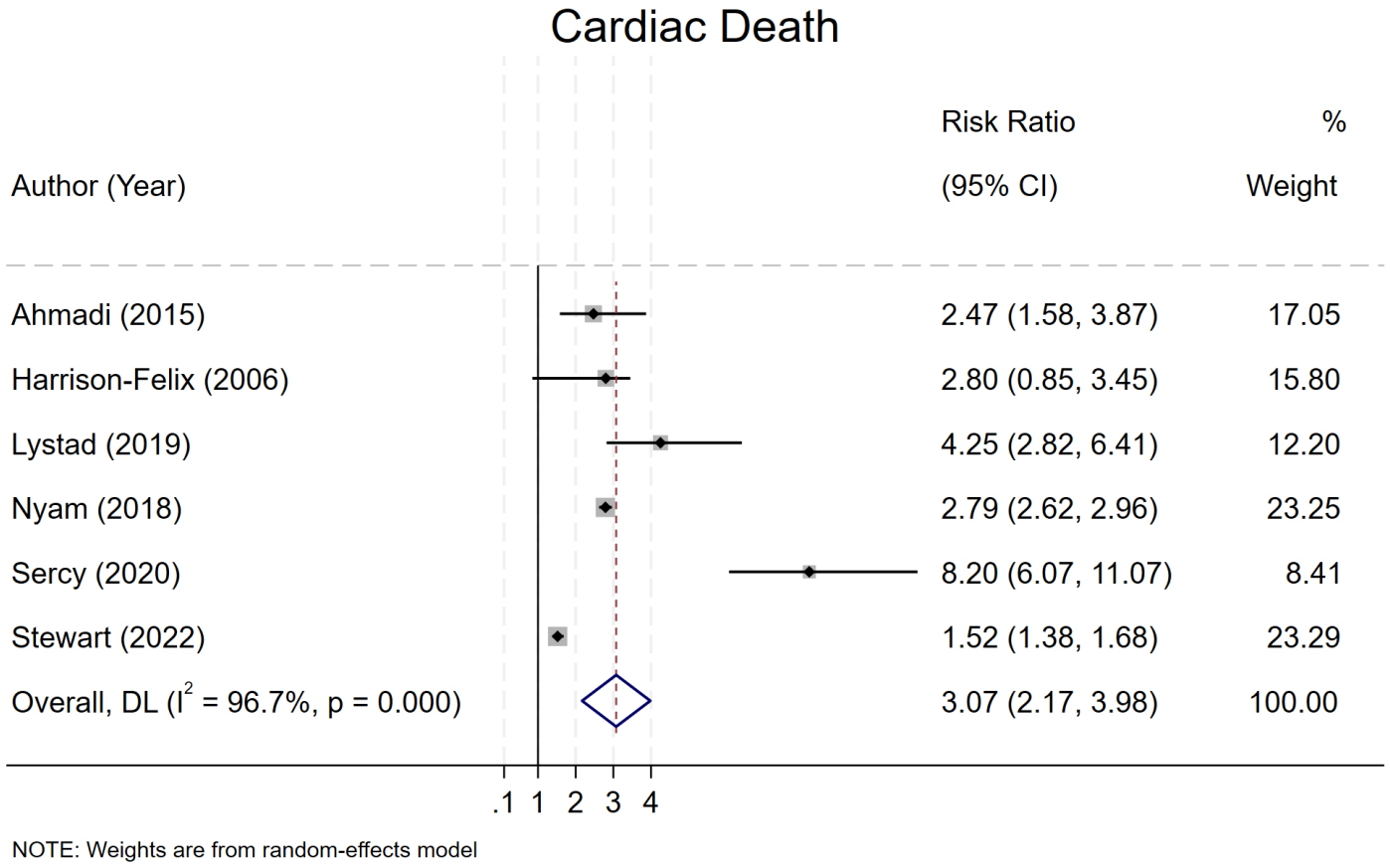
	Observed deaths	Expected deaths	SMR[a]	95% confidence interval
Overall	844	376	**2.25**	**2.10-2.40**
Age at injury, y				
15-19	30	6.3	**4.78**	**3.07-6.49**
20-24	31	9.6	**3.22**	**2.09-4.36**
25-34	63	18.0	**3.50**	**2.64-4.36**
35-44	119	31.3	**3.80**	**3.12-4.48**
45-54	149	40.9	**3.64**	**3.06-4.22**
55-64	122	49.5	**2.47**	**2.03-2.90**
65-74	139	70.0	**1.99**	**1.66-2.32**
75-84	139	99.9	**1.39**	**1.16-1.62**
85+	52	46.7	1.11	0.81-1.42

Harrison-Felix C, Kolakowsky-Hayner SA, Hammond FM, Wang R, Englander J, Dams-O'Connor K, Kreider SE, Novack TA, Diaz-Arrastia R. Mortality after surviving traumatic brain injury: risks based on age groups. *J Head Trauma Rehabil*. 2012 Nov-Dec;27(6):E45-56.

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Elevated Risk of Cardiac Mortality Following TBI

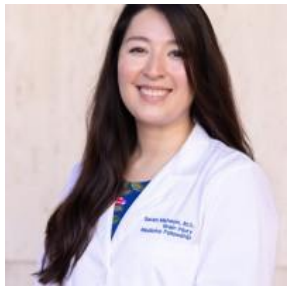


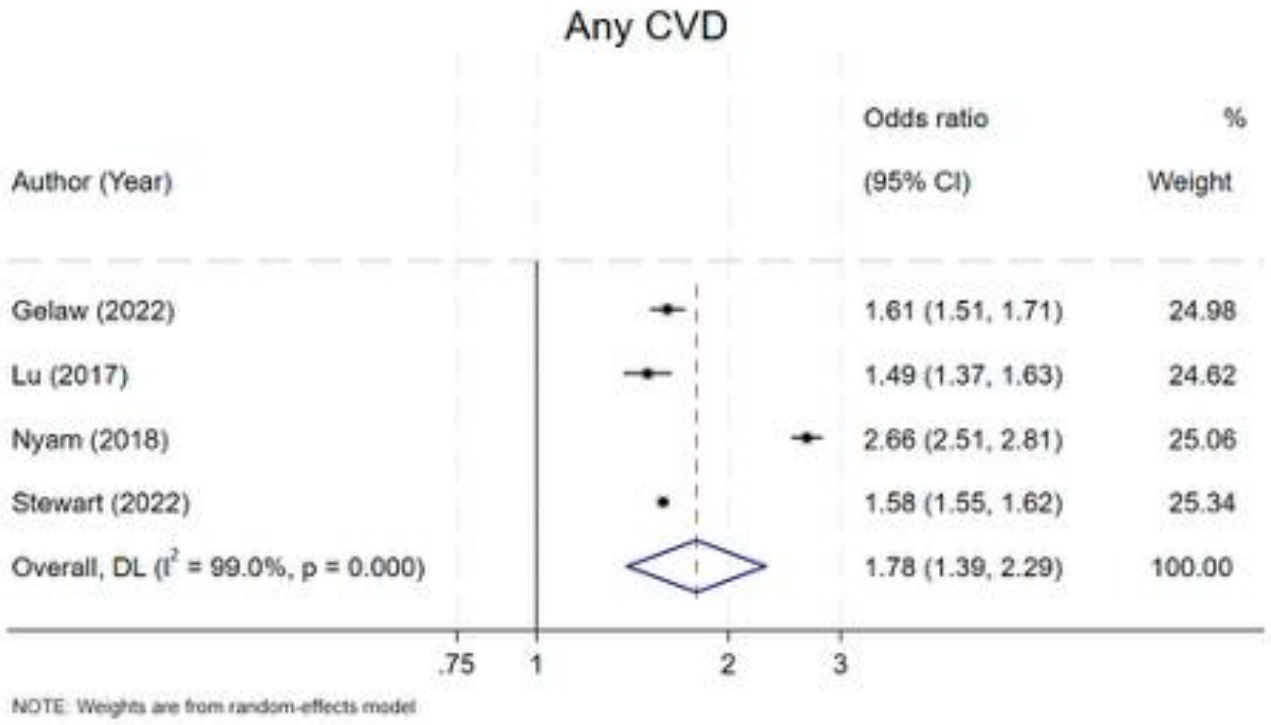


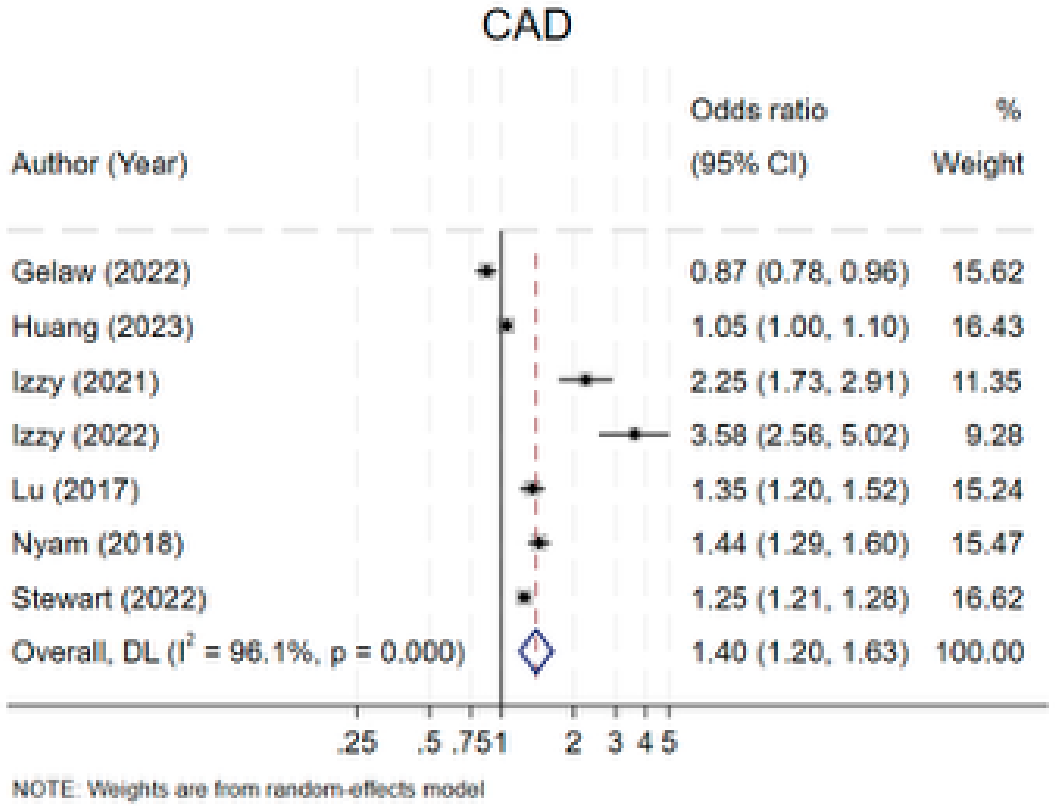
Mahasin SZ, Thakur B, Champagne P, Joshi PH, Bell KB, Driver S, Whitfill JD, Vigen R, Pinto SM. The Association Between Traumatic Brain Injury and Cardiovascular Disease: A Systematic Review and Meta-Analysis. *J Head Trauma Rehabil*. 2026 Mar 19.

