Whole-body Heat Therapy for Health and Rehabilitation: What are the Treatment Protocols and Core Temperature Changes Related to Positive Health Outcomes?

An Industry Whitepaper for Health Mate

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Abstract

Whole-body heat therapy is a rapidly evolving modality used to promote positive health outcomes in active and clinical populations. This paper consolidates and outlines the treatment protocols of common whole-body heat therapy modalities that correspond to improved rehabilitation and health in healthy, diseased, and aged cohorts. This review encompasses a wide range of heat therapy protocols used in cardiovascular and metabolic diseases, as well as among aging, sedentary and active individuals. The paper categorises the treatment protocols based on specific populations and discusses the resulting changes in body temperature that contribute to positive health outcomes, such as improved disease management, cardiovascular fitness, and muscle strength. Additionally, potential risks associated with heat therapy in certain populations are briefly addressed, and suggestions for further research are provided to optimize treatment protocols and achieve targeted body temperature changes based on specific experimental cohorts and clinical conditions.

Introduction

Heat therapy is a fast-evolving modality used to confer positive health outcomes in active and clinical populations. It involves the application of heat to isolated areas of the body (i.e., localised treatment) with heat sources such as heat-generating pads or hot packs. It may also involve exposing the entire body to heat, with the deliberate purpose of increasing deep body temperatures (i.e., core temperature). Mechanisms underpinning heat therapy include increased expression of heat shock proteins, upregulation of anabolic, anti-inflammatory, anti-oxidant, nitric oxide and mitochondrial biogenesis signalling pathways, resulting in improved cardiovascular, metabolic and musculoskeletal health (1–3). Although there is growing evidence supporting both localised and whole-body (WB) heat treatments, WB modalities may be more efficient in increasing tissue temperatures for a given treatment time, and hence provide a more potent stimulus activating desired physiological responses (2).

Common WB heat therapy include the use of heat rooms or chambers, Finnish or infrared saunas and hot water immersion (HWI). A plethora of studies have utilised such WB modalities investigating recovery from exercise (4–6), as well as cardiovascular (7), metabolic (8,9) and skeletal muscle adaptations (2,10) in healthy, diseased, and aged populations. While most of this research demonstrate beneficial outcomes following WB heat therapy, less is known regarding the optimal target core temperatures. Core temperatures above 38.5°C have been shown to upregulate skeletal muscle anabolic signalling (2), as well as confer beneficial cardiovascular adaptations (11,12) following acute and longer-term treatment, respectively. As such, acquiring core temperatures above 38.5°C may be fundamental to harness the physiological benefits associated with WB heat therapy. However, there is extensive literature on the efficacy of saunas on health outcomes in cardiovascular disease patients, where WB protocols typically involve only 15-20 min of exposure at 60°C (13–15). While such protocols are unlikely to increase core temperatures to >38.5°C, they seem to confer positive health benefits within this patient group (13–15). Therefore, optimal body temperatures following WB treatments may likely be population specific. Moreover, variations in treatment modalities, such as air-based (sauna) versus water-based (HWI) have resulted in a wide range of recommended treatment temperatures and durations that are specific to each modality. This consequently warrants research outlining population-specific treatment protocols (i.e., temperature and duration) for different WB modalities.

Optimal heat therapy protocols are critical for achieving maximum therapeutic benefits and improving overall health and wellness while minimizing the risk of adverse effects. Therefore, this review aims to consolidate and outline the treatment protocols of common WB heat therapy modalities that correspond to improved rehabilitation and health in healthy, diseased, and aged cohorts.

Heat Therapy and Cardiometabolic Health

Cardiovascular health and metabolic function are cornerstones underpinning healthy living and vitality. Diseases associated with these organ systems are among the leading causes of death worldwide contributing to significant morbidity and mortality (16,17). **Table 1.** outlines recent meta-analyses investigating the effect of heat therapy on cardiometabolic health in healthy and clinical populations, which, taken together, provide considerable support for the use of this modality.

Table 1. *Overview of meta-analyses investigating the effect of heat therapy on cardiometabolic health*

