

# Scientific Evidence-Based Effects of Hydrotherapy on Various Systems of the Body

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## Abstract

The use of water for various treatments (hydrotherapy) is probably as old as mankind. Hydrotherapy is one of the basic methods of treatment widely used in the system of natural medicine, which is also called as water therapy, aquatic therapy, pool therapy, and balneotherapy. Use of water in various forms and in various temperatures can produce different effects on different system of the body. Many studies/reviews reported the effects of hydrotherapy only on very few systems and there is lack of studies/reviews in reporting the evidence-based effects of hydrotherapy on various systems. We performed PubMed and PubMed central search to review relevant articles in English literature based on “effects of hydrotherapy/balneotherapy” on various systems of the body. Based on the available literature this review suggests that the hydrotherapy has a scientific evidence-based effect on various systems of the body.

**Keywords:** Evidence-based effects, Hydrotherapy, Various systems

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## Introduction

Hydrotherapy is the external or internal use of water in any of its forms (water, ice, steam) for health promotion or treatment of various diseases with various temperatures, pressure, duration, and site. It is one of the naturopathic treatment modality used widely in ancient cultures including India, Egypt, China, etc.<sup>[1]</sup> Though many countries used water to produce different physiological/therapeutic effects on different part of the system for maintaining health, preventing, and treating the diseases, the scientific evidence-based effects are not well documented. There are many studies/reviews that reported either physiological or therapeutic or combination of both the effects of hydrotherapy on particular system but did not report in all the major systems of the body, which made us to do this review

with the aim and objective to report scientific evidenced-based effects of hydrotherapy on various systems of the body. In order to provide a general overview, we performed PubMed and PubMed central search to review relevant articles in English literature based on “effects of hydrotherapy/balneotherapy” on various systems of the body. Articles published from 1986 to 2012 were included in this review.

## Hydrotherapy in general

Superficial cold application may cause physiologic reactions such as decrease in local metabolic function, local edema, nerve conduction velocity (NCV), muscle spasm, and increase in local anesthetic effects.<sup>[2]</sup>

One hour head-out water immersions (WI) in various temperatures (32°C, 20°C, and 14°C) produced various effects. Immersion at 32°C did not change metabolic rate (MR) and rectal temperature (Tre), but it lowered the heart rate (HR) by 15%, systolic blood pressure (SBP) and diastolic blood pressure (DBP) by 11% and 12%, respectively, compared, with controls at ambient air temperature. Along with HR and blood pressure (BP), the plasma renin activity, plasma cortisol, and aldosterone concentrations were also lowered by 46%, 34%, and 17%, respectively, while diuresis was increased by 107%.<sup>[3]</sup>

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Immersion at 20°C produced similar decrease in plasma renin activity, HR, SBP, and DBP, in spite of lowered Tre and increased MR by 93%. Plasma cortisol concentrations tended to decrease, while plasma aldosterone concentration was unchanged. Diuresis was increased by 89%. No significant differences in changes in plasma renin activity, aldosterone concentration, and diuresis compared with subjects immersed in 32°C.<sup>[3]</sup>

Immersion at 14°C lowered Tre and increased MR by 350%, HR, SBP, and DBP by 5%, 7%, and 8%, respectively. Plasma noradrenaline and dopamine concentrations were increased by 530% and by 250%, respectively, while diuresis increased by 163%, which was more than at 32°C. Plasma aldosterone concentrations increased by 23%. Plasma renin activity was reduced. Cortisol concentrations tended to decrease. Plasma adrenaline concentrations remained unchanged. Changes in plasma renin activity were not related to changes in aldosterone concentrations.<sup>[3]</sup>

WI in different temperatures did not increase blood concentrations of cortisol. There was no correlation between changes in Tre and changes in hormone production. The physiological changes induced by WI are mediated by humoral control mechanisms, while responses induced by cold are mainly due to increased activity of the sympathetic nervous system (SNS).<sup>[3]</sup>

Regular winter swimming significantly decreased tension, fatigue, memory, and mood negative state points with the duration of swimming period; significantly increased vigor-activity scores; relieved pain who suffered from rheumatism, fibromyalgia, or asthma; and improved general well-being in swimmers.<sup>[4]</sup>