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Elevated Odds of CVD Following TBI



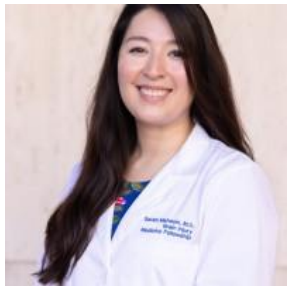


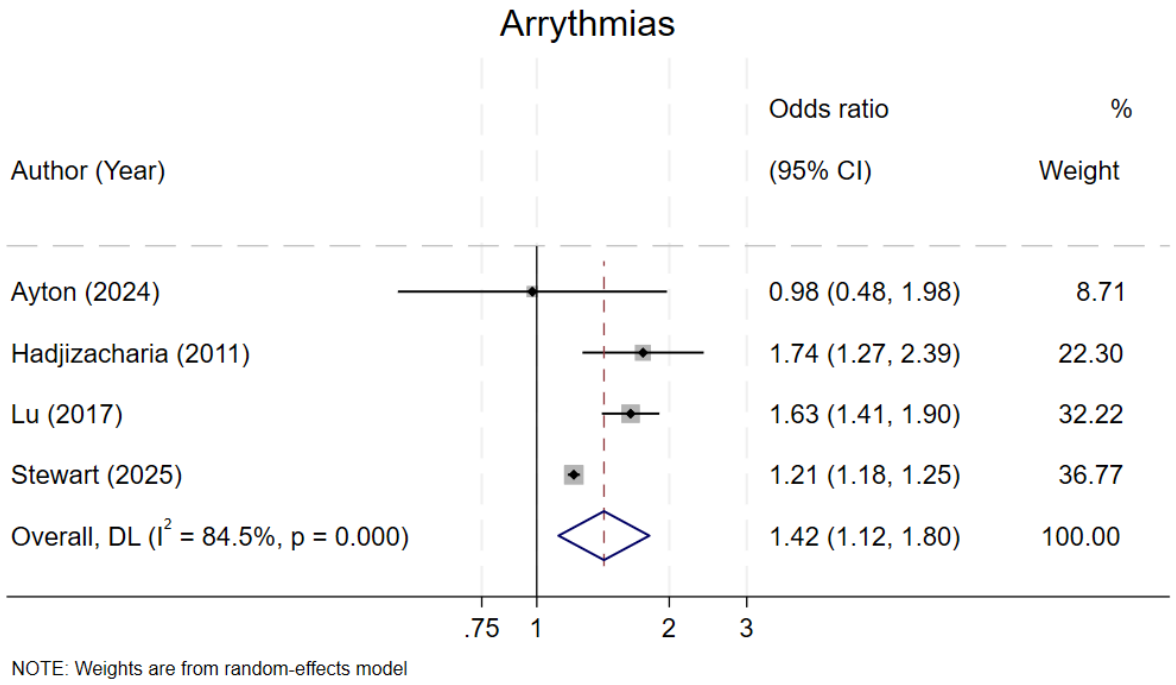


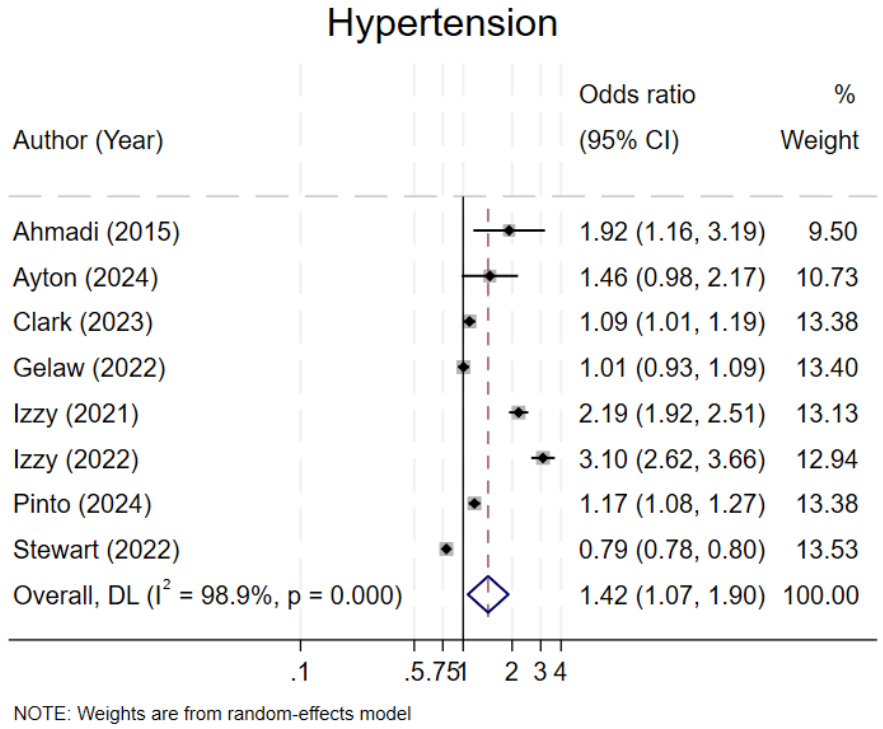
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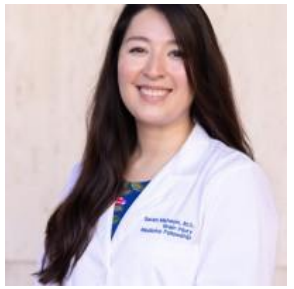




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Stratification Based on TBI Severity



	TBI Severity	N	Odds Ratio/Risk Ratio*	95% CI	p-value
Cardiac Mortality*	Mild	3	3.62	1.14 – 6.11	< 0.001
	Moderate/Severe	2	2.14	1.41 – 2.86	< 0.001
CAD	Mild	2	1.94	1.01 – 3.73	0.046
	Moderate/Severe	2	2.34	0.79 – 6.88	0.123
Arrhythmia	Moderate/Severe	2	1.25	1.16– 1.35	< 0.001
Hypertension	Mild	3	2.39	1.93 – 2.96	< 0.001
	Moderate/Severe	2	2.26	1.00 – 5.13	0.051

*Risk ratio for cardiac mortality, rest are odds ratios

Mahasin SZ, Thakur B, Champagne P, Joshi PH, Bell KB, Driver S, Whitfill JD, Vigen R, Pinto SM. The Association Between Traumatic Brain Injury and Cardiovascular Disease: A Systematic Review and Meta-Analysis. *J Head Trauma Rehabil*. 2026 Mar 19.

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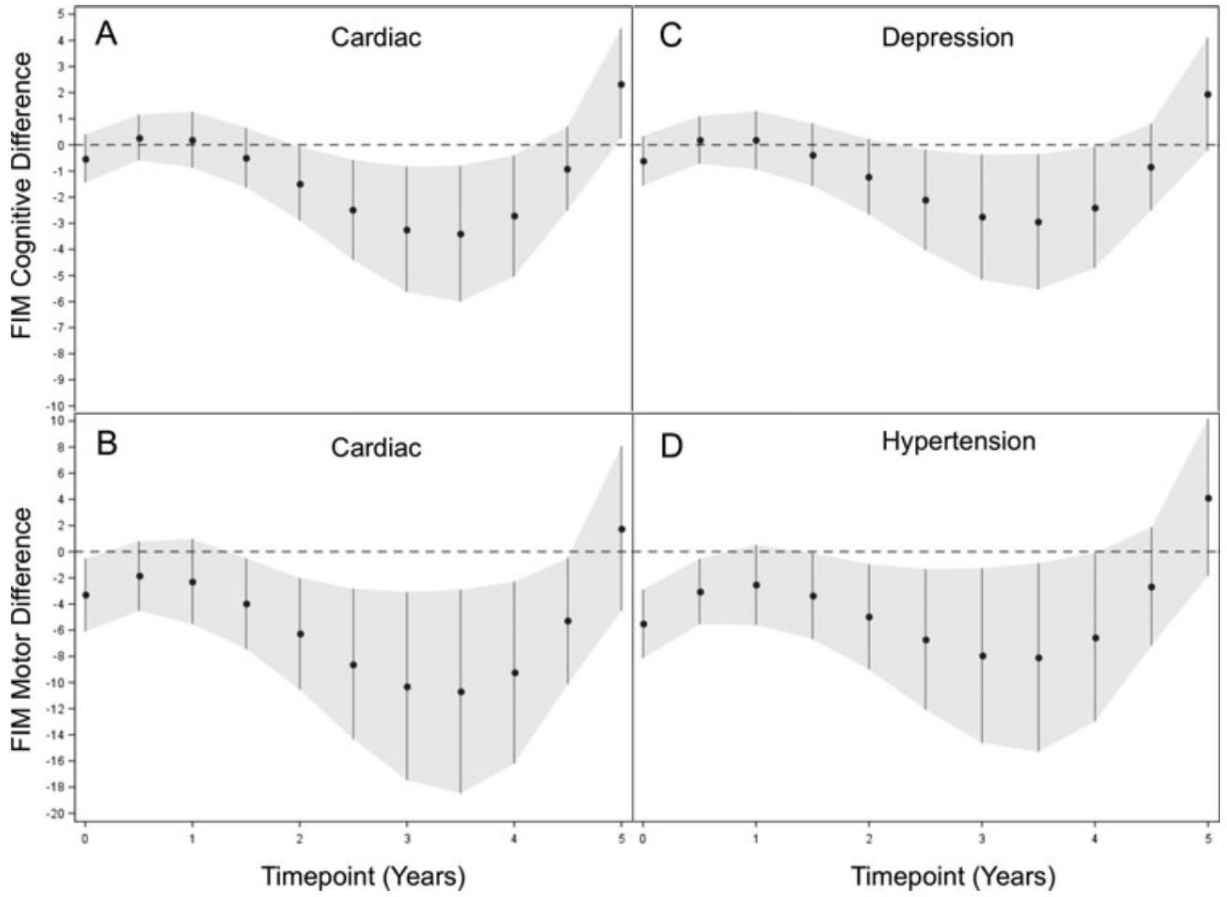
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Co-Morbid Cardiac Disease and Hypertension are Associated with Worse Outcomes after TBI

Condition	FIM Cognition T-value (p-value)	FIM Motor T-value (p-value)
Hypertension	-2.51 (0.0121)	-4.11 (< 0.0001)
Cardiac Disease	-1.10 (0.2715)	-2.32 (0.0204)