Study	Participants	Outcome Measures	Key Findings	Conclusion
Pizzey et al. (7)	Healthy & Clinical (HF, Obese, PCOS, CV risk)	**Vascular function** (FMD, CVC, PWV, AS), **BP**	↓ BP, ↓AS, ↓PWV, ↑FMD & ↑CVC	HT improved CV health
Sebok et al. (9)	T2D with comorbidities	**Metabolic markers** (FGLU, HBA1C), **Blood lipids** (HDL, LDL, TCL, TG)	↔ FGLU, HBA1C ↔ HDL, LDL, TCL, TG	HT showed strong tendency to improve cardiometabolic health
Ye et al. (15)	Heart Failure	**Cardiac function & structure** (EF, CTR, LVEDD, LAD), **Vascular function** (FMD), **BP, Others** (BNP, HDP, NYHA-C, QOL)	↑EF, ↓CTR, ↓LVEDD, ↓LAD, ↑FMD, ↓BP, ↓BNP, ↓HDP, ↑QOL, ↑*NYHA-C	HT improved disease symptoms, quality of life, cardiac function & geometry in HF patients
Li et al. (13)	CV disease & CV disease risk	**Cardiac function & structure** (EF, CTR, LVEDD, LAD), **Vascular function** (FMD), **BP, Others** (6MWD, BNP)	↑EF, ↓CTR, ↓LVEDD, ↓LAD, ↓BP, ↓BNP, ↑FMD, ↑6MWD	HT improved endurance, cardiac function & geometry in patients with CV disease
Kallstrom et al. (14)	Heart Failure	**Cardiac function & structure** (EF, CTR, LVEDD, LAD), **Vascular function** (FMD), **BP, Others** (BNP)	↑EF, ↓CTR, ↓LVEDD, ↓BNP	HT improved cardiac function & geometry in patients with HF

AS; arterial stiffness**, BNP**; brain natriuretic peptide**, BP**; blood pressure, **CTR**; cardiothoracic ratio, **CV**; cardiovascular, **CVC**; cutaneous vascular conductance **EF**; ejection fraction, **FGLU**; fasting glucose, **FMD**; flow mediated dilation, **HBA1C**; glycated haemoglobin, **HDL**; high-density lipoprotein, **HDP**; hydroperoxide, **HF**; heart failure, **HT**; heat therapy, **LAD**; left atrial dimension, **LDL**; low-density lipoprotein, **LVEDD**; left ventricular end-diastolic dimension, **NYHA-C**; new york heart association classification, **PCOS**; polycystic ovary syndrome, **PWV**; pulsed wave velocity, **QOL**; quality of life, **TCL**; total cholesterol, **TG**; triglyceride, **T2D**; type 2 diabetes, **6MWD**; 6-minute walk distance.

↑*; *improved,* ↑*increase,* ↓*decrease,* ↔*unchanged*

Both functional [i.e., arterial stiffness, cutaneous vascular function, blood pressure (BP), ejection fraction (EF), flow-mediated dilation (FMD)] and structural [i.e., cardiothoracic ratio (CTR), left ventricular end-diastolic diameter (LVEDD), left atrial diameter (LAD)] cardiovascular indices are reported to be improved following heat therapy (7,13–15), with indices such as EF and BP to be notably improved through longer intervention periods (i.e., 4 weeks vs. 2-3 weeks of intervention) (13). Additionally, heat therapy tended to improve glucose profiles in patients with type 2 diabetes (9) while shown to improve glucose and insulin profiles in overweight men (18) and obese women with polycystic ovary syndrome (PCOS) (19).

Heat Therapy Protocols in Healthy and Clinical Populations

Cardiovascular outcomes, alongside respective heat therapy protocols in healthy and clinical groups are summarised in **Tables 2** and **3**, respectively. WB protocols increasing core temperatures between >1°C (females) and 1.5°C (males) have been shown to improve vascular function and blood lipid profile in young, healthy cohorts (20–22). While the changes in body temperature seem comparable between the sauna- and HWI-based protocols, the session and intervention durations varied considerably between the modalities. The former involved 30 to 50 min exposures and 7 to 10 sessions in 2 weeks (20,21), whilst the latter involved 90 minute sessions, with a total of 36 sessions across 8 weeks (i.e., 4–5 sessions per week) (22). The heat load conferred by HWI substantially exceeds that of the sauna as well. Briefly, the sauna-based protocols increased rectal temperatures by 1.1°C and 1.5°C for males and females, respectively (20,21). However, the HWI was designed to prolong exposure at core temperatures between 38.5 and 39°C, and given the treatment time of 90

Table 2. *Effect of heat of heat therapy on cardiometabolic outcomes in healthy individuals*

Study	Participants (age)	Protocol	Core Temperature Δ	Duration	Main Findings
Hesketh et al. (8)	Sedentary men (21 ± 1 y)	HC (40-50 min @ 40°C)	No change	3x/wk for 6 wks (total = 18 sessions)	↑* **endurance** (↑VO_{2peak}) ↑* **metabolic profile** (↑ IS) **Others** (↑muscle capillarity)
Brunt et al. (22)	Sedentary mixed (22 ± 1 y)	HWI (90 min @ 40.5°C). WBI for 25-30 min followed by WLI @ T_{re} 38.5-39°C	Δ > 1.5°C (i.e., >38.5 to 39.0°C in T_{re})	4-5x/wk for 8 wks (total = 36 sessions)	↑* **vascular function** (↑FMD, ↓AS) **Others** (↓DBP)
Gryka et al. (20)	Active men (20.9 ± 0.9 y)	FS (3 x 15 min @ 90°C)	Δ1.6°C in T_{re} (37.0 ± 0.2 to 38.6 ± 0.3)	5x/wk for 2 wks (total = 10 sessions)	↑* **lipid profile** (↓TG, ↓LDL, ↓TCL, ↔HDL)
Pilch et al. (21)	Sedentary women (19.8 ± 0.9 y)	FS (1 x 30 min or 2 x 20 min @ 80°C)	Δ1.1°C in T_{re} (37.3 ± 0.3 to 38.4 ± 0.3)	3-4x/wk for 2 wks (total = 7 sessions)	↑***lipid profile** (↔TG, ↔LDL, ↓TCL, ↑HDL)