### Cardiovascular system

Cold exposure (CE) to small surface area produced compensatory vasodilatation in deeper vascular system resulting increased blood flow to the tissues underlying the site of exposure. This vascular reaction occurs mainly to maintain constant deep tissue temperature.<sup>[2]</sup>

In patient with chronic heart failure (CHF), thermal vasodilatation following warm-water bathing and low-temperature sauna bathing (LTSB) at 60°C for 15 min improves cardiac function;<sup>[5]</sup> repeated sauna-therapy (ST) increased left ventricular ejection fraction; increased 6-min walk distance in association with improvement in flow-mediated dilation and increase in number of circulating CD34 (+) cells; reduced plasma levels of norepinephrine and brain natriuretic peptide. These indicates that ST improves exercise tolerance in association with improvement in endothelial function.<sup>[6]</sup> LTSB improves peripheral circulation in cerebral palsy (CP).<sup>[5]</sup>

After ST reduced level of total and low density lipoprotein (LDL)-cholesterol concentration, while increased level of high density lipoprotein (HDL)-cholesterol was observed. These changes are good prognoses for the prevention of ischemic heart disease.<sup>[7]</sup> ST increases endothelial nitric oxide synthase (eNOS) activity and improves cardiac function in heart failure and improve peripheral blood flow in ischemic limbs. In myocardial infarction (MI)-induced Wistar rats ST increases myocardial eNOS, vascular endothelial growth factor mRNA levels. It attenuates cardiac remodeling after MI through improving coronary vascularity in the noninfarcted myocardium and thus ST might serve as a novel noninvasive therapy for patients with MI.<sup>[8]</sup> Acute MI was thought to result from thrombosis or plaque rupture because of coronary artery spasm. The vasospasm might be induced by stimulation of the alpha-adrenergic receptors during alternating heat exposure during sauna bath followed by rapid cooling during cold water bath. This effect showed the dangers of rapid cooling after sauna bathing in patients with coronary risk factors.<sup>[9]</sup> Regular ST (either radiant heat or far-infrared units) appears to be safe and produce multiple health benefits but use of ST in early pregnancy is a potential concern because evidence suggesting that hyperthermia might be teratogenic.<sup>[10]</sup>

Cold water immersion (CWI) induces significant physiological and biochemical changes in the body such as increase in HR, BP, metabolism, and peripheral catecholamine concentration; and decrease in cerebral blood flow.<sup>[11]</sup>

Reduction in HR, and increases in systolic and diastolic biventricular functions, were observed during acute warm-WI.<sup>[12]</sup> In contrast, increase in HR and a decrease in SBP and DBP were observed in 30 min of head-out WI (38.41 ± 0.04°C).<sup>[13]</sup>

Hyperthermic immersion (HI) produced shortening of activated partial thromboplastin time. During HI plasminogen activator inhibitor (PAI) activity was decreased; thrombocyte count was increased; increases in tissue-type plasminogen activator concentration and leukocytes count were attributed to hemoconcentration. Immediately after HI, fibrinogen concentration decreased but increased during recovery. During thermo-neutral immersion prothrombin time, PAI activity and granulocyte count increased. Warm water bathing leads to hemoconcentration and minimal activation of coagulation; decrease in PAI-1 activity. During warm water bathing, marked risk for thrombotic or bleeding complications in healthy males could not be ascertained.<sup>[14]</sup> During contrast baths, longer duration in the second heating phase was required to produce sufficient fluctuation in blood flow.<sup>[15]</sup>

WI up-to shoulder levels at different temperatures (25°C, 34°C, and 40°C) showed no significant effect on cardiac output in 25°C compared with 34°C, but in 40°C a considerable increase in cardiac output was observed.<sup>[16]</sup>

Carbon dioxide (CO<sub>2</sub>) enriched WI reduced free radical plasma levels, raised antioxidants levels, and induce peripheral vasodilatation suggests improvement in microcirculation.<sup>[17,18]</sup> Decrease in tympanic temperature; increase in cutaneous blood flow at immersed site was significantly greater in CO<sub>2</sub>-WI compared with fresh WI.<sup>[18]</sup> The three main effects of CO<sub>2</sub> enriched WI are decline in core temperature, increase in cutaneous blood flow, and elevation of score on thermal sensation, which were analyzed.<sup>[19]</sup>