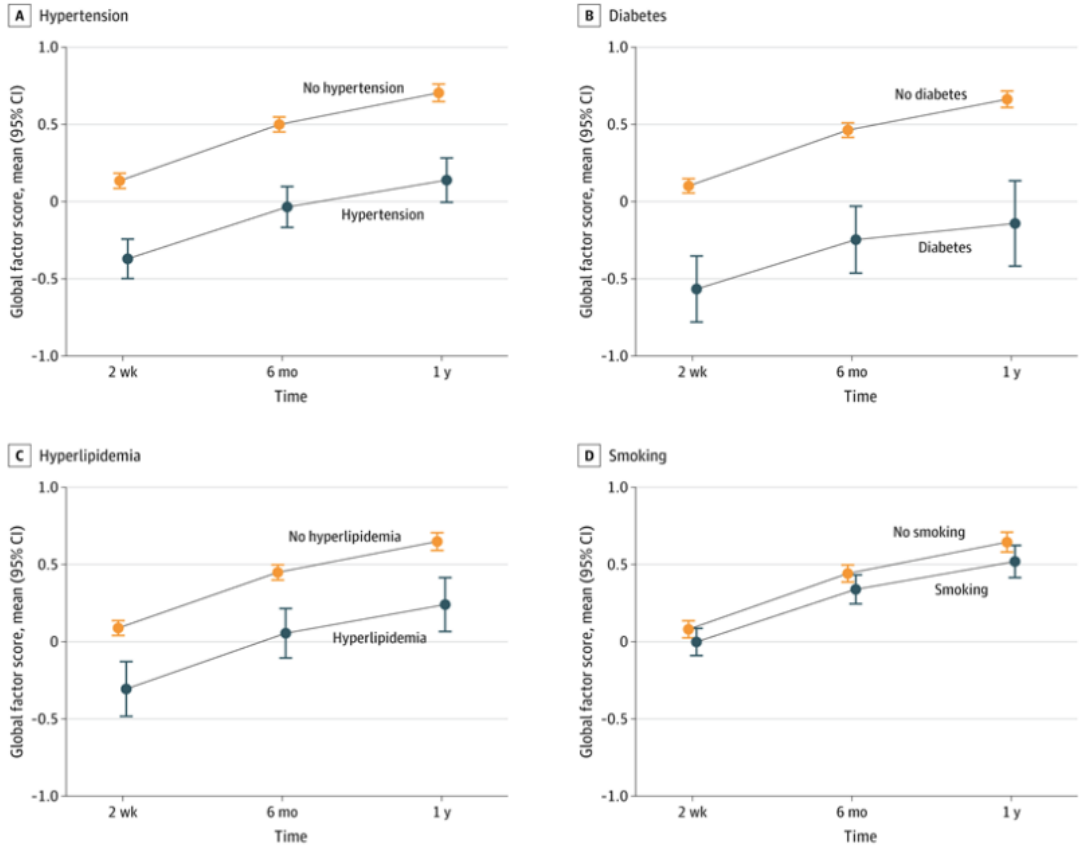


Corrigan JD, Zheng T, Pinto SM, Bogner J, Kean J, Niemeier JP, Guerrier TP, Haaland B, Horn SD. Effect of Preexisting and Co-Occurring Comorbid Conditions on Recovery in the 5 Years After Rehabilitation for Traumatic Brain Injury. *J Head Trauma Rehabil*. 2020 May/Jun;35(3):E288-E298.

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Co-Morbid Vascular Risk Factors are Associated with Worse Cognitive Outcomes after TBI

Figure 2. Mean (95% CI) for Cognitive Performance (Global Cognitive Factor Score) at 2 Weeks, 6 Months, and 1 Year Postinjury by Vascular Risk Factor Status



Schneider ALC, Hunzinger KJ, Brett BL, Sandsmark DK, Jain S, Sun X, Gardner RC, Manley GT, Diaz-Arrastia R, Nelson LD; TRACK-TBI Study Investigators. Vascular Risk Factors and 1-Year Cognitive Change Among Individuals With Traumatic Brain Injury. *JAMA Netw Open*. 2025 Aug 1;8(8):e2525719.

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Heart Health = Brain Health

Stroke
Volume 48, Issue 10, October 2017; Pages e284-e303
https://doi.org/10.1161/STR.0000000000000148

AHA/ASA PRESIDENTIAL ADVISORY

Defining Optimal Brain Health i
Advisory
Stroke As

Philip B. Gorel

Stroke
Volume 52, Issue 6, June 2021; Pages e295-e308
https://doi.org/10.1161/STR.0000000000000367

Stroke
Volume 55, Issue 12, December 2024; Pages e425-e438
https://doi.org/10.1161/STR.0000000000000476

AHA SCIENTIFIC STATEMENT

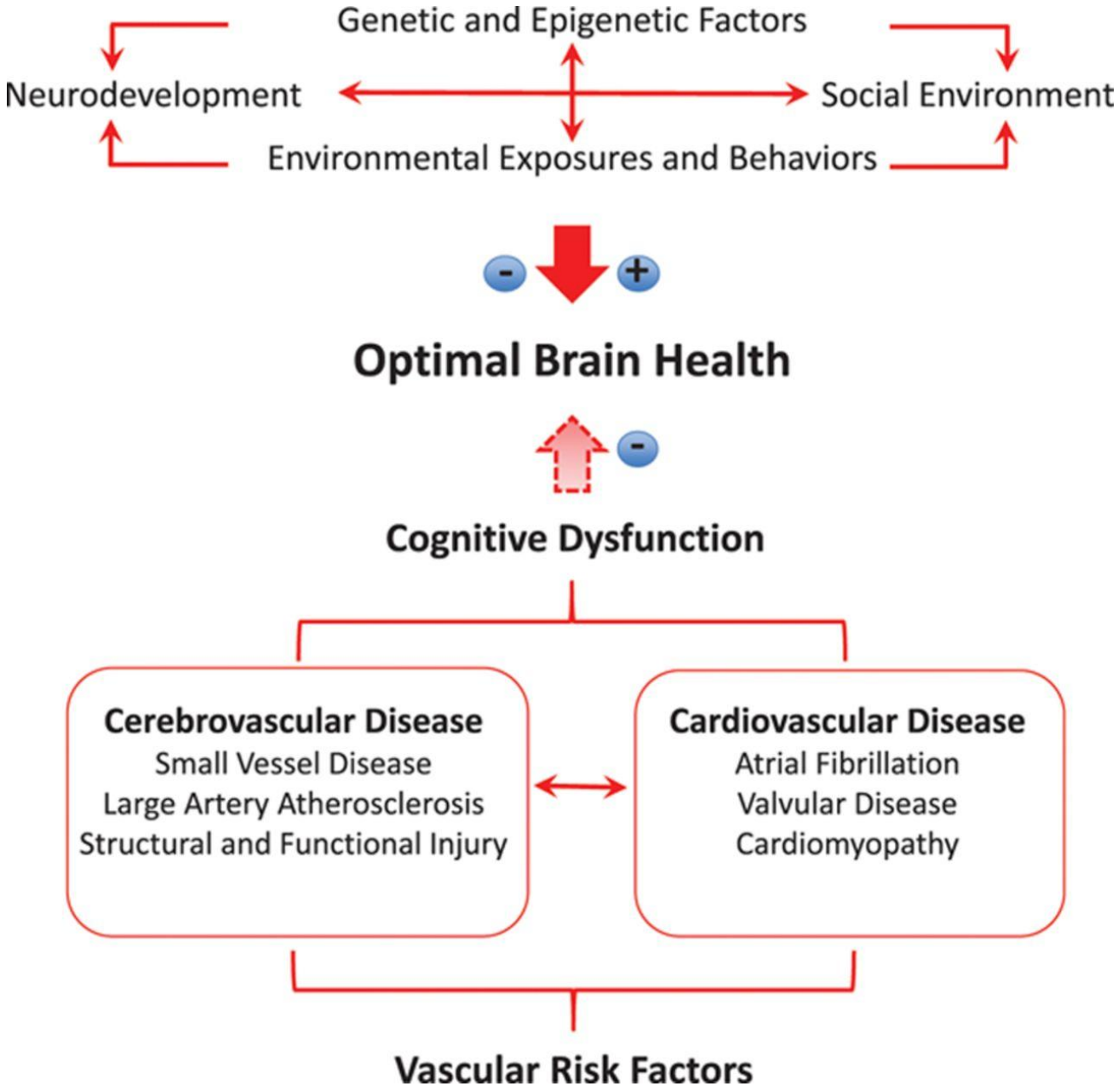
Cardiac Contributions to Brain Health: A Scientific Statement From the American Heart Association

Fernando D. Testai, MD, PhD, FAHA, Chair, Philip B. Gorelick, MD, MPH, FAHA, Vice Chair,

A Scientific
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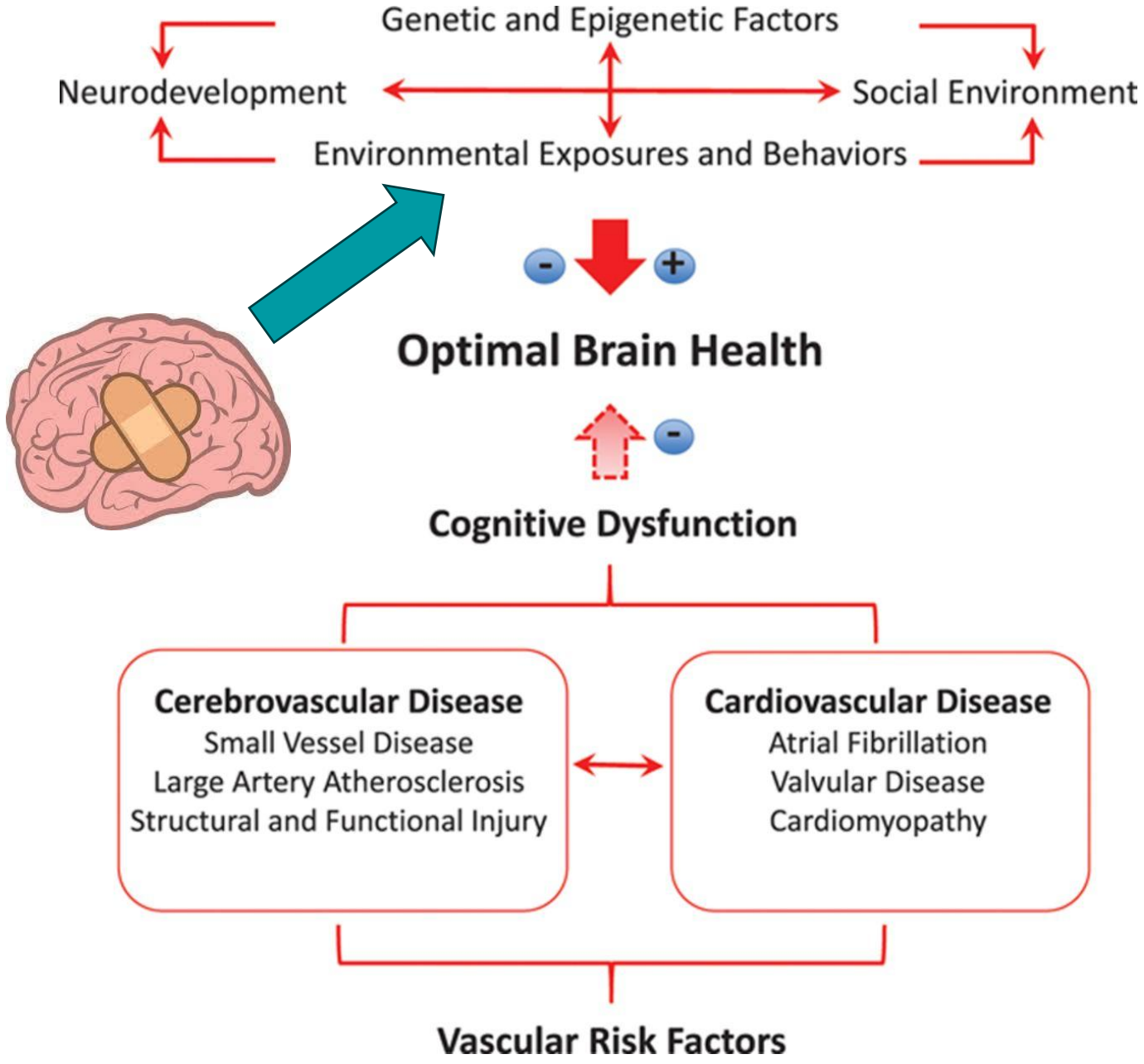
FAHA, Vice Chair, Walter N.

