A HEART OF STONE TO A HEART OF FLESH:

Hydrotherapy as A Cardiovascular Treatment Modality in Clinical practice

Nana Kwarteng

1

OBJECTIVES

- Understand the history of hydrotherapy and its use in modern medicine
- Explain the mechanism by which hydrotherapy can improve endothelial function and reduce inflammation in congestive heart failure and hypertension
- Describe how hydrotherapy can be used to address other ailments that hinder individuals with cardiovascular disease from participating in lifestyle interventions
- List contraindications and indications for various hydrotherapy treatments
- Summarize how to give an effective hydrotherapy treatment for several conditions

2

HYDROTHERAPY

Therapeutic application of water in all its forms (solid, liquid or vapor) to maintain or restore health

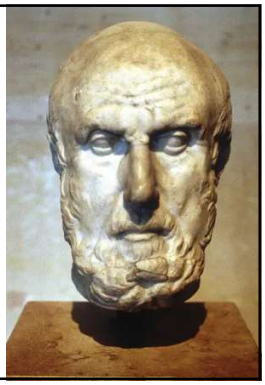
SINCLAIR, 2008

3

HISTORY OF HYDROTHERAPY

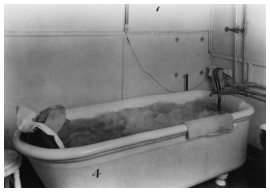
Hippocrates (460-377 BC)	• Thermal baths • Neutral baths
Roman empire (510 BC-478 AD)	• whole body immersions • swimming • hot and cold springs
Priessnitz (1799-1851 AD) and Hydropathy movement	• cold water treatments • healthy dietary practices

SINCLAIR, 2008



4

BATTLECREEK SANITARIUM (1876-1902)



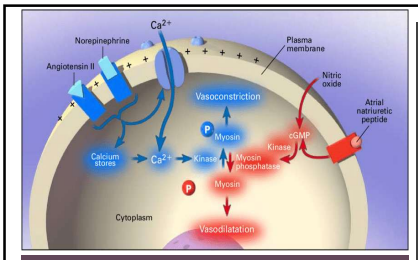
5

HYDROTHERAPY IN MODERN MEDICINE

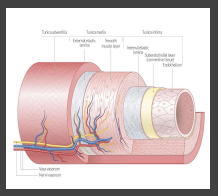
Sports Medicine/Physical Therapy

Urology/Midwifery/Gastroenterology

6



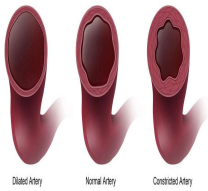
REGULATION OF VASCULAR SMOOTH MUSCLE TONE



LANDRY AND OLIVIER, 2001

7

PRINCIPLES OF HYDROTHERAPY



Use of water temperature to affect the circulation of the blood through influencing diameter of blood vessels

- Hot water causes vasodilation of the blood vessels
- Cold water causes vasoconstriction of the blood vessels***

8

WATER TEMPERATURE EFFECTS

HOT	COLD
Increases blood flow and metabolism	Primary action is to reduces blood flow
Increases swelling and edema	Reduced swelling and edema
Relaxed muscles	Contraction of muscle
Decreased systemic inflammation	Promotes analgesia
Promotes analgesia	

BERGERON, BLEAKLEY, AND COSTELLO, 1999; AN, LEE AND YI, 2019; GÁLVEZ, TORRES-PYLES, ORTEGA-RINCÓN, 2018

9

HYDROTHERAPY PRINCIPLES

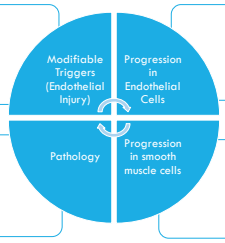
Use pathophysiology of the condition and understand the pharmacokinetics of drug modalities

Attempt to use lifestyle interventions that are physiology guided.