### Respiratory system

WI up-to shoulder levels at different temperatures (25°C, 34°C, and 40°C) showed increased MR, oxygen (O<sub>2</sub>) consumption (VO<sub>2</sub>) only at 25°C. Two main factors affecting O<sub>2</sub> transport during immersion are temperature and hydrostatic pressure. O<sub>2</sub> transport was improved above neutral temperature, because of increase in cardiac output resulting from the combined actions of hydrostatic counter pressure and body heating. Below neutral temperature, O<sub>2</sub> transport is altered. At any of the temperatures tested, the pulmonary tissue volume and arterial blood gases were not significantly affected.<sup>[16]</sup>

Significant decrease in vital capacity (VC) with bath temperature was observed (i.e., VC at 40°C > 34°C > 25°C). Significant increase in tidal volume (VT) in cold or hot water compared with thermo neutral water (i.e., VT 40°C > 34°C < 25°C). Alterations in respiratory muscles functioning might produce variations of the pulmonary volumes as a function of water temperature.<sup>[20]</sup>

CWI was associated with increase in respiratory minute volume and decrease in end tidal CO<sub>2</sub> partial pressure.<sup>[11]</sup> Repeated cold water stimulations reduced frequency of infections; increased peak expiratory flow, lymphocyte counts, and expression of gamma-interferon; modulated interleukin expression; and improved quality of life (QOL) in patients with chronic obstructive pulmonary disease.<sup>[21]</sup>

In children suffering from recurrent and asthmatic bronchitis in remission, a single total air bath, or douche and local (cooling of the feet with water) exposure to mild cold did not raise noticeable disorders of the respiratory function. Local cold procedures improve bronchial patency but heat exposure resulted in its worsening.<sup>[22]</sup>

Inhaling hot air while in a sauna produced no significant impact on overall symptom severity of common

cold.<sup>[23]</sup> A male track and field athlete, a case of breathing difficulties at rest and during exercise, was exacerbated in the supine position and during WI.<sup>[24]</sup>

### Nervous system

Three cold modalities such as ice massage, ice pack, and CWI applied to right calf region for 15min reduced skin temperature (Tsk) (mean 18.2°C); reduced amplitude and increased latency and duration of compound action potential. It also reduced sensory NCV by 20.4, 16.7, and 22.6 m/s and motor NCV by 2.5, 2.1, and 8.3 m/s, respectively. Even though all three modalities effectively reduced Tsk and sensory conduction at a physiological level, CWI is the most indicated, effective modality for inducing therapeutic effects associated with the reduction of motor nerve conduction.<sup>[25]</sup>

Temperature and pressure of water in aquatic or hydrotherapy can block nociceptors by acting on thermal receptors and mechanoreceptors and exert positive effect on spinal segmental mechanisms, which is useful for painful condition.<sup>[26]</sup> Forty sessions of Ai Chi aquatic exercise (AE) program improves pain, spasms, disability, fatigue, depression, and autonomy in patient with multiple sclerosis.<sup>[27]</sup>

In a study on physiotherapy on land or water in patient with Parkinson's disease (PD), functional reach test was improved in both therapies, but Berg Balance Scale (BBS) and Unified Parkinson's Disease Rating Scale (UPDRS) were improved only in aquatic therapy group. It indicates improvement in postural stability in PD was significantly larger after aquatic therapy.<sup>[28]</sup>

Sauna bath on paraplegic (P) group and tetraplegic (T) group, HR increased significantly during sauna but decreased significantly during postsauna phase in P group. DBP significantly reduced in T group during postsauna phase but no significant changes in SBP in both the groups.<sup>[29]</sup>

In a study on CP, LTSB produced increase in HR and cardiac output; decrease in BP and total peripheral resistance; significant improvement in skin blood flow, blood flow velocity, pulsatile index, and resistive index; decrease in numbness and chronic myalgia of the extremities with no adverse effects.<sup>[5]</sup>