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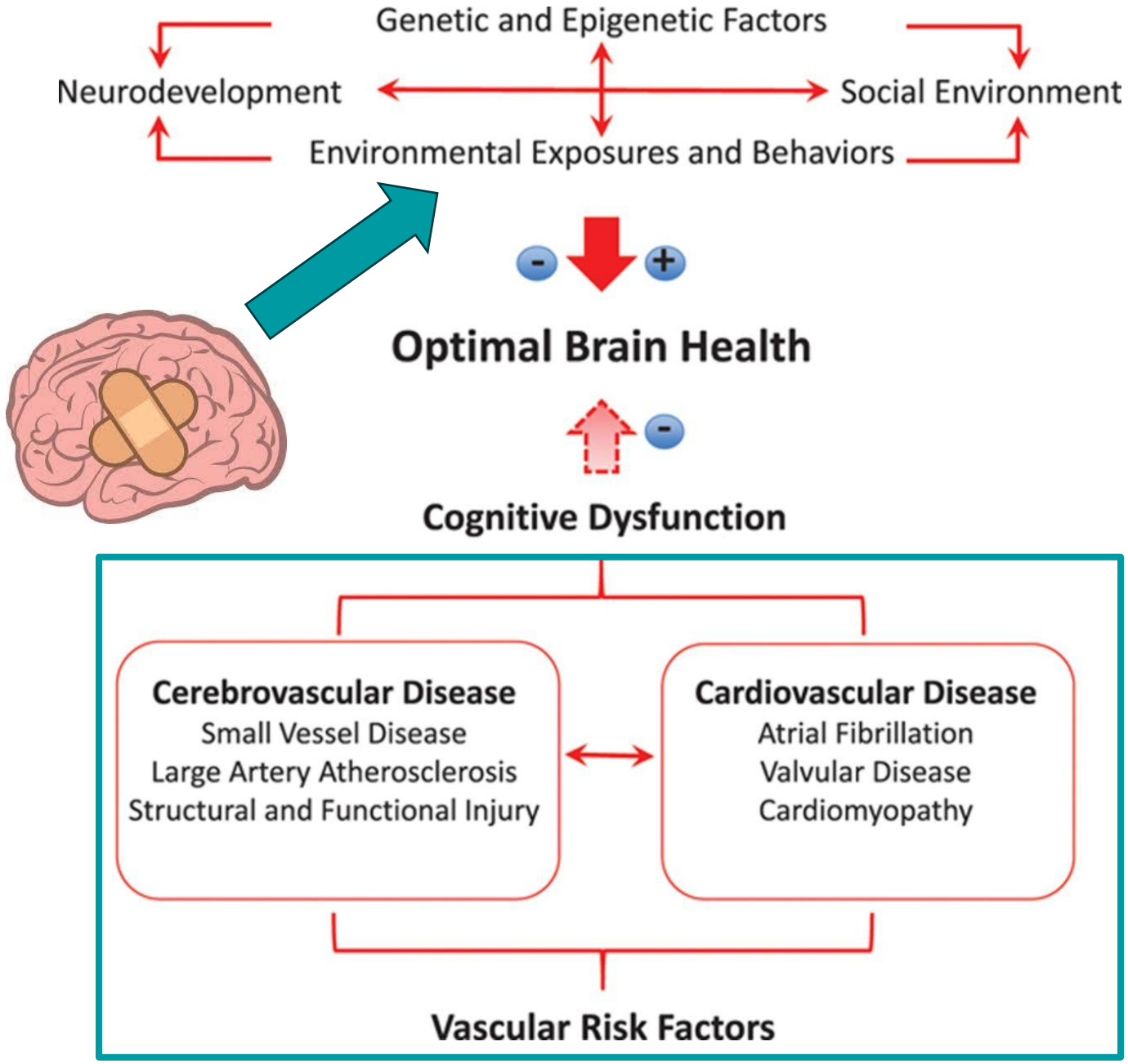
Gorelick PB, et al. American Heart Association/American Stroke Association. Defining Optimal Brain Health in Adults: A Presidential Advisory From the American Heart Association/American Stroke Association. *Stroke*. 2017 Oct;48(10):e284-e303.

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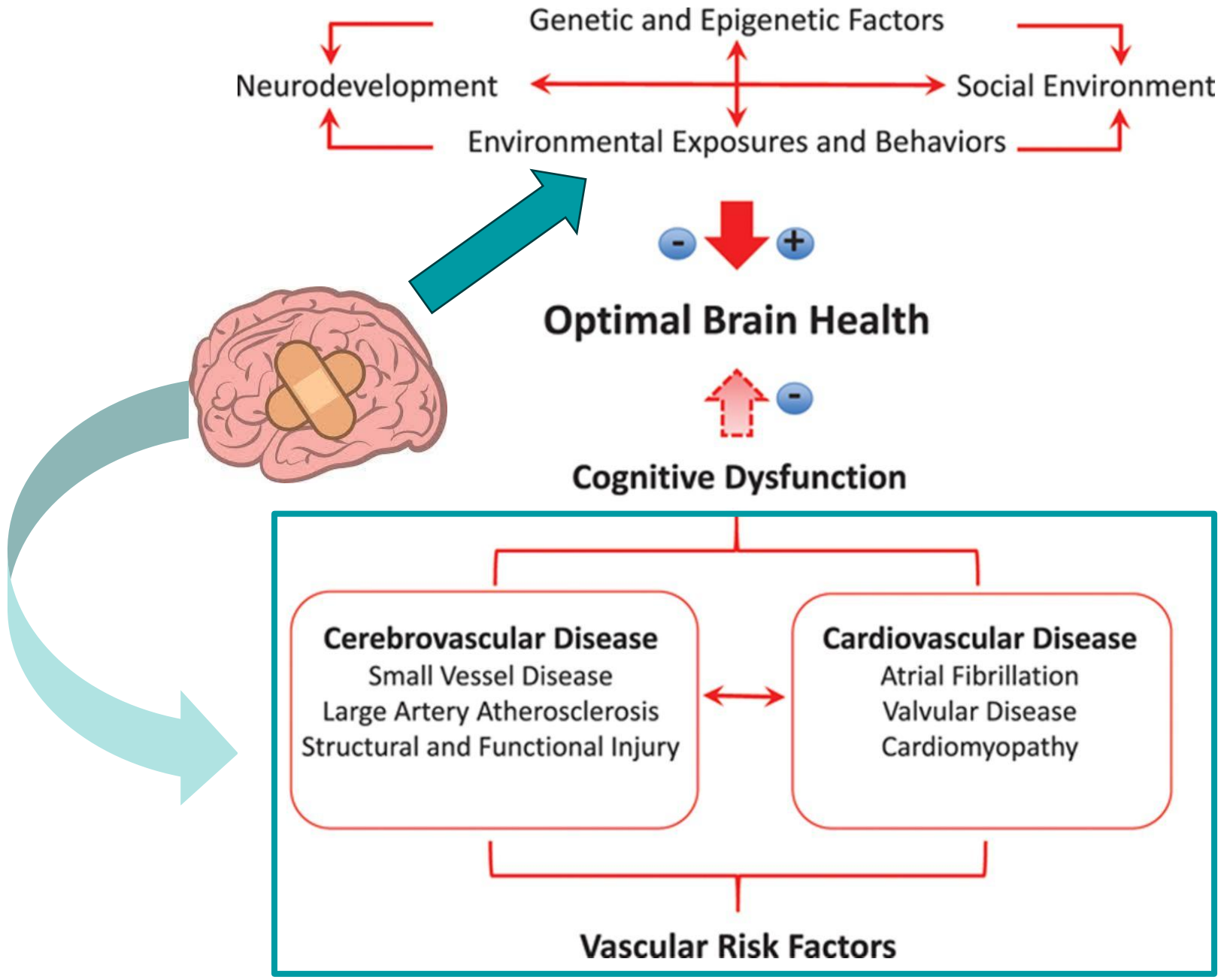
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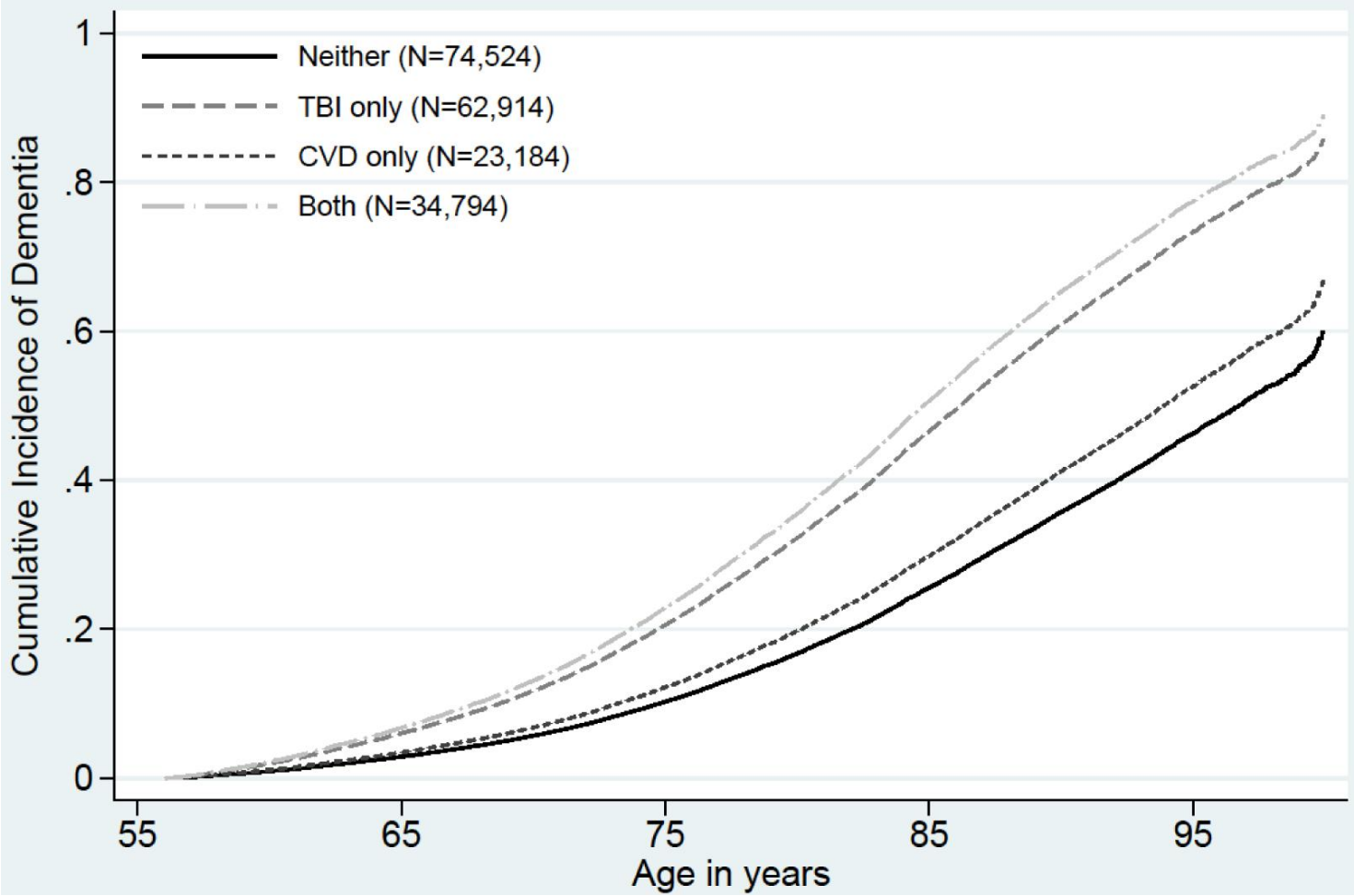
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Additive Effect of TBI+CVD on Dementia Risk