AS; arterial stiffness, **DBP**; diastolic blood pressure, **FMD**; flow-mediated dilation, **FS**; Finnish sauna, **HC**; heat chamber, **HDL**; high-density lipoprotein, **HWI**; hot water immersion, **IS**; insulin sensitivity, **LDL**; low-density lipoprotein, **TCL**; total cholesterol, **TG**: triglyceride, **T_{re}**; rectal temperature, **VO_{2peak}**; peak oxygen uptake, **WBI**; whole-body immersion, **WLI**; waist-level immersion

↑*; *improved,* ↑*increase,* ↓*decrease,* ↔*unchanged*

minutes, core temperatures were maintained within this range for 55 to 60 minutes (22). Hence, it is unknown to what extent sauna-based protocols administered by Gryka et al. (20) and Pilch et al. (21) may improve vascular outcomes described in Brunt et al. (22).

Within clinical conditions, protocols were diverse and ranged between 20 and 60 minutes, and between 2 and 8 weeks for treatment time and intervention duration, respectively (**Table 3**). Despite the diversity, it is notable that glucose profiles were improved in most groups, but not all (23), with protocols providing only mild heat stress (i.e., 30 min HWI @ 38-41°C) [**Table 3.** (24,25)]**.** Unfortunately, it is unclear to what extent such protocols increased core temperature (24,25)**.** Hooper (25) reported a 0.8°C increase in oral temperature. However, oral temperatures are poor indicators of deep body temperatures, especially during heat stress (26). Also notable is that improvements in other indices such as systemic inflammation, insulin profile and cardiovascular risk factors were only evident in the cohorts employing more aggressive protocols increasing core temperatures above 1.5°C (i.e., > 38.5°C) (12,18). These findings may indicate that improvements in cardiometabolic indices other than blood glucose profile in this population may require substantial increases in core temperature. Additionally, WB protocols increasing core temperatures between 1.5 and 2.0°C can be safely undertaken in clinical cohorts described in **Table 3**. (12,18).

Table 3. *Overview of heat therapy protocols on cardiometabolic outcomes in clinical cohorts*

Study	Participants (age)	Protocol	Core Temperature ∆	Duration	Conclusion
Ely et al. (12)	Obese females with PCOS (27 ± 4 y)	HWI (60 min @ 40.5°) *30-35 min WBI followed by WLI @ T_{re} 38.5 - 39°C	∆ > 1.5°C (i.e., >38.5 to 39.0°C in T_{re})	3-4 x/wk for 8-10 wks (total = 30 sessions)	↑* **lipid profile** (↓TCL, ↓LDL, ↔HDL) ↑***BP** (↓SBP. ↓DBP) ↑* **metabolic profile** (↓FGLU) ↑* **vascular function** (↑ FMD, ↓AS) **Others** (↓INF)
Ely et al. (19)	Obese females with PCOS (27 ± 1 y)	HWI (60 min @ 40.5°) *30-35 min WBI followed by WLI @ T_{re} 38.5 - 39°C	∆ > 1.5°C (i.e., >38.5 to 39.0°C in T_{re})	3-4 x/wk for 8-10 wks (total = 30 sessions)	↑* **lipid profile** (↓TCL, ↓NEFA) ↑* **metabolic profile** (↓FGLU, ↑IS, ↓IR) **Others** (↓INF)
Hoekstra et al. (18)	Overweight men (33.2 ± 10.1 y)	HWI (45-60 min @ 39°C)	∆ 1.6°C (37.1 ± 0.6 to 38.7 ± 0.4°C)	5 x/wk for 2 wks (total = 10 sessions)	↑* **metabolic profile** (↓FGLU, ↓FIN) **Others** (↓INF)
Qiu et al. (23)	T2D with LEAD mixed (61-65 y)	HWI (20 min @ 39°C, (spa therapy)	NR	5 x/wk for 4 wks (total = 28 sessions)	↔ **metabolic profile**
Olah et al. (24)	Obese mixed (61.7 ± 7.1 y), Hypertensive mixed (70.1 ± 6.5 y)	HWI (30 min @ 38°C, (balneotherapy)	NR	5 x/wk for 3 wks (total = 15 sessions)	↑* **metabolic profile** (↓FGLU, ↓ HBA1C) ↔ **lipid profile** **Others** (↔INF)
Hooper (25)	T2D mixed (43 - 68 y)	HWI (30 min @ 38-41°C)	∆ 0.8°C in oral temperature	6x/wk for 3 wks (total = 18 sessions)	↑* **metabolic profile** (↓FGLU, ↓HBA1C)