Ten minutes of immersions in whirlpools produced increases in pulse and finger temperature with increased feelings of well-being and decreased state anxiety.<sup>[30]</sup> CO<sub>2</sub>-WI activates parasympathetic nerve activity in humans.<sup>[18]</sup>

Adapted cold shower might have antipsychotic effect similar to that of electroconvulsive therapy because it

could work as mild electroshock applied to sensory cortex. Additionally, cold shower is example of stress-induced analgesia and would also be expected to “crowd out” or suppress psychosis-related neurotransmission within mesolimbic system.<sup>[31]</sup>

CE can activate components of reticular activating system such as locus ceruleus and raphe nuclei, which can result in activation of behavior and increased capacity of central nervous system (CNS) to recruit motoneurons.<sup>[32]</sup> CE activates SNS; increase blood level of beta-endorphin and noradrenaline; and increase synaptic release of noradrenaline in brain. Antidepressive effect of cold shower attributed to presence of high density of cold receptors in skin expected to send an overwhelming amount of electrical impulses from peripheral nerve endings to the brain. It has significant analgesic effect and it does not cause dependence or noticeable side effects.<sup>[33]</sup> Most narcotics administered rectally can cause intoxication. There is a significant co-morbidity of schizophrenia with intestinal illnesses and thus colon cleansing can significantly improve mental state.<sup>[31]</sup>

### Musculo skeletal system

Walking in water at umbilical level increases the activity of erector spinae and activates rectus femoris to levels near to or higher than walking on dry ground.<sup>[34]</sup> CWI <15°C is one of the most popular intervention used after exercise,<sup>[11,35]</sup> which significantly lowered ratings of fatigue and potentially improved ratings of physical recovery immediately after immersion with reduction in delayed onset muscle soreness at 24, 48, 72, and 96 h follow-ups after exercise compared with passive interventions involving rest or no intervention.<sup>[35]</sup>

Rate of decrease in plasma lactate concentration over 30 min recovery period after intense anaerobic exercise was significantly higher in contrast-WI [hot (36°C) and cold (12°C)] compared with passive recovery on bed for both genders.<sup>[36]</sup>

Leg immersion in warm water (44 ± 1°C) for 45 min before stretch-shortening exercise reduced most of the indirect markers of exercise-induced muscle damage, including muscle soreness, creatine kinase activity in the blood, maximal voluntary contraction force, and jump height. Decreasing muscle damage did not improve voluntary performance, therefore clinical application of muscle prewarming may be limited.<sup>[37]</sup>

Contrast water therapy (CWT) [alternating 1-min hot (38°C) and 1-min cold (15°C)] for 6/12/18 min lowered subjective measures of thermal sensation and muscle soreness compared with control (seated rest) but no consistent differences were observed in whole

body fatigue. It indicates CWT for 6 min assisted acute recovery from high-intensity running and CWT duration did not have dose-response effect on running performance recovery.<sup>[38]</sup> Contrast baths have been suggested for reducing pain; hand volume; and stiffness in affected extremities but it had no significant effect on pre- and/or postoperative hand volume in carpal tunnel syndrome.<sup>[39]</sup>

Cold water or cold/thermoneutral water did not induce modifications of inflammatory and hematological markers. The performances of athletes were not negatively influenced by CWI or CWT. Reduced perception of fatigue after training session was the principal effect of CWI<sup>[45]</sup> because CE increases opioid tone and high MR, which could diminish fatigue by reducing muscle pain and accelerating recovery of fatigued muscle, respectively,<sup>[32]</sup> which can improve training and competitions in young soccer players.<sup>[40]</sup>

A systematic review on management of fibromyalgia syndrome (FMS) through hydrotherapy described as “there is strong evidence for the use of hydrotherapy in the management of FMS” and it showed positive outcomes for pain; tender point count; and health-status.<sup>[41]</sup> Combination of ST (once daily for 3 days/week) and underwater exercise (once daily for 2 days/week) for 12 weeks significantly reduced pain and symptoms (both short- and long-term); and improved QOL in patients with FMS.<sup>[42]</sup> Pool-based exercise using deep water running three times/week for 8 weeks is safe and effective intervention for FMS because it showed significant improvement in general health and QOL compared with control; and significant improvement in fibromyalgia impact questionnaire score, incorporating pain; fatigue; physical function; stiffness; and psychological variables.<sup>[43]</sup>