Condition	HR (95% CI)
CVD only	1.21 (1.15-1.28)
TBI only	2.17 (2.09-2.25)
TBI+CVD	2.51 (2.41-2.61)

Kornblith E, Bahorik A, Li Y, Peltz CB, Barnes DE, Yaffe K. Traumatic brain injury, cardiovascular disease, and risk of dementia among older US Veterans. *Brain Inj*. 2022 Apr 16;36(5):628-632.

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Outline

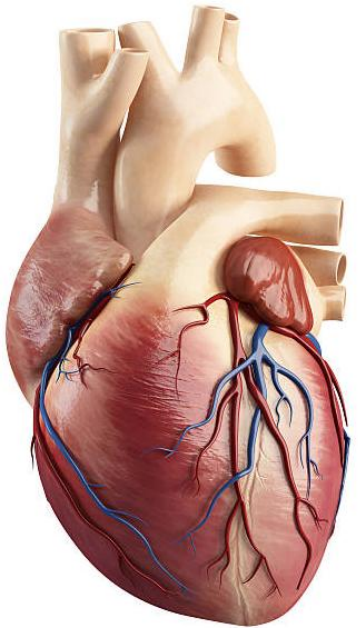
- Epidemiology of Cardiovascular Disease after TBI
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Why Cardiovascular Disease after TBI?



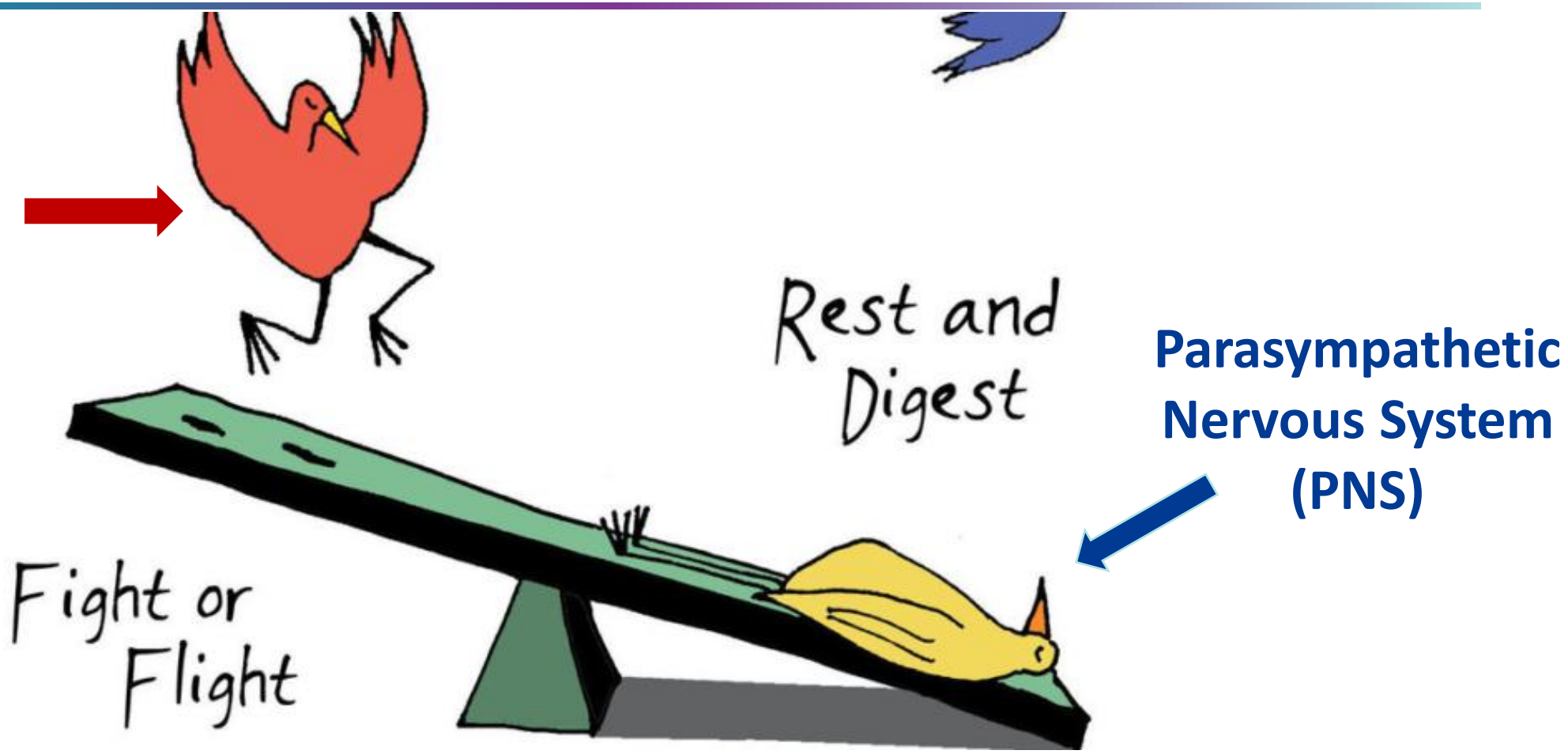
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Overview of the Autonomic Nervous System

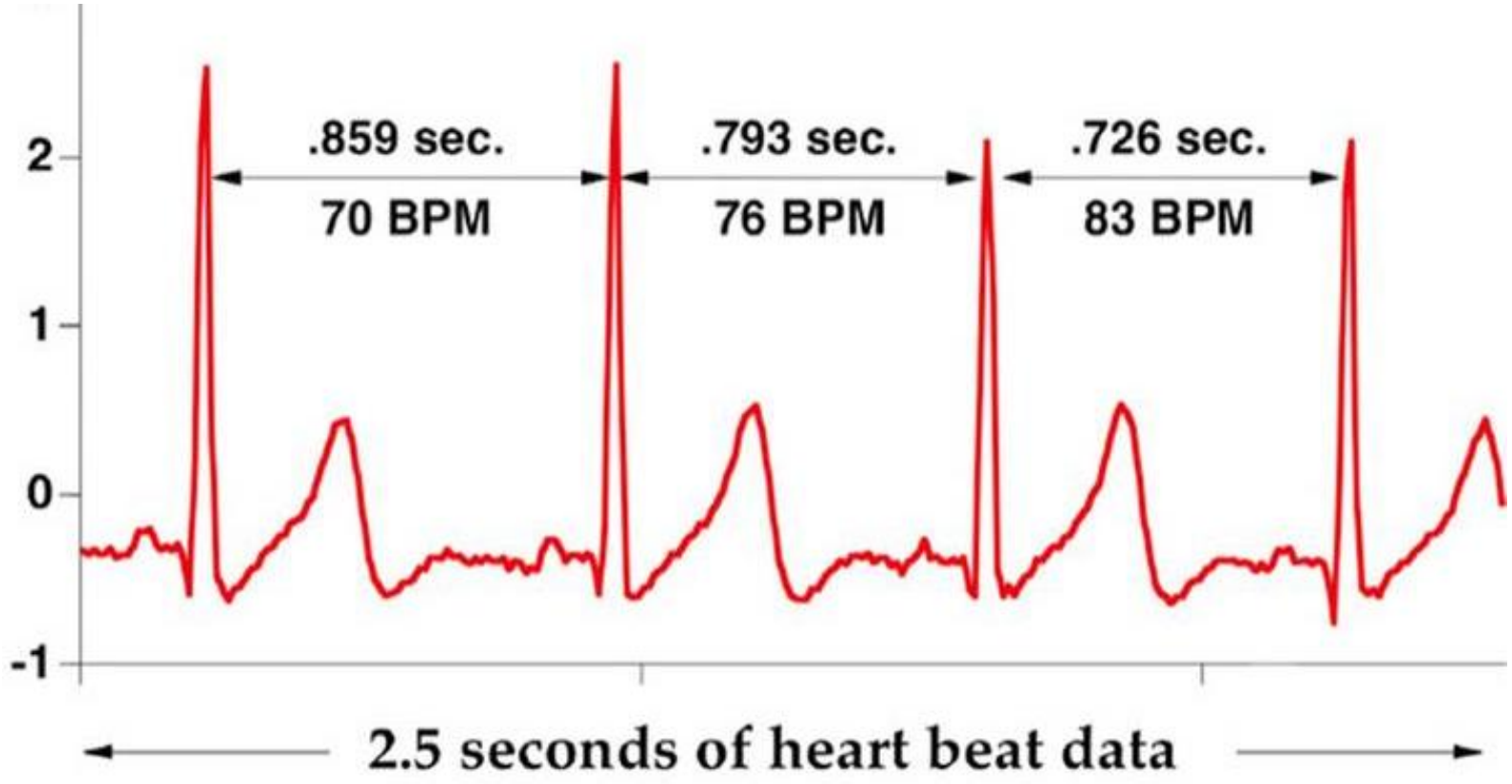
Sympathetic Nervous System (SNS)



Parasympathetic Nervous System (PNS)