10

HYDROTHERAPY TARGET IN CVD: ENDOTHELIAL DYSFUNCTION

- Shear Stress
- Inflammation (eg comorbidities, hypoxia, lifestyle practices)
- Oxidative stress



- Apoptosis
- Proliferation
- Metabolism
- Pro-coagulation factors
- Imbalanced vasoactive factors

- Vasoconstriction
- Thrombus Formation
- Muscularization
- Vascular lesions
- Hypertrophy

- Vasoconstriction
- Proliferation
- Metabolism

ADAPTED FROM KUMARESA ET AL, 2021

11

ENDOTHELIAL VASOACTIVE SUBSTANCES

Vasodilators	Vasoconstrictors
Nitric oxide	Endothelin
Prostaglandins	Angiotensin II
Natriuretic peptides	Thromboxane A2

HEGEDUS, 2022

12

CONGESTIVE HEART FAILURE (CHF) AND ENDOTHELIAL DYSFUNCTION

- Decreased shear stress due to reduced peripheral perfusion
- Chronic inflammation increases ROS /oxidative stress that reduces NO and cGMP
- A decrease in cardiac output stimulates the release of epinephrine, norepinephrine, endothelin-1 (ET-1), and vasopressin→ vasoconstriction/ increased afterload

DHEBA ET AL., 2024; SAJAD, MALIK, CHHABRA, 2025

13

CHF AND TREATMENT

- Guideline Directed Medical Treatment include:
  - -ACE inhibitors
  - -Loop Diuretics
  - -Beta Blockers
- Result: decreased pre and afterload, decreased heart rate, increased cardiac output, stroke volume, blood volume, and stroke work

CANADIAN PHARMACY ASSOCIATION (CPHA) 2019 AND 2024

14

HYDROTHERAPY AND CHF TREATMENT TARGET

In CHF, adequate perfusion is key to symptoms and disease management

- Increasing vasodilation and decreasing inflammation

15

HYDROTHERAPY IN CLINICAL PRACTICE

38-year-old male into the clinic for his 1st visit in the 22-day medical program

GOALS:

-Manage his congestive heart failure

-lose weight

MEDICAL HISTORY:

CHF, obesity (BMI=77.31), Testicular cancer,

R knee OA, HTN, Hyperlipidemia,

GERD, sleep apnea (BIPAP)

MEDICATIONS:

torsemide 20 mg 1 tablet po BID 5 days a week

LIFESTYLE PRACTICES:

Water drinks > 2 L daily

Exercise-none for several months

16

PHYSICAL EXAMINATION

Vitals

- BP=140/100
- HR=105
- SpO2 =95 at rest and 90 when talking on 2L 02 via NP

PE: Trace edema to ankles

17

HEATING TREATMENTS AND ENDOTHELIAL DYSFUNCTION

- Hot baths or sauna baths can improve quality of life by increasing daily activities, improving appetite, sleep quality and general well being for those with CHF.
- In a review of done by Ye and associates, it was found that after a hot bath or a sauna bath, there was a 40% decrease in peripheral [vascular] resistance and subsequent increase in peripheral circulation with effects lasting up to 120 minutes after heat exposure

18

HEAT TREATMENT MECHANISM OF ACTION

- Heat treatments cause sympathetic activation which leads to a transient increase in BP as the body warms up the sympathetic activity decreases and blood vessels near the body's surface vasodilate increasing blood flow to the skin in the body's attempt to cool off, increasing peripheral blood flow
- Increase shear stress also decreases endothelin-1 expression
- Heat stress downregulates proinflammatory molecules (NF-KB and TNF→IL-1, IL-6)

LAUKKANEN J., LAUKKANEN, T., AND KUNUTSOR, 2018; HALL, E. 2024; BRUNT AND MOSEN, 2021

19

STUDY: SAUNA TREATMENT AND CHF

30 patients with New York Heart Association functional class 2 and 3 participated in 2-week study

- INTERVENTION GROUP: infra-red sauna treatment at 60 degrees C (140 degrees F) for 15 minutes followed by 30 minutes of rest
- CONTROL GROUP: placed on a bed in a temperature-controlled room for 45 minutes.