AS; arterial stiffness, **BP**; blood pressure, **DBP**; diastolic blood pressure**, FGLU**; fasting glucose, **FIN**; fasting insulin, **FMD**; flow-mediated dilation, **HBA1C**; glycated hemoglobin, **HDL**; high-density lipoprotein, **HWI**; hot water immersion, **INF**; inflammation, **IR**; insulin resistance, **IS**; insulin sensitivity, **LDL**; low-density

lipoprotein**,** **LEAD**; lower extremity arterial disease, **NEFA**; non-esterified fatty acid**,** **NR**; not reported**,** **PCOS**; polycystic ovary syndrome, **SBP**; systolic blood pressure**,** **TCL**; total cholesterol, **T_{re}**; rectal temperature, **T2D**; type 2 diabetes, **WBI**; whole-body immersion, **WLI**; waist-level immersion
↑**; improved,* ↑*increase,* ↓*decrease,* ↔*unchanged*

Heat Therapy Protocols in Cardiovascular Diseases

Table 4. provides a comprehensive description and summary of the heat therapy protocols that were examined in recent meta-analytic reviews (refer to **Table 1**). Approximately 86% of the studies utilised whole-body (WB) heat therapy modalities. Further, Woan (i.e., soothing warm) therapy seemed to be the prevalent modality in the treatment of heart failure (HF). This protocol involved 15 minutes of far-infrared sauna (FIRS) exposure at 60°C, followed by a 30-minute rest covered in blankets to retain body heat (27,28). As summarised (**Table 4**), this FIRS-based protocol demonstrates remarkable efficacy in the treatment of HF (29,30,39,31–38). Treatment frequency is 5 sessions per week, and interventions are typically 2 weeks, with some studies employing longer durations of 3-4 weeks (29–32,34). Whilst improvements in aerobic capacity typically occur following 3-4 weeks of heat therapy, disease severity (i.e., NYHA-C) is notably improved following 2 weeks alongside indices of cardiac function and structure (i.e., EF, CTR, LAD, LVEDD), vascular function, BP and neurohumoral factors [i.e., brain natriuretic peptide (BNP)] (**Table 4**). However, it is unclear whether longer treatment periods would confer additional improvements within these variables.

Table 4. Effect of heat of heat therapy on cardiovascular disease

Study	Participants (age)	Protocol	Core Temperature Δ	Duration	Conclusion
Tei et al. (39)	HF mixed (66 ± 16 y)	FIRS (15 min @ 60°C) + 30 min in blankets (Woan therapy)	NR	5x/wk for 2 wks (total = 10 sessions)	↑***endurance*** (↑6MWD) ↑***CFS*** (↔ EF, ↓CTR LVEDD & LAD) ↔**BP** **others** (↔BNP, ↑*NYHA-C)
Sobajima et al. (29)	HF mixed (69 ± 14 y)	FIRS (15 min @ 60°C) + 30 min in blankets (Woan therapy)	NR	7x/wk for 3 wks (total = 21 sessions)	↑***endurance*** (↑6MWD) ↑***CFS*** (↑EF, ↓CTR ↓LVEDD, ↓LAD) ↑***Vascular function*** (↑FMD) ↔**BP** **others** (↓BNP)
Oyama et al. (43)	HF mixed (68.7 ± 4.0 y)	HWI (10 min @ 40°C) +60 min in warm room (28°C) (Balneotherapy)	NR	5x/wk for 2 wks (total = 10 sessions)	↑***CFS*** (↑EF, ↓CTR ↔LVEDD & LAD) ↔**BP** **Others (**↑*NYHA-C, ↓BNP, ↓INF)
Ohori et al. (30)	HF mixed (68.3 ± 13.5 y)	FIRS (15 min @ 60°C) + 30 min in blankets (Woan therapy)	NR	5x/wk for 3 wks (total = 15 sessions)	↑***endurance*** (↑6MWD, ↑VO_{2peak}) ↑***CFS*** (↑EF, ↓LVEDD, ↓LAD) ↑***Vascular function*** (↑FMD) ↔**BP** **others** (↓BNP)