Hydrotherapy may have some short-term benefit to passive range of movement in rehabilitation after rotator cuff repair.<sup>[44]</sup> Spa water (37°C) and tap water heated to 37°C for the duration of 20 min/day for 5 days/week for the period of 2 weeks with home-based exercise program improved the clinical symptoms and QOL in patient with osteoarthritis of knee (OAK). However, pain and tenderness statistically improved in spa water.<sup>[45]</sup> It may be due to that spa waters are not only naturally warm, but their mineral content is also significant. Spa water has mechanical, thermal, and chemical effects.

In ankylosing spondylitis (AS) patients, balneotherapy statistically improved pain; physical activity; tiredness and sleep score; Bath Ankylosing Spondylitis Disease Activity Index (BASDAI); Nottingham Health Profile (NHP); patient’s global evaluation and physician’s global evaluation at 3 weeks, but only on modified

Shober test and patient's global evaluation parameters at 24 weeks. It indicates the effect of balneotherapy in improving disease activity and functional parameters in AS patients.<sup>[46]</sup> Infrared sauna, a form of total-body hyperthermia was well tolerated; no adverse effects; and no exacerbation of disease were reported in patients with rheumatoid arthritis (RA) and AS in whom pain, stiffness, and fatigue showed clinical improvements during the 4 weeks treatment period but these did not reach statistical significance.<sup>[47]</sup>

Aqua-jogging without caloric restrictions in obese persons for 6 weeks was associated with reductions in waist circumference and body fat; improvement of aerobic fitness and QOL.<sup>[48]</sup>

AE may be an excellent alternative to land exercise for individuals who lack confidence, have high risk of falling, or have joint pain.<sup>[49]</sup> Water buoyancy reduces the weight that joints, bones, and muscles have to bear.<sup>[50]</sup> Warmth and pressure of water also reduce swelling and reduces load on painful joints, remotes muscle relaxation.<sup>[51]</sup> AE has significant effects on pain relief and related outcome measurements for locomotor diseases. Patients may become more active and improve their QOL as a result of AE.<sup>[52]</sup> Water-based and land-based exercises reduced pain and improved function in patients with OAK and that water-based exercise was superior to land-based exercise for relieving pain before and after walking.<sup>[53]</sup> Hydrotherapy is highly valued by RA patients who were treated with hydrotherapy (30-min session/week) reported feeling much better/very much better than those treated with land exercises (similar exercises on land) immediately on completion of the treatment program (6 weeks). But this benefit was not reflected on 10 m walk times, functional scores, QOL measures, and pain scores by differences between groups.<sup>[51]</sup> Hot compress (HC) with surrounding electroacupuncture needling was significantly effective on rear thigh muscles strain and it was superior to conventional needling method and cupping in improving symptoms and physical signs as well as recovery of walking function of athletes.<sup>[54]</sup>

### Gastrointestinal system

Drinking water significantly elevates the resting energy expenditure (REE) in adults but in overweight children transient decrease in REE was observed immediately after drinking 10 ml/kg cold water (4°C). Then a subsequent rise in REE was observed, which was significant after 24 min and the maximal mean REE values were seen after 57 min, which was 25% higher than baseline. The recommended daily amount of water consumption in children could result in energy expenditure equivalent to additional weight loss of about 1.2 kg/year suggesting

that water drinking could assist overweight children in weight loss or maintenance.<sup>[55]</sup> Exposure to cold increases MR, for example, head-out immersion in cold water of 20°C almost doubles MR, while at 14°C it is more than quadrupled.<sup>[3]</sup>

When very-HC applied to lumbar region of healthy female for 10-min blood flow to the back increased to 156% with increased blood flow to upper arm. Immediately after HC, bowel sounds increased 1.7 times compared with before application, which suggest that a very HC can be useful to promote flatus or defecation.<sup>[56]</sup> Low mineral water intake normalizes the intestinal permeability of patients with atopic dermatitis.<sup>[57]</sup>