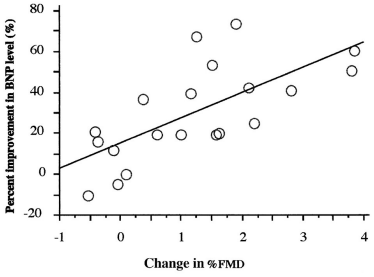
KIHARA AT AL. 2002

20

STUDY: SAUNA TREATMENT AND CHF

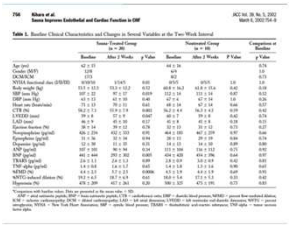
Figure 1.

Relationship between the change in percent flow-mediated dilation (%FMD) and the percent improvement in brain natriuretic peptide (BNP) concentration in the sauna-treated group. There is a positive correlation between the change in %FMD and the percent improvement in BNP concentration before and after two weeks of sauna therapy ($r = 0.69$, $p = 0.0005$).



21

STUDY: SAUNA TREATMENT AND CHF



KIHARA AT AL. 2002

22

HOT WATER IMMERSION THERAPY AND ENDOTHELIAL DYSFUNCTION

- Immersion in hot water has been found to increase peripheral perfusion
- Several studies have looked at immersion to lower leg, to waist and to subclavian level
- Temperatures of water in immersion therapy can be lower than sauna due heat conductivity of water

  Hot water immersion: 38-42 degrees C (100.4-107.6 degrees F)

  Sauna: 60-100 degree C (140-212 degrees F)

YE ET AL. 2014 ; TEI ET AL. 1995; ROMERO ET AL. 2016; THOMAS, VAN HEE, LUCAS, AND COTTER, 2016

23

STUDY: IMMERSION THERAPY AND ENDOTHELIAL DYSFUNCTION

In 1995, Tei and Associates compared vasodilation via sauna bathing compared to warm water bath in patients with chronic CHF

34 study participants with NYHA functional class between II-IV (range EF of 9-44%)

Warm-Water Bath: Participant were immersed in 42 degrees C water up to subclavian level 10 minutes

Infra-red sauna: Participants placed in 60 degrees C sauna for 15 minutes

Both groups: rested for 30 minutes after treatments

TEI, ET AL, 1995

24

WARM-WATER BATH VS SAUNA BATH RESULTS

	Warm-Water Bath (n=26)			Sauna Bath (n=32)		
	Control	During	After	Control	During	After
Maximum O_2 consumption, mL	204±26	256±25[1]	216±25	209 ±29	250±25[1]	219±30
METs	1.06±0.14	1.33 ±0.14[1]	1.12±0.13	1.09±0.15	1.30±0.13[1]	1.14±0.14
Deep temperature, °C	37.0±0.3	38.2±0.4[1]	37.5 ±0.4[1]	36.9±0.3	38.1±0.4[1]	37.4±0.4[1]
Heart rate, bpm	76±14	101±20[1]	85±15[1]	77±18	97±22[1]	81 ±20[1]
Systolic blood pressure, mm Hg	117±20	120 ±19	115±19	115±18	116±19	110±18
Diastolic blood pressure, mm Hg	79±12	75±10	68±10[2]	78 ±10	70±12[2]	67±11[1]

TEI, ET AL, 1995

25

WARM-WATER BATH VS SAUNA BATH RESULTS

	Warm-Water Bath (n=20)		Sauna Bath (n=28)	
	Before	After	Before	After
SVR	1842 ±592	1077±296[1]	1342±340[1]	1795±468
PVR	248±69	191 ±65[1]	201±61[1]	238±74
EF%	23.8±9.5	29.2±10.6[1]	24.1 ±8.2	28.5±8.6[1]

TEI, ET AL, 1995

26

WARM-WATER BATH VS SAUNA BATH RESULTS

- With warm water bathing right atrial, pulmonary arterial and pulmonary capillary wedge pressures significantly increased during bath, but decreased when water immersion therapy ended

  increased venous return→ increased intracardiac pressures due to hydrostatic pressure

- No anginal, dyspneic episodes during interventions

- Recommendation: water immersion lower than subclavian level and keep exposed skin warm with a towel