Fujita et al. (31)	HF mixed (64 ± 14 y)	FIRS (15 min @ 60°C) + 30 min in blankets (Woan therapy)	NR	5x/wk for 4 wks (total = 20 sessions)	↑***CFS (**↑EF, ↓CTR) ↔**BP** **Others** (↓BNP, ↓OS)
Kuwahata et al. (32)	HF mixed (63 ± 15 y)	FIRS (15 min @ 60°C) + 30 min in blankets (Woan therapy)	NR	5x/wk for 4 wks (total = 20 sessions)	↑***CFS** (↑EF, ↓LVEDV, ↑CO, ↓CTR ↓HR) ↑***BP** (↓SBP) **Others** (↑*ANSF)
Olah et al. (24)	Obese mixed (61.7 ± 7.1 y), Hypertensive mixed (70.1 ± 6.5 y)	HWI (30 min @ 38°C, (balneotherapy)	NR	5x/wk for 3 wks (total = 15 sessions)	↑* **metabolic profile** (↓FGLU, ↓ HBA1C) ↔ **lipid profile** **Others** (↔INF)
Sohn et al. (33)	HF mixed (62.3 ± 9.2 y)	FIRS (15 min @ 60°C) + 30 min in blankets (Woan therapy)	Δ1.1°C in oral temperature (35.9 ± 0.4 to 37.0 ± 0.9)	5x/wk for 2 wks (total = 10 sessions)	↑***CFS** (↑EF, ↓LVEDV, ↔LVEDD Others (↔ NYHA-C)
Gruner Svealve et al. (44)	HF mixed (69 ± 7 y)	HWI (45 min @ 34°C)	NR	2x/wk for 8 wks (total = 16 sessions)	↔**CFS**
Kudo et al. (42)	HF mixed (75.0 ± 3.4 y)	HWI (10 min @ 40°C) +60 min in warm room (28°C) (Balneotherapy)	NR	5x/wk for 2 wks (total = 10 sessions)	↑***CFS (**↑EF, ↔ CTR) ↑***vascular function** (↓PWV) ↑***BP** **Others** (↑*NYHA-C, ↓BNP)
Miyata et al. (28)	HF mixed (63 ± 13 y)	FIRS (15 min @ 60°C) + 30 min in blankets (Woan therapy)	NR	5x/wk for 2 wks (total = 10 sessions)	↑***CFS** (↑EF, ↓CTR, ↓LVEDV, ↓LAD) ↑***BP** (↓SBP, ↓DBP)

					others (↓BNP, ↑*NYHA-C)
Miyamoto et al. (34)	HF mixed (62 ± 15 y)	FIRS (15 min @ 60°C) + 30 min in blankets (Woan therapy)	NR	5x/wk for 4 wks (total = 20 sessions)	↑***endurance** (↑6MWD, ↑VO_{2peak}, ↑AT) ↑***CFS** (↑EF, ↓CTR ↔LVEDD & LAD) ↑***BP** (↓SBP) **others** (↔NYHA-C)
Imamura et al. (35)	CV risk men (38 ± 7)	FIRS (15 min @ 60°C) + 30 min in blankets (Woan therapy)	NR	5x/wk for 2 weeks (total = 10 sessions)	↑***BP (**↓SBP, ↓DBP) ↑***vascular function (**↑FMD) ↑***metabolic profile** (↓FGLU)
Tei & Tanaka (36)	HF mixed (NR)	Sauna therapy	NR	5x/wk for 4 wks (total = 20 sessions)	↑***CFS** (↑EF, ↓LVEDD, ↓CTR) **others** (↑*NYHA-C)
Kihara et al. (37)	HF mixed (62 ± 15 y)	FIRS (15 min @ 60°C) + 30 min in blankets (Woan therapy)	NR	5x/wk for 2 wks (total = 10 sessions)	↑***BP** (↓SBP, ↔DBP) ↑***CFS** (↔EF**,** ↓CTR, ↓LVEDD) ↑***vascular function** (↑FMD) **others** (↑*NYHA-C, ↓BNP)
Kihara et al. (38)	HF mixed (59 ± 3 y)	FIRS (15 min @ 60°C) + 30 min in blankets (Woan therapy)	NR	5x/wk for 2 wks (total = 10 sessions)	↑***CFS** (↑EF, ↑LVEDD, ↑LAD, ↓CTR) ↔**BP** **others** (↑*NYHA-C, ↓BNP, ↑HRV)

AT; anaerobic threshold, **ANSF**; autonomic nervous system function, **BNP**; brain natriuretic peptide**,** **BP**; blood pressure**,** **CFS**; cardiac function & structure, **CO**; cardiac output, **CTR**; cardiothoracic ratio, **CV**; cardiovascular, **DBP**; diastolic blood pressure, **EF**; ejection fraction, **FIRS**; far-infrared sauna, **FGLU**; fasting glucose, **FMD**; flow mediated dilation **HBA1C**; glycated haemoglobin, **HF**; heart failure, **HR**; heart rate, **HRV**; heart rate variability, **HWI**; hot water immersion, **INF**; inflammation, **LAD**; left atrial dimension **LVEDD**; left ventricular end-diastolic dimension, **LVEDV**; left ventricular end-diastolic volume, **NR**; not reported, **NYHA-C**; New York heart association classification, **OS**; oxidative stress, **PWV**; pulsed wave velocity, **SBP**; systolic blood pressure, **VO_{2peak}**; peak oxygen uptake, **6MWD**; 6-minute walk distance.
↑*; improved, ↑increase, ↓decrease, ↔unchanged*