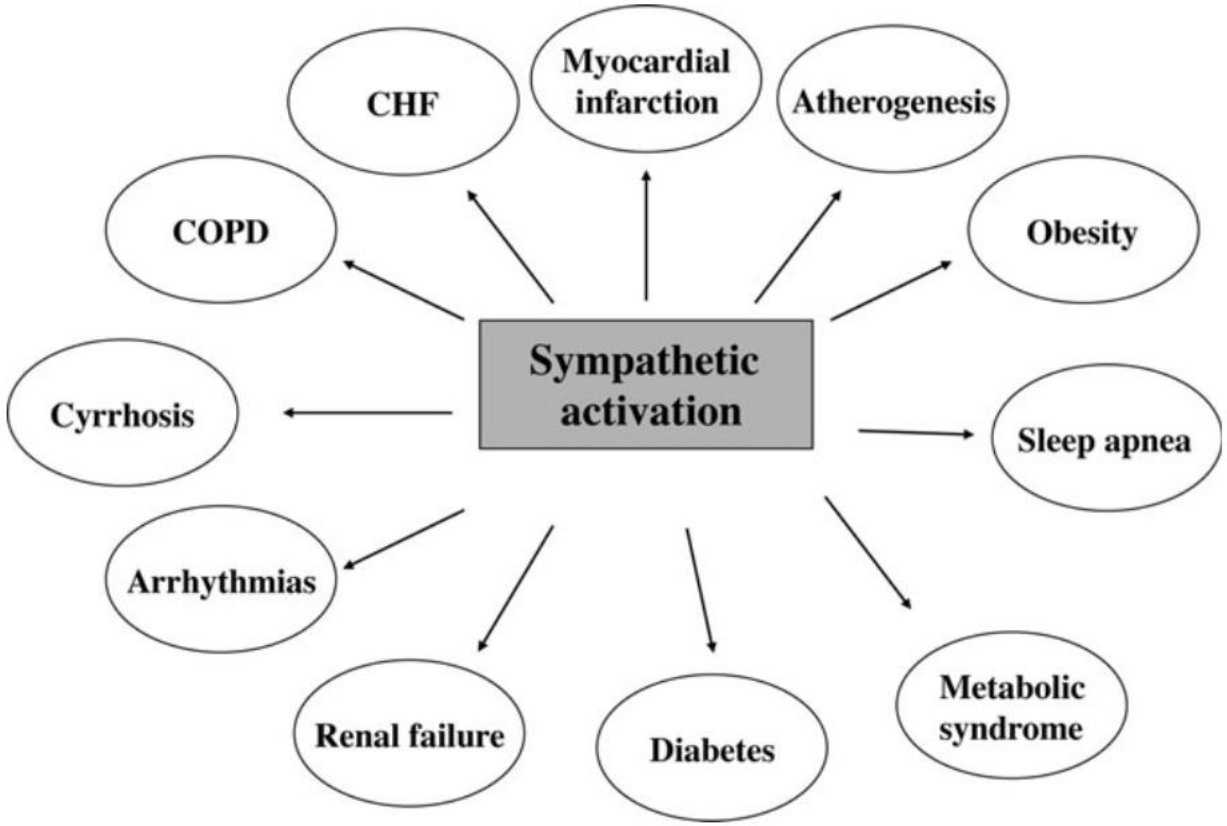
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Heart Rate Variability (HRV)



Normal-to-normal (NN) interval = interval between each successive QRS complex

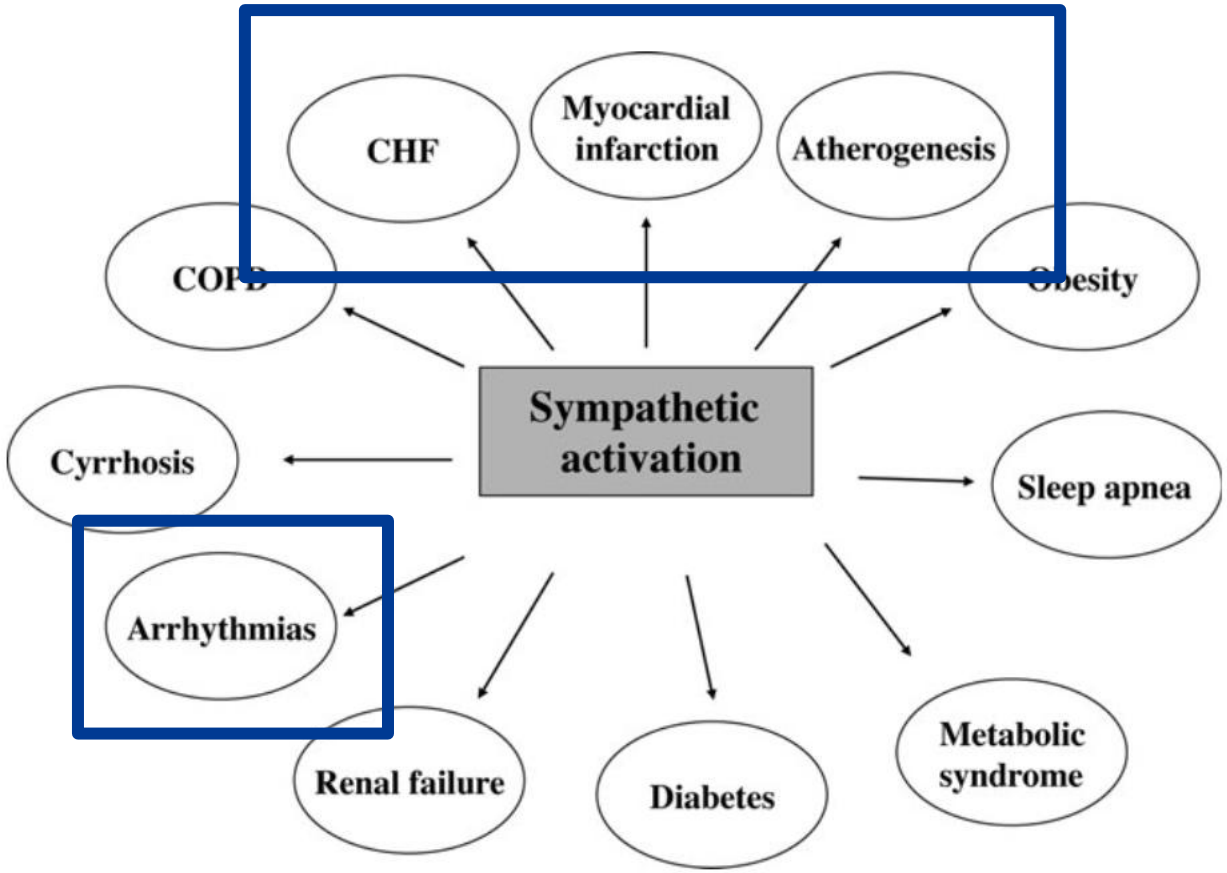
Sympathetic Nervous System Overactivity and Clinical Disease



Grassi G, Seravalle G, Mancia G. Sympathetic activation in cardiovascular disease: evidence, clinical impact and therapeutic implications. *Eur J Clin Invest.* 2015 Dec;45(12):1367-75. doi: 10.1111/eci.12553. Epub 2015 Nov 18.

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Sympathetic Nervous System Overactivity and Clinical Disease



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Next Steps



“Sympathetic Activation and Inflammation after TBI: Neuroimmune Mechanisms Causing CVD and Mortality”

Young Investigator Seed Grant of $25,000

Grantee: Benjamin Young, Ph.D. University of Texas Southwestern Medical Center

Mentor: Shanti Pinto, M.D.

Traumatic brain injury (TBI) is associated with almost a decade shorter life expectancy and patients are 2-3 times more likely to develop and die from cardiovascular disease (CVD). Studies suggest that autonomic dysfunction, particularly sympathetic nervous system (SNS) overactivity, and inflammation are major causes of CVD after TBI. This project aims to characterize these pathways, and the extent that the SNS is responsible for inflammation after TBI in humans.

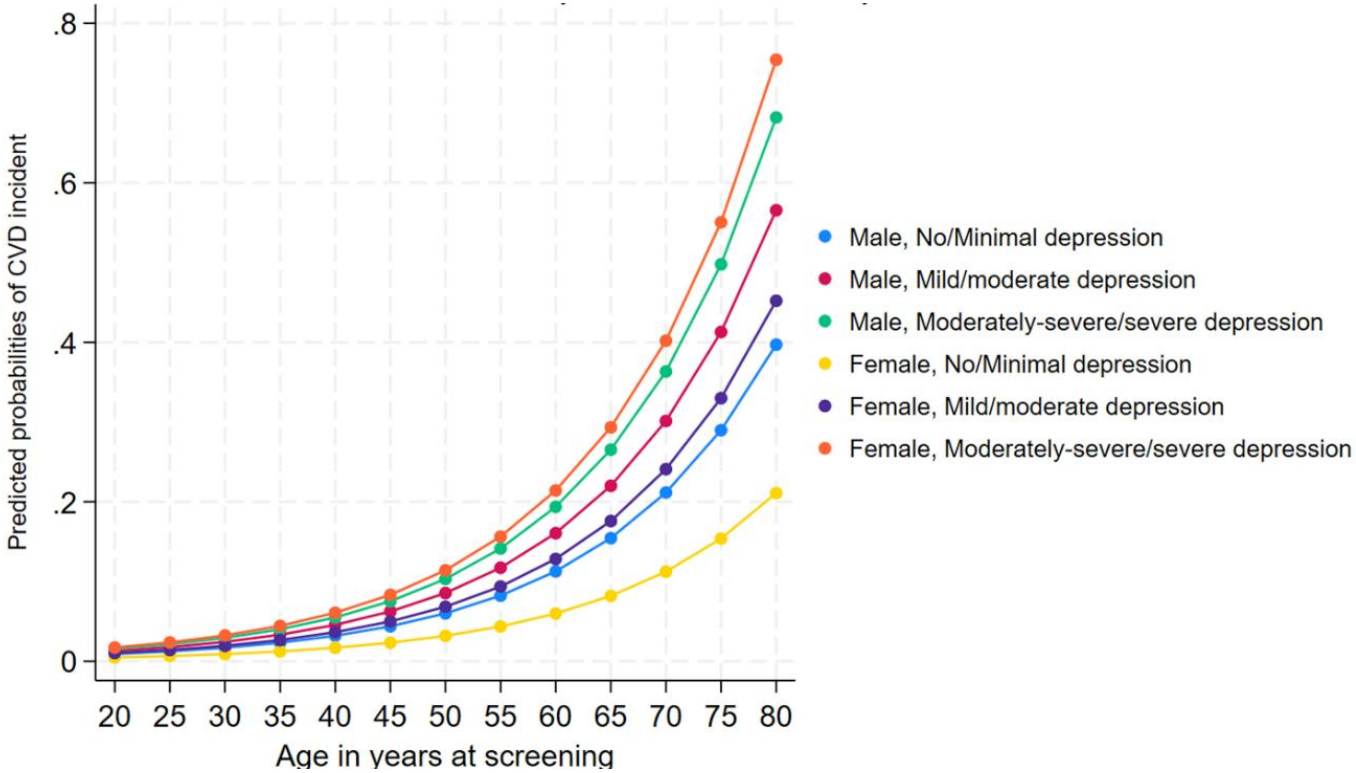
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Depression as a Risk Factor for CVD in General Population



- 14,699 adults aged 20-years-old and older who completed the NHANES survey between 2013-2018

- Mild to moderate depressive symptoms
  - PHQ-9 5-9
  - aPR 1.42 (95% CI: 1.17 – 1.73)
- More severe depressive symptoms
  - PHQ-9 $\geq$ 10
  - aPR:1.72 (95% CI 1.19 – 2.48)



Thakur B, Strenth C, Arnold EM, Schneider FD. Sex Differences in the Association of Depression Symptoms and Cardiovascular Disease in Adults in the United States. *Am J Health Promot.* 2024 Nov;38(8):1199-1209. doi: 10.1177/08901171241262249.