TEI, ET AL, 1995

27

HOT WATER IMMERSION OF LOWER LIMBS AND ENDOTHELIAL DYSFUNCTION

Study of Hemodynamic and cardiovascular responses in subjects with peripheral arterial disease compared to healthy elderly adults

- Design: Immersion in 42 degrees C water to the waist for 30 minutes
- Frequency: 2 sessions, 1-3 weeks apart

THOMAS, VAN XIE, LUCAS, AND COTTER, 2016

28

RESULTS

- Hot water immersion led to induced anterograde shear stress patterns and increased lower limb perfusion
- However, one of the limitations in clinical practice is the exacerbation of edema with application of heat to lower legs

THOMAS, VAN XIE, LUCAS, AND COTTER, 2016

29

HEATING TREATMENT CONTRAINDICATIONS

Unstable angina
Recent Myocardial infarction
Uncontrolled hypertension
Ischemic or decompensated heart failure
Aortic stenosis

LAUKKANEN, LAUKKANEN AND KUNUTSOR, 2018

30

HEATING THERAPY* CONTRAINDICATIONS IN CLINICAL PRACTICE

- Tachycardia
- Pregnancy
- Poor thermal regulation
- Swelling/lymphedema
- Hypotension
- Severe Anemia
- Pulmonary Edema

* sauna/whole body heating therapies (including immersions)

HALL E, 2024

31

EFFECTS OF ALTERATING COLD AND HOT WATER

Increases circulation to area without the congestion derived from hot water treatments

Contrast treatment have been shown to decrease pain in those with arthritis and muscle soreness

BUCUZEN, BLEAKLEY, AND COSTELLO, 1999; AN, LEE AND YI, 2019; FOKMARE AND PHANOPKAR, 2023

32

CONTRAST WATER TREATMENTS

Study by Fokmare and Phanopkar (2023) investigating the effect of contrast bath therapy on osteoarthritis

- Design: Control: alternating between 4 minutes immersion in warm water at a temperature of 38-40 degrees C (100.4-104 degrees F) and1 minute of cold-water immersion at a temperature of 12-14 degrees C (53-57 degrees F) for total of 20 minutes. with exercises
- Intervention :Knee pad device (vibration and heat of 40-45 degrees C) for 4 minutes followed by 1 minute of ice pack application with alternation for 20 minutes
- Duration: 3 sessions a week for 2 weeks
- Results: Significant improvements in improved pain, 2-minute walk test and knee range of motion with contrast water immersion therapy and intervention group

33

CONTRAST TREATMENT METHOD IN CLINICAL PRACTICE

- Involves placing a warm fomentation or immersed in water (102-110 degrees F) to affected area for 3-4 minutes
- Alternating with cold friction using a towel to the area for 30 seconds or immersion in cold water (50-60 degrees F)
- Repeat this sequence 3-4 times and allow the client to rest for 20 minutes

SINCLAIR, 2008; HALL, E. 2024

34

CONTRAST WATER THERAPY CONTRAINDICATIONS IN CLINICAL PRACTICE

CONTRAINDICATION	ALTERNATIVE
Pronounced swelling	Use lower temperatures or shorter time application of hot and longer application of cold (eg 2 minutes hot then 1 minute cold)
Neuropathy/Peripheral vascular disease	Use warm and cold temperature as opposed to hot and cold

HALL, E. 2024

35

HYDROTHERAPY IN CLINICAL PRACTICE

The client was prescribed Sauna therapy and contrast water therapy to lower limbs, but pain to knees warranted to abort the Sauna therapy

36

4 WEEKS LATER

BP=120-125/84-94
At times forgot furosemide, no longer on lisinopril
Walking 4000-5000 steps per day
knee pain resolved
Lost 30 lbs
No signs of decompensation (ie 96% on RA)

37

CONTRAST TREATMENTS

His outcomes where consistent with findings in Michalsen and associates' study (2003) involving contrast water treatment to legs.