Despite the prevalent use and reported benefits, body temperature changes following Woan therapy are not well documented and generally inconsistent. The Woan protocol reportedly increases deep body temperature (measured by pulmonary artery catheterisation) by 1.1°C (40). However, vast majority of work on Woan therapy rarely report or measure core temperature changes (**Table 4**). Sohn et al. (33) reported a 1.1°C increase in oral temperatures following Woan therapy. However, oral temperatures are highly unrepresentative of deep body temperatures, particularly during passive hyperthermia. For instance, 20 minutes of passive heat stress (~37°C environment) increased oral temperatures by ~0.8°C, while rectal temperatures remained unchanged (28). Additionally, 30 minutes of exposure to FIRS @ 55°C has been shown to increase rectal temperatures by 0.5°C (41), which does not corroborate with the purported 1.1°C in deep body temperature (40). While it is acknowledged that differences in participant characteristics (i.e., healthy individuals vs. HF patients) could substantially account for this disparity, it is inconclusive to what extent Woan therapy can increase deep body temperatures.

Other modalities used to treat HF includes lower body or WB HWI (42–44). Notably, some involved a 10-min immersion (between sternum and waist) at water temperatures of 40°C, followed by a 60-minute passive rest in warm temperatures (~28°C) supplemented with blankets (42,43). While treatment outcomes following these works are generally comparable to Woan therapy (42,43), it is unknown to what extent deep body temperatures were influenced. Regardless, heat therapy protocols for the treatment of HF generally seem designed to provide sustained but mild heat stress, with slight elevations in deep body temperature (i.e., <1°C) to confer the best therapeutic potential while minimizing the risk of adverse events.

Heat Therapy in the Treatment of Musculoskeletal Disorders

Localised heat applications have been utilised to treat chronic musculoskeletal conditions such as lower back pain, osteoarthritis, tendinosis, and fibromyalgia, demonstrating promising treatment outcomes in indices such as pain, strength, stiffness, and range of motion (45). However, there is limited information on the treatment efficacy of WB modalities on such conditions (**Table 5**). For instance, 12 weeks (3 sessions per week) of Woan therapy has been shown to improve quality of life, pain, and symptoms in patients with fibromyalgia syndrome, with benefits retained following 6 months (46). Conversely, FIRS treatment, while acutely relieved pain, stiffness, and fatigue, demonstrated limited benefit following 4 weeks of treatment in patients with rheumatoid arthritis and ankylosing spondylitis (47). It is unclear what are the clinically beneficial tissue, core body temperatures, or treatment durations for such musculoskeletal conditions. Developing optimal WB heat therapy protocols for such patient groups may be highly valuable, given the possibility of simultaneously harnessing the cardiometabolic benefits.

Table 5. *Overview of heat therapy protocols utilised in treating musculoskeletal disorders*

Study	Participants (age)	Protocol	Core Temperature Δ	Duration	Conclusion
Matsumoto et al. (46)	Females with FMS (42.8 ± 11.0 y)	FIRS (15 min @ 60°C) + 30 min in blankets (Woan therapy)	NR	3x/wk for 12 wks (total = 36 sessions)	↑QOL, ↓pain, ↓FMS symptoms
Oosterveld et al. (47)	Rheumatoid arthritis mixed (47 ± 13 y)	FIRS (30 min @ 55°C)	*Δ 0.5°C in T_{re}	2x/wk for 4 wks (total = 8 sessions)	Immediate ↓pain, ↓stiffness & ↓fatigue No longer-term
Oosterveld et al. (47)	Ankylosing spondylitis mixed (44 ± 10 y)	FIRS (30 min @ 55°C)	*Δ 0.5°C in T_{re}	2x/wk for 4 wks (total = 8 sessions)	benefits

FIRS; far-infrared sauna, **FMS**; fibromyalgia syndrome, **NR**; not reported, **QOL**; quality of life, **T_{re}**: rectal temperature

**from previous work by same authors*

↑*increase,* ↓*decrease,* ↔*unchanged*

Table 6. *Effect of heat of heat therapy on cardiovascular and musculoskeletal fitness*

Study	Participants (age)	Protocol	Core Temperature Δ	Duration	Conclusion
Sugie et al. (48)	Geriatric mixed (79.6 ± 6.5 y)	FIRS (15 min @ 60°C) + 30 min in blankets (Woan therapy)	NR	2x/wk for 12 wks (total = 24 sessions)	↑***endurance** (↑VO_{2peak}) **others** (↓frailty, ↓GS, ↔ strength & MM)
Hesketh et al. (8)	Sedentary men (21 ± 1 y)	HC (40-50 min @ 40°C)	No Δ in T_{re}	3x/wk for 6 wks (total = 18 sessions)	↑*** endurance** (↑VO_{2peak}) ↑***metabolic profile** (↑IS) **others** (↑muscle capillarity)
Racinais et al. (10)	Active men (33 ± 8 y)	HC (60 min @ 45-50°C)	Δ 2.0°C in T_{re} (~ 39.0°C)	5-6x/wk for 2 wks (total = 11 sessions)	↑ muscle strength
Tei et al. (39)	HF mixed (66 ± 16 y)	FIRS (15 min @ 60°C) + 30 min in blankets (Woan therapy)	NR	5x/wk for 2 wks (total = 10 sessions)	↑***endurance** (↑6MWD) ↑***CFS** (↔ EF, ↓CTR, LVEDD & LAD) ↔**BP** (↔SBP) **others** (↔BNP, ↑*NYHA-C)
Sobajima et al. (29)	HF mixed (69 ± 14 y)	FIRS (15 min @ 60°C) + 30 min in blankets (Woan therapy)	NR	7x/wk for 3 wks (total = 21 sessions)	↑***endurance** (↑6MWD) ↑***CFS** (↑EF, ↓CTR ↓LVEDD, ↓LAD) ↑***Vascular function** (↑FMD) ↔**BP** **others** (↓BNP)