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Depression is Associated with Increased CVD Risk after TBI



Prevalence of Cardiovascular Conditions after TBI			
	Depressed (n = 2,730)	**Not Depressed (n = 6,116)**	**p-value**
%	30.9%	69.1%	
Hypertension	1,122 (40.9%)	2,116 (34.7%)	< 0.001
Congestive Heart Failure	116 (4.3%)	165 (2.7%)	< 0.001
Heart Attack	152 (5.6%)	227 (3.7%)	< 0.001

Thakur B, Bombardier C, Walker W, Rabinowitz A, Driver S, Wright B, Tefertiller C, Wilmoth K, Wagner A, Callender L, Pinto SM. Depression and cardiovascular comorbidities in individuals with complicated mild to severe traumatic brain injury (TBI): A TBI Model System study. *Journal of Head Trauma Rehabilitation.* Accepted for publication.

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Depression is Associated with Increased CVD Risk after TBI



	Adjusted Prevalence Ratio (aPR)*	95% Confidence Interval	p-value
Hypertension	1.18	1.11 – 1.25	< 0.001
Congestive Heart Failure	1.63	1.27 – 2.08	< 0.001
Heart Attack	1.74	1.41 – 2.15	< 0.001

*Controlling for age at follow-up interview, time since injury, body mass index (BMI), duration of post-traumatic amnesia (PTA), motor function at follow-up interview, sex, race, ethnicity, marital status, education, smoking status, alcohol use, rehab payor, number of times engaging in sport outside the home each week, level of socialization with others each week, and geographic region

Thakur B, Bombardier C, Walker W, Rabinowitz A, Driver S, Wright B, Tefertiller C, Wilmoth K, Wagner A, Callender L, Pinto SM. Depression and cardiovascular comorbidities in individuals with complicated mild to severe traumatic brain injury (TBI): A TBI Model System study. *Journal of Head Trauma Rehabilitation.* Accepted for publication.

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Increased Depressive Symptoms Are Associated with Increased CVD Risk after TBI



Outcomes	Depression Severity	aPR	95% CI	P-value
Hypertension	Mild vs. None	1.10	1.02 – 1.19	0.020
	Moderate to Severe vs. None	1.23	1.15 – 1.31	<0.001
Congestive heart failure	Mild vs. None	1.49	1.05 – 2.11	0.025
	Moderate to Severe vs. None	1.72	1.29 – 2.28	<0.001
Heart attack	Mild vs. None	1.23	0.89 – 1.71	0.202
	Moderate to Severe vs. None	2.09	1.64 – 2.66	<0.001

*Controlling for age at follow-up interview, time since injury, body mass index (BMI), duration of post-traumatic amnesia (PTA), motor function at follow-up interview, sex, race, ethnicity, marital status, education, smoking status, alcohol use, rehab payor, number of times engaging in sport outside the home each week, level of socialization with others each week, and geographic region

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AHA's Ideal Cardiovascular Health



Health Behaviors

- Diet
- Physical Activity
- Nicotine Exposure
- Sleep

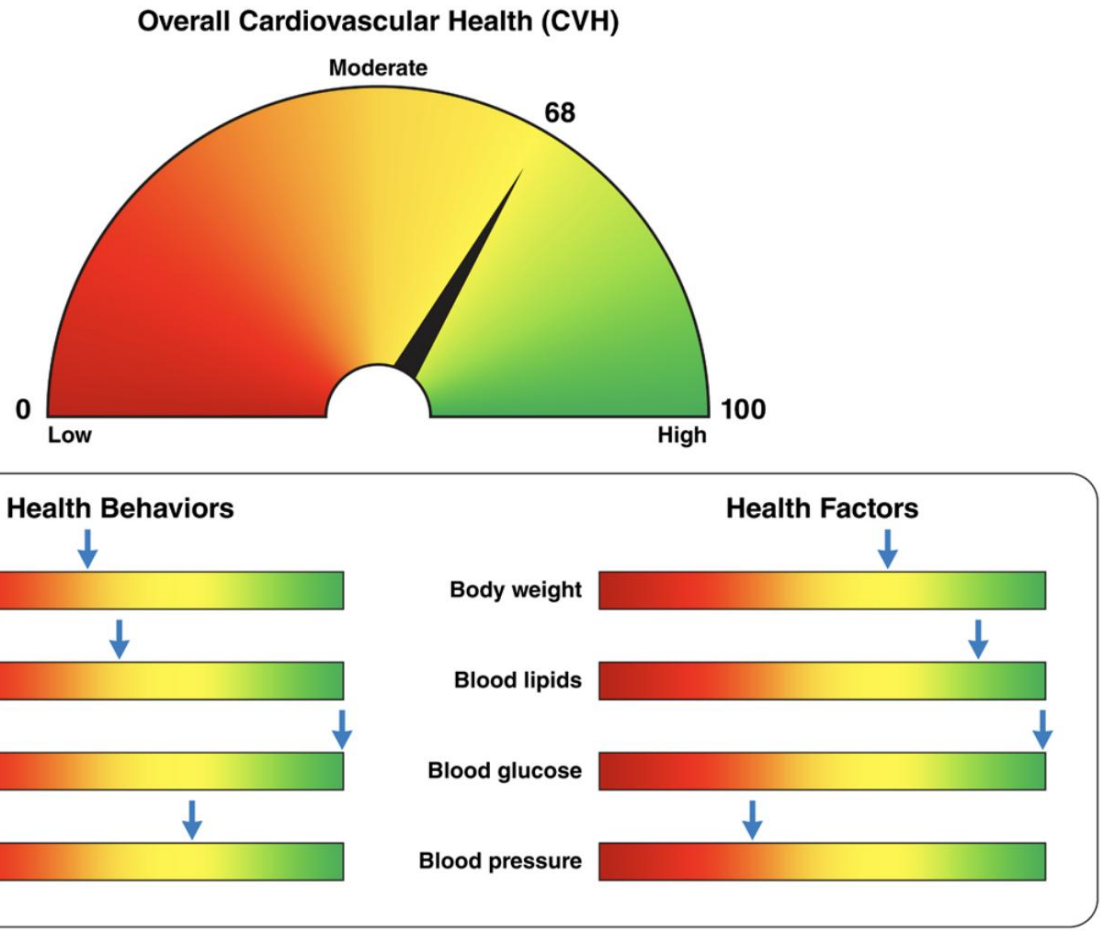
Health Factors

- Body Mass Index
- Blood Lipids
- Blood Glucose
- Blood Pressure

Lloyd-Jones DM et al. Life's Essential 8: Updating and Enhancing the American Heart Association's Construct of Cardiovascular Health: A Presidential Advisory From the American Heart Association. *Circulation*. 2022 Aug 2;146(5):e18-e43.

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Association Between LE8 Score and Post-Stroke Depression

- NHANES Data from 2005 – 2018
- 1,071 adults aged 20-years-old and older with stroke
  - 202 (18.9%) with depression

Table 2 Weighted logistic regression analysis on the association between LE8 score and PSD

	Model I		Model II	
	OR [95% CI]	***P* value**	**OR [95% CI]**	***P* value**
Continuous LE8 score (per 10 points increase)	0.60 (0.52,0.70)	< 0.001***	0.62 (0.52,0.74)	< 0.001***
High CVH (80–100)	Reference	–	Reference	–
Moderate CVH (50–79)	7.84 (1.95,21.50)	0.004**	8.08 (1.46,19.94)	0.02*
Low CVH (0–49)	22.22 (5.93,43.27)	< 0.001***	19.72 (3.69,34.62)	< 0.001***

Data are presented as OR (95% CI). Model I: unadjusted model. Model II adjusted for age, sex, race, education levels, marital, poverty income ratio, DM, coronary heart disease, congestive heart failure, COPD and viral hepatitis

LE8 Life's Essential 8, *PSD* post-stroke depression, *CVH* cardiovascular health, *DM* diabetes, *COPD* chronic obstructive pulmonary disease

*** *P* value < 0.001, ** *P* value < 0.01, * *P* value < 0.05

Ma R, Song J, Ding Y. Associations between Life's Essential 8 and post-stroke depression and all-cause mortality among US adults. *Eur J Med Res*. 2024;29(1):229. doi:10.1186/s40001-024-01834-3

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Managing Cardiovascular Health After TBI



Multiple barriers to addressing in PM&R clinics

- Typical management by primary care
  - Lack of education about cardiovascular health and medication management
  - Need for close follow-up for medication management
- Limited time in clinic appointments

Easy Opportunities to Increase Awareness

- Pro-active education about blood pressure, sleep, physical activity
- Communicate with primary care providers

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Diabetes Prevention Program as a Potential Lifestyle Intervention

The NEW ENGLAND JOURNAL of MEDICINE

CURRENT ISSUE SPECIALTIES TOPICS

ORIGINAL ARTICLE

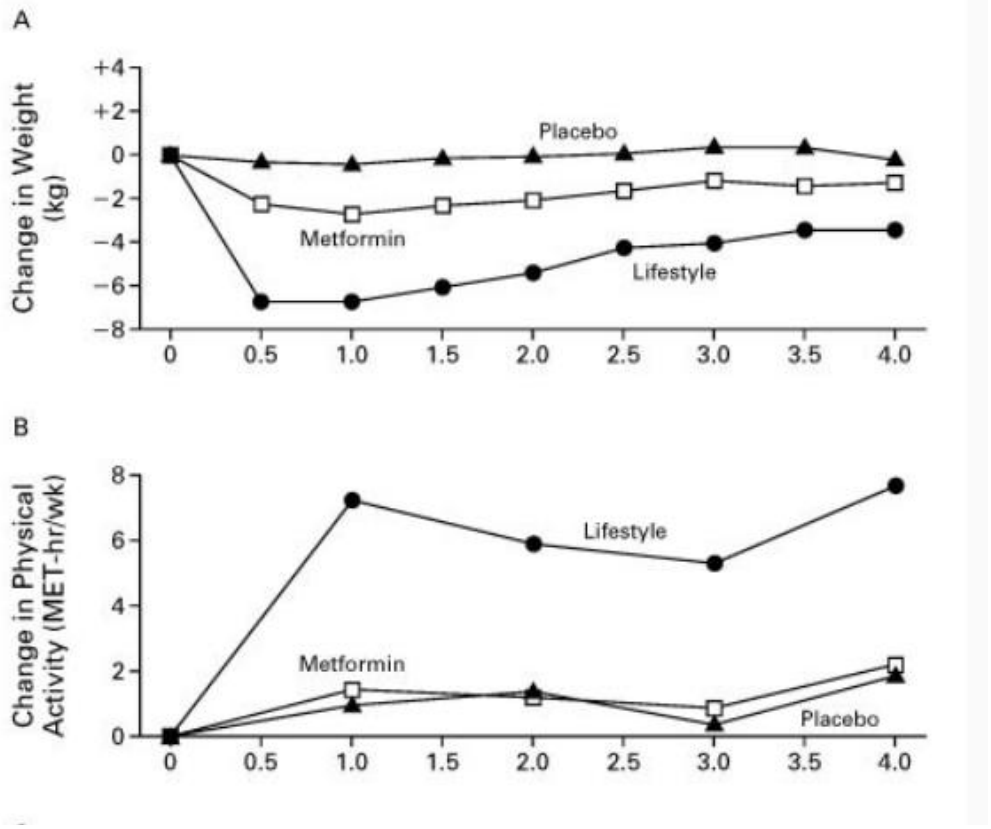
Reduction in the Incidence of Type 2 Diabetes with Lifestyle Intervention or Metformin