Findings included improvement in physical capacity

38

HYPERTENSION (HTN) AND ENDOTHELIAL DYSFUNCTION

- Endothelial dysfunction involves increased myogenic tone of resistance of the arteries through activation of Renin angiotensin system (RAS), catecholamines and growth factors leading to vasoconstriction , vascular modelling and then to increased peripheral blood pressure
- Mental Stress can also lead to increased blood pressure and endothelial dysfunction

GALLO, VOLPE AND SAVOIA, 2022; SARA ET AL. 2022

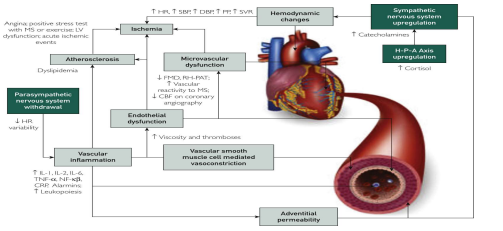
39

MENTAL STRESS AND ENDOTHELIAL DYSFUNCTION/CARDIOVASCULAR DISEASE

- A study by Lima and associates in 2019 found that those participants who displayed endothelial dysfunction in the lab setting had a 78% high incidence of cardiovascular event
- Kershaw and Associates (2017) also found that chronic stress was associated with endothelial dysfunction

40

MENTAL STRESS AND VASCULAR EFFECTS



SARA ET AL., 2022

41

HYPERTENSION AND TREATMENT

One first line treatment is beta blockers as competitively inhibit binding of endogenous catecholamines to beta receptors during sympathetic activity

CHPA, 2024

42

HYDROTHERAPY AND HTN TREATMENT TARGET

In HTN goal is to decrease vascular resistance by decreasing activation of several systems including sympathetic nervous system

43

HOT FOOT BATH MECHANISM

Hot foot bath increases perfusion to the legs and stimulate the parasympathetic system leading to lower blood pressure and lower heart rate

AYDIN ET AL., 2016; HALL, E., 2024

44

HOT FOOT BATH

- Fill a bucket or tub above ankles with water between 103-110 degrees F (maximum 102 degrees F with neuropathy)
- Apply a cold compress to the client's head
- Continue to add hot water to maintain temperature
- Finish treatment by pouring cold water over the feet
- Dry feet thoroughly
- Have client rest for 20-30 minutes in bed

HALL, E. 2024

45

HOT FOOT BATH CONTRAINDICATIONS IN CLINICAL PRACTICE

- Gout
- Joints that are hot and swollen
- Swelling to legs
- Impaired sensation**** (caution)

HALL E, 2024

46

HOT FOOT BATH IN CLINICAL PRACTICE

80-year-old Caucasian male

GOALS:

-manage diabetes and HTNwithout medication if possible

-manage diabetes and blood pressure in order to have surgery of his shoulder

MEDICAL HISTORY: hypertension, diabetes, sleep apnea(tx with cpap machine)

MEDICATIONS: LASIX 40 mg po OD prn

LIFESTYLE HISTORY:

Whole food plant based; Early time restricted fasting

Exercised daily

Drank 8 cups of water

Trusted in the Lord

47

HOT FOOT BATH IN CLINICAL PRACTICE

Echocardiogram: unremarkable, stress test unremarkable

PHYSICAL EXAM

Unremarkable except some tenderness to right shoulder with palpation

Blood pressure during program:138-165/73-90

48

HYPERTENSIVE EPISODE

Blood pressure during program:138-165/73-90

One episode: Blood pressure =173/100.

The client declined hospital transfer and evaluation

Treatment: Hot foot bath

Post hot foot bath

BP=140/80

Mood: Client states he felt so relaxed after the treatment

49

HOT FOOT BATH UTILITY IN CLINICAL PRACTICE

- Use as an adjunct to lifestyle interventions and herbs/medications
- Self care practice
- Reiterates the importance of a whole person treatment plan

50

A HEART OF STONE TO A HEART OF FLESH

Several hydrotherapy modalities can directly or indirectly improve endothelial function

Hydrotherapy can provide another opportunity to provide care to clients showing the love of Christ

51

REFERENCES

Aydın, D., Hartiningsih, S., Izgi, M., Bay, S., Unlu, K., Tatar, M., Alparslan, A., Ozeri, M., and Dane, S. (2016). Potential beneficial effects of foot bathing on cardiac rhythm. Clinical & Investigative Medicine. 39. 48. doi:10.25011/cim.v39i6.27501.