Ohori et al. (30)	HF mixed (68.3 ± 13.5 y)	FIRS (15 min @ 60°C) + 30 min in blankets (Woan therapy)	NR	5x/wk for 3 wks (total = 15 sessions)	↑***endurance** (↑6MWD, ↑VO_{2peak}) ↑***CFS** (↑EF, ↓LVEDD, ↓LAD) ↑***Vascular function** (↑FMD) ↔**BP** **others** (↓BNP)
Miyamoto et al. (34)	HF mixed (62 ± 15 y)	FIRS (15 min @ 60°C) + 30 min in blankets (Woan therapy)	NR	5x/wk for 4 weeks (total = 20 sessions)	↑***endurance** (↑6MWD, ↑VO_{2peak}, ↑AT) ↑***CFS** (↑EF, ↓CTR ↔LVEDD & LAD) ↑***BP** (↓SBP) **others** (↔NYHA-C,)

AT; anaerobic threshold, **BNP**; brain natriuretic peptide; **BP**; blood pressure, **CFS**; cardiac function & structure**, CTR**; cardiothoracic ratio, **EF**; ejection fraction, **FIRS**; far-infrared sauna, **FMD**; flow mediated dilation, **GS**; geriatric syndrome, **HC**; heat chamber, **HF**; heart failure, **IS**; insulin sensitivity, **LAD**; left atrial dimension, **LVEDD**; left ventricular end-diastolic dimension, **MM**; muscle mass, **NR**; not reported, **NYHA-C**; New York heart association classification, **SBP**; systolic blood pressure, **T_{re}**; rectal temperature, **VO_{2peak}**; peak oxygen uptake, **6MWD**; 6-minute walk distance

↑*; *improved,* ↑*increase,* ↓*decrease,* ↔*unchanged*

Effect of Heat Therapy on Cardiovascular Fitness and Muscle Strength

Research shows that cardiometabolic adaptations conferred by WB heat therapy can translate to improved physical fitness attributes amongst different experimental groups (**Table 6**). For instance, HF, geriatric and young sedentary groups have exhibited improved cardiovascular fitness following repeated WB heat therapy (8,29,30,39,48). These studies utilised FIRS or heat chambers to deliver WB heat therapy (**Table 6**), with an estimated maximal core temperature increase of 1°C following the FIRS-based protocols. Interestingly, using heat chambers, Hesketh et al. (6) reported no increases in core temperature following their heat therapy protocol (i.e., 40-50 min @ 40°C, **Table 6**), yet reported improved aerobic capacity following 6 weeks of treatment. These works demonstrate that short-term treatment (i.e., 2-3 weeks) resulting in modest elevations in core temperature (i.e., 0.5 - 1°C) can improve exercise capacity in HF patients. Likewise, in sedentary groups, prolonged treatment interventions with repeated increases in skin temperature, independent of core temperature, may confer improvements in aerobic capacity (8).

While FIRS-based Woan therapy seems a remarkable modality to improve endurance in geriatric groups, similar outcomes in strength-related tasks such as handgrip strength and timed-up-and-go tests were not evident (48). This contrasts with recent work demonstrating improved muscle contractility in active males receiving 2 weeks of WB heat therapy (49). It is likely that deep tissue temperatures achieved by Sugie et al. (48) were insufficient to stimulate signalling events upregulating muscle mass and strength. This is supported by work demonstrating enhanced skeletal muscle signalling when heat therapy elevated core and/or muscle temperatures to 39.1°C and 38.8°C to 40°C, respectively (2,50), but not at muscle temperatures between 37.5 and 38.0°C (2,51,52). Therefore, WB heat therapy modalities should target to achieve core body temperatures between 38.5°C and 39°C to stimulate adaptations to muscle mass and strength. However, it is uncertain if such levels of heat stress can be safely administered to geriatric or cardiovascular-risk populations. More work is required to determine the optimal thermal load necessary to confer strength-related adaptations within these cohorts.