Author: Diabetes Prevention Program Research Group* Author Info & Affiliations

Published February 7, 2002 | N Engl J Med 2002;346:393-403 | DOI: 10.1056/NEJMoa012512 | VOL. 346 NO. 6

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NATIONAL DIABETES PREVENTION PROGRAM

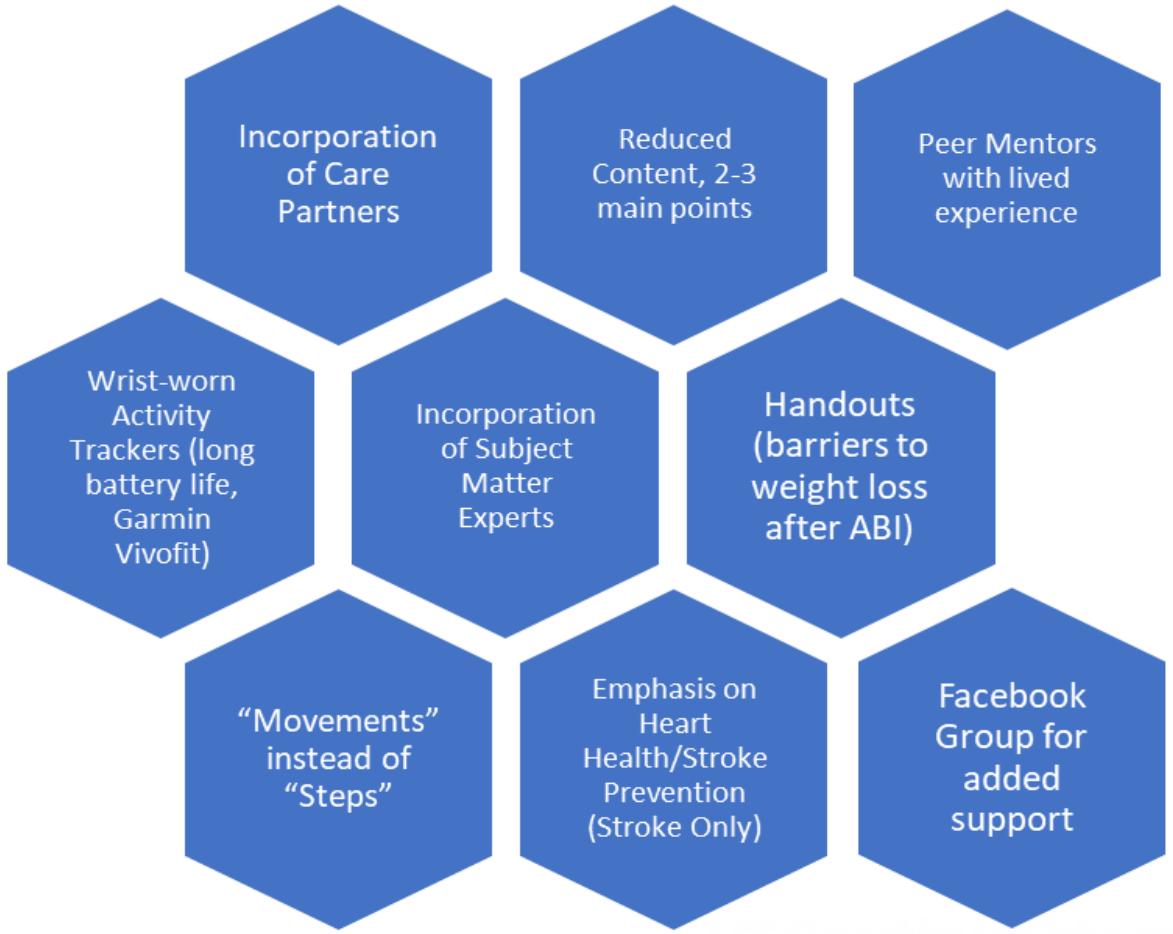


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Development of a Modified Version of the DPP-GLB for Persons with TBI (GLB-TBI)



- 25 partners
  - Patients, care partners, clinicians, etc.
  - 1-day workshop
  - Iterative revisions
  - DPSC review and approval

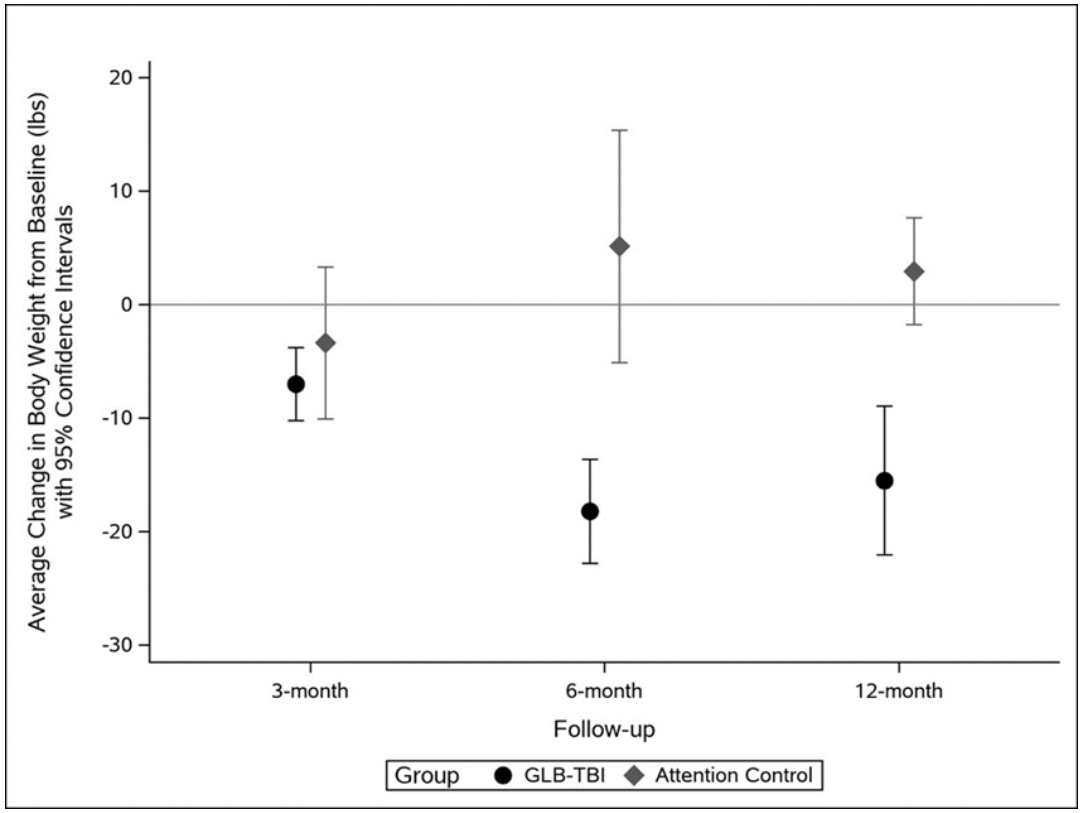


Driver S, et al. Modifying an evidence-based lifestyle programme for individuals with traumatic brain injury. *Brain Injury*. 2017; 31 (12): 505-11.

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Initial GLB-TBI RCT Compared with Group-Based Attention Control





Metabolic Risk Factors

Percent change from baseline to the end of study of the GLB group

-10%	-5%	-26.5%
Waist Size	Systolic Blood Pressure	Triglycerides

GLB-TBI Group (n = 28): 17.8lbs (7.9%) weight loss
Attention Control (n = 27): 0lbs weight loss



90% of people stayed in the program

Driver S, et al. Efficacy of the Diabetes Prevention Program Group Lifestyle Balance Program Modified for Individuals with TBI (GLB-TBI): Results from a 12-month Randomized Controlled Trial. *Ann Behav Med.* 2023 Feb 4;57(2):131-145.

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Take Home Points

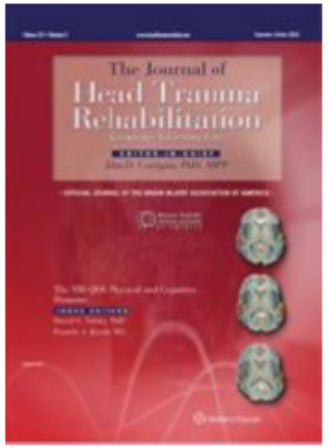
- Individuals with TBI have 3 times greater risk of cardiovascular death than those without TBI
  - ~40% more likely to have coronary artery disease, arrhythmia, and hypertension
- Heart health = brain health
- Etiology of cardiovascular disease after TBI is unknown but co-morbid depression and autonomic nervous system dysfunction may play a role
- Interventions are needed
  - Diabetes Prevention Program is an example of an efficacious intervention, but greater implementation is needed

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JHTR Special Issue March 2027

Call for Manuscripts

Cardiovascular Health after TBI



A Topical Issue of the Journal of Head Trauma Rehabilitation (JHTR), a Wolters Kluwer Publication (https://journals.lww.com/headtraumarehab/pages/default.aspx)

Topical Issue Editors: Shanti M. Pinto, MD, MSCS; Simon Driver, PhD

JHTR is a leading, peer-reviewed journal that provides up-to-date information on the clinical management and rehabilitation of persons with traumatic brain injuries (TBI). It is the official journal of the Brain Injury Association of America.

There is increasing evidence that individuals with TBI are at increased risk for adverse cardiovascular outcomes, including increased risk of cardiovascular mortality, compared with the general population. This added risk is noted in people with all severities of injury, from concussion to severe TBI. Furthermore, there is clear evidence in the general medical literature that mid-life cardiovascular health is important for cognitive function in late life, but this has yet to be studied in persons with TBI.

There is great need for more research to understand the burden of adverse cardiovascular health after TBI, underlying mechanisms leading to adverse cardiovascular outcomes after TBI, and best practices for evaluation and management of cardiovascular health after TBI.

Thank You!

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- Tianyu Wang, PhD
- Kristin Wilmoth, PhD
- Rong Zhang, PhD
- Kathleen Bell, MD

NIH National Institute of Neurological Disorders and Stroke

TBIMS Traumatic Brain Injury Model System Since 1987

NIDILRR National Institute on Disability, Independent Living, and Rehabilitation Research

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