An, J., Lee, I., and Yi, Y. (2019). The Thermal Effects of Water Immersion on Health. Outcomes: An Integrative Review. International Journal of Environmental Research and Public Health. Retrieved from https://www.mdpi.com/1660-4601/16/7/1280

Bieuzen F, Bleakley CM, Costello JT (2013) Contrast Water Therapy and Exercise Induced Muscle Damage: A Systematic Review and Meta-Analysis. PLoS. ONE 8(4): e62356. Retrieved from https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0062356

Brenner, K. (1999). Immune changes in humans during cold exposure: effects of prior heating and exercise. Journal of Applied Physiology. 87 (2). Retrieved from https://www.physiology.org/doi/pdf/10.1152/jappl.1999.87.2.699

Brunt, V. E., & Minson, C. T. (2021). Heat therapy: mechanistic underpinnings and applications to cardiovascular health. Journal of applied physiology (Bethesda, Md. : 1985), 130(6), 1684–1704. https://doi.org/10.1152/japplphysiol.00141.2020

52

REFERENCES

Canadian Pharmacy Association (Cpha) (2019). Angiotensin-Converting Enzyme (ACE) Inhibitors. CPhA monograph. Retrieved from CPS from cpha app

Canadian Pharmacy Association (Cpha) (2021). Maxallt. CPhA monograph. Retrieved from CPS from cpha app

Canadian Pharmacy Association (Cpha) (2024). Beta-adrenergic blocking agents. CPhA monograph. Retrieved from CPS from cpha app

Drera, A., Rodella, L., Brangi, E., Riccardi, M., & Vizzardi, E. (2024). Endothelial Dysfunction in Heart Failure: What Is Its Role?. Journal of clinical medicine, 13(9), 2534. https://doi.org/10.3390/jcm13092534

Ezekowitz JA, O'Meara E, McDonald MA et al. 2017 Comprehensive update of the Canadian Cardiovascular Society guidelines for the management of heart failure. Can J Cardiol. 2017;33:1342–33. doi: 10.1016/j.cjca.2017.08.022.

53

REFERENCES

Fokmare, P., & Phansopkar, P. (2023). The Effect of Contrast Bath Therapy and Knee Pad Device on Pain, Range of Motion, and Functional Disability in Patients With Osteoarthritis Knee: A Randomized Control Trial. Cureus, 15(10), e47586. https://doi.org/10.7759/cureus.47586

Gallo, G., Volpe, M., & Savoia, C. (2022). Endothelial Dysfunction in Hypertension: Current Concepts and Clinical Implications. Frontiers in medicine, 8, 798958. https://doi.org/10.3389/fmed.2021.798958

Gálvez, I., Torres-Piles, S., & Ortega-Rincón, E. (2018). Balneotherapy, Immune System, and Stress Response: A Hormetic Strategy?. International journal of molecular sciences, 19(6), 1687. https://doi.org/10.3390/ijms19061687

Hall, E. (2024). Hydrotherapy Remedies for Health and Healing. Wildwood Sanitarium Inc

Higashi Y. (2022). Roles of Oxidative Stress and Inflammation in Vascular Endothelial Dysfunction-Related Disease. Antioxidants (Basel, Switzerland), 11(10), 1958. https://doi.org/10.3390/antiox11101958

Kershaw, K. N., Lane-Cordova, A. D., Carnethon, M. R., Tindle, H. A., & Liu, K. (2017). Chronic Stress and Endothelial Dysfunction: The Multi-Ethnic Study of Atherosclerosis (MESA). American journal of hypertension, 30(1), 75–80. https://doi.org/10.1093/ajh/hpw103

Kurakula, K., Smolders, V. F. E. D., Tura-Ceide, O., Jukema, J. W., Quax, P. H. A., & Goumans, M.-J. (2021). Endothelial Dysfunction in Pulmonary Hypertension: Cause or Consequence? Biomedicines, 9(1), 57. https://doi.org/10.3390/biomedicines9010057