Conclusion and Recommendations

Figure 1 summarises the core temperature changes and corresponding improvements in health outcomes following heat therapy in different populations. Most clinical populations seem to benefit from a 0.5 to 1°C increase in core temperature. For instance, the metabolic profile is improved in all clinical groups and sedentary counterparts. In addition, a 0.5 to 1°C increase in core temperature confers remarkable positive cardiovascular outcomes in HF patients and improved cardiovascular fitness, decreased frailty, and geriatric syndrome within the elderly. However, it is not entirely known if the cardiovascular and geriatric benefits observed within the respective groups are evident between the patient groups, given their comparable age.

In contrast to the clinical and sedentary counterparts, greater increases in core temperature (i.e., > 1°C) seem required to provide positive physiological outcomes in active groups, with higher levels of heat strain (1.5 to 2.0°C) shown to improve muscle mass and strength. While HF and geriatric groups would benefit from increased muscle strength, it is unlikely that similar treatment dose surmounting to core temperature increases of 1.5 to 2.0°C can be safely undertaken within these populations. Future work needs to determine the required body temperature changes, or suitable combination therapies to upregulate such adaptations within these populations. Heat therapy providing greater increases in core temperature (i.e., 1.5 to 2.0°C) seems well tolerated amongst obese and sedentary groups, and such increases seem to confer additional cardiovascular, metabolic, and inflammatory benefits.

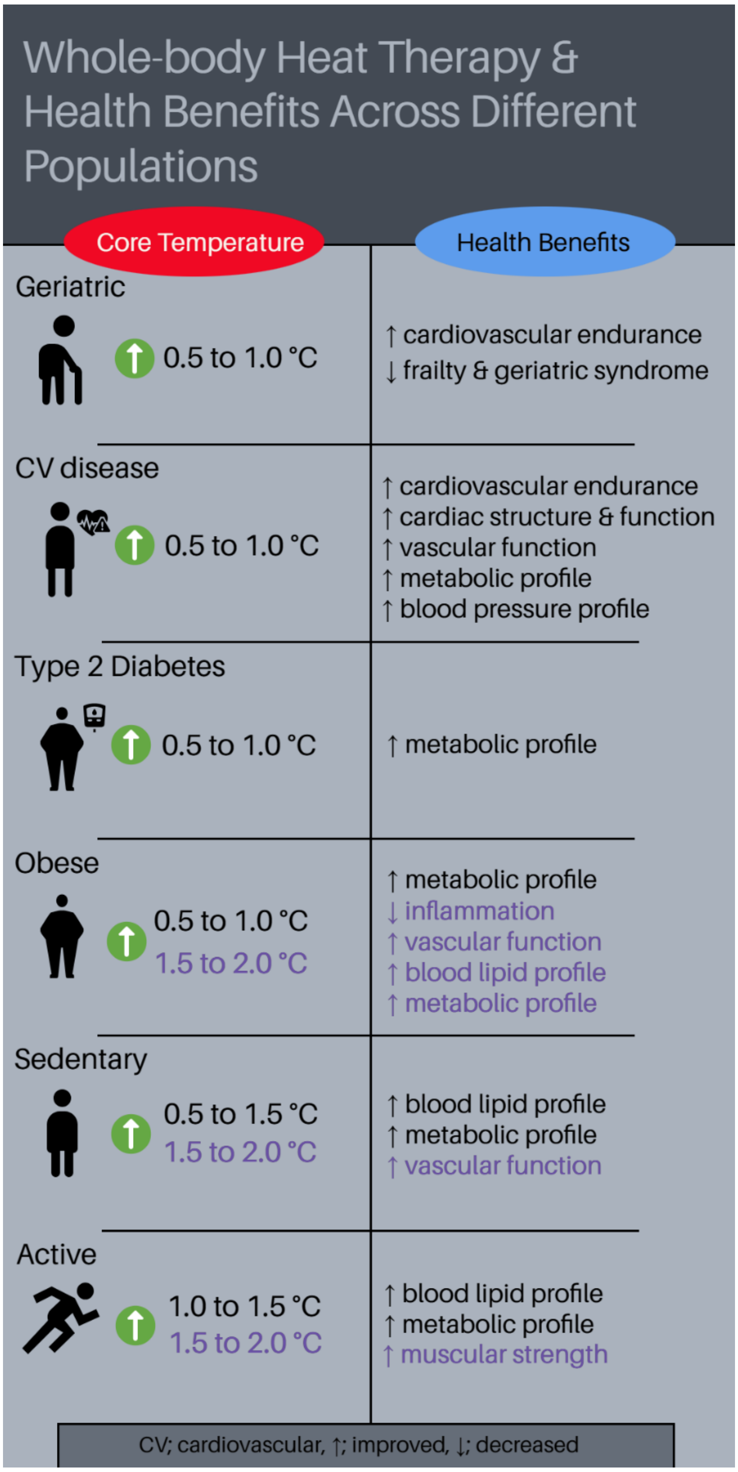

Figure 1. Infographic summary of core temperature changes and corresponding improvements in health outcomes following heat therapy in different populations

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