54

REFERENCES

Kihara, T., Biro, S., Imamura, M., Yoshifuku, S., Takasaki, K., Ikeda, Y., Otuji, Y., Minagoe, S., Toyama, Y., & Tei, C. (2002). Repeated sauna treatment improves vascular endothelial and cardiac function in patients with chronic heart failure. Journal of the American College of Cardiology, 39(5), 754–759. https://doi.org/10.1016/s0735-1097(01)01824-1

Kurakula, K., Smolders, V. F. E. D., Tura-Ceide, O., Jukema, J. W., Quax, P. H. A., & Goumans, M.-J. (2021). Endothelial Dysfunction in Pulmonary Hypertension: Cause or Consequence? Biomedicines, 9(1), 57. https://doi.org/10.3390/biomedicines9010057

Laukkanen J, Laukkanen T, and Kunutsor S J 2018). Cardiovascular and Other health Benefits of Sauna Bathing: A Review of the evidence. Mayo Clinic Proceedings. August 2018; 93(8): 1111-1121. Retrieved from https://www.mayoclinicproceedings.org/article/S0025-6196(18)30275-1/fulltext on April 29, 2025

Landry, D. W., & Oliver, J. A. (2001). The pathogenesis of vasodilatory shock. The New England journal of medicine, 345(8), 588–595. https://doi.org/10.1056/NEJMra002709

Michalsen, A., Lüdtke, R., Bühring, M., Spahn, G., Langhorst, J., & Dobos, G. J. (2003). Thermal hydrotherapy improves quality of life and hemodynamic function in patients with chronic heart failure. American heart journal, 146(4), 728–733. https://doi.org/10.1016/S0002-8703(03)00314-4

Mučka, S., Miodońska, M., Jakubiak, G. K., Starzak, M., Cieślar, G., & Stanek, A. (2022). Endothelial Function Assessment by Flow-Mediated Dilation Method: A Valuable Tool in the Evaluation of the Cardiovascular System. International Journal of Environmental Research and Public Health, 19(18), 11242. https://doi.org/10.3390/ijerph191811242

Rao, S., Pena, C., Shurmur, S., & Nugent, K. (2021). Atrial Natriuretic Peptide: Structure, Function, and Physiological Effects: A Narrative Review. Current cardiology reviews, 17(6), e051121191003. https://doi.org/10.2174/1573403X17666210202102210

55

REFERENCES

Sara, J., Toya, T., Ahmad, A. Clark, M., Gilliam, W., Leman, L., and Leman, A (2022). Mental Stress and its Effect on Vascular Health. Mayo Clinic Proceedings.97(5); 951-990. Retrieved on April 29, 2025 from https://www.mayoclinicproceedings.org/action/showPdf?pii=S0025-6196%2822%2900104-5

Shams P, Malik A, Chhabra L (2025). Heart Failure (Congestive Heart Failure) StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK430873/

Sinclair, M. (2008). Modern Hydrotherapy for the Massage Therapist. Lippincott Williams & Wilkins. Philadelphia, PA

Tei, C., Horikiri, Y., Park, J. C., Jeong, J. W., Chang, K. S., Toyama, Y., & Tanaka, N. (1995). Acute hemodynamic improvement by thermal vasodilation in congestive heart failure. Circulation, 91(10), 2582–2590. https://doi.org/10.1161/01.cir.91.10.2582

Thomas, K. N., van Rij, A. M., Lucas, S. J., & Cotter, J. D. (2017). Lower-limb hot-water immersion acutely induces beneficial hemodynamic and cardiovascular responses in peripheral arterial disease and healthy, elderly controls. American journal of physiology. Regulatory, integrative and comparative physiology, 312(3), R281–R291. https://doi.org/10.1152/ajpregu.00404.2016

Zhou, M., Yu, Y., Chen, R., Liu, X., Hu, Y., Ma, Z., Gao, L., Jian, W., & Wang, L. (2023). Wall shear stress and its role in atherosclerosis. Frontiers in cardiovascular medicine, 10, 1083547. https://doi.org/10.3389/fcvm.2023.1083547

56