Warm water is effective for colonic spasm in which significantly less discomfort was reported compared with control group and this may be useful as an alternative for glucagon (expensive) and hyoscyamine (has side effects) because it has no side effects and costs practically nothing.<sup>[58]</sup>

In patients with acute anal pain due to hemorrhoids or anal fissures, neither cold water (<15°C) nor hot water (>30°C) sitz bath (SB) did control pain statistically.<sup>[59]</sup> Similarly, after sphincterotomy for anal fissure, SB produced no significant difference in pain but significant relief in anal burning and better satisfaction score with no adverse effects were observed compared with control group.<sup>[60]</sup> Healing and pain relief was not significant in SB but it improved patient satisfaction in acute anal fissures.<sup>[61]</sup>

Though there was no strong evidence to support the use of SB for pain relief and to accelerate fissure or wound healing among adult patients with anorectal disorders (ARDs), patients were satisfied with using SB and no severe complications were reported.<sup>[62]</sup> In contrast, warm-water SB (40°C, 45°C, and 50°C for 10 min each time) in ARD, pain relief was more evident and lasted longer at higher bath temperatures. Pain relief after SB might attribute to internal anal-sphincter relaxation, which might be due to thermosphincteric reflex, resulting in diminution of the rectal neck pressure. The higher the bath temperature, the greater the drop in rectal neck pressure and internal sphincter electromyographic activity, and longer the time needed to return to pretest levels.<sup>[63]</sup>

In posthemorrhoidectomy care, water spray method could provide a safe and reliable alternative to SB as a more convenient and satisfactory form of treatment.<sup>[64]</sup>

Spa treatment with mineral water Nizhnevinskaya (sulfate calcium) induced clinical remission of the disease, normalization of the echoscopic picture of stomach and

gallbladder, their motor function, tesiocystalloscopic characteristics of saliva suggest its effectiveness in rehabilitation of patients with gastric and gallbladder motor-evacuatory dysfunction.<sup>[65]</sup> Intake of sulfate-chloride-sodium mineral water activates regulation of carbohydrate metabolism by insulin and cortisol due to the formation of adaptive reactions. It promoted trophic effects of insulin and gastrin in animals with significant reduction in peptic ulcer size and enhanced resistance to stressful factors.<sup>[66]</sup>

Immersion in Dead Sea water produced significant reduction in blood glucose in type-2 diabetes mellitus (DM) and no significant differences in insulin, cortisol, and c-peptide levels were observed between DM patients and healthy volunteers following immersion.<sup>[67]</sup>

### Genito urinary system

Mean labor pain scores were significantly higher in control group than immersion bath (IB) group suggest that use of IB as an alternative form of pain relief during labor.<sup>[68]</sup> WI in primipara at any stage of labor, from 2 cm external opening of the uterine cervix, significantly decreased parturition duration compared with traditional delivery. It raised both the amplitude and frequency of uterine contractions proportional to uterine cervix gaping with no disturbances in contraction activity of the uterus. A 3-cm gaping of uterine cervix is the optimal timing for WI in the primipara because earlier WI at 2-cm uterine cervix gaping also accelerated the labor but required repetitions of WI or use of oxytocin for correcting weakened uterine contraction.<sup>[69]</sup>

In contrast, IB did not influence the length of labor and uterine contractions frequency. However, contractions length was statistically shorter in IB and it can be an alternative for woman's comfort during labor, since it provides relief to her without interfering on labor progression or jeopardizing the baby.<sup>[70]</sup>

WI during first stage of labor reduces the use of epidural/spinal/paracervical analgesia/anesthesia compared with controls and there is no evidence of increased adverse effects to fetus/neonate or woman from laboring in water or water birth.<sup>[71]</sup> Neonatal swimming can accelerate babies growth in early stage.<sup>[72]</sup> In a microbiological study, comparing neonatal bacterial colonization after water birth to conventional bed deliveries with or without relaxation bath showed no significant difference between three groups in neonatal outcome, infant's and maternal infection rate.<sup>[73]</sup>

Cold-SB but not warm-SB, significantly reduced edema during postepisiotomy period<sup>[74]</sup> and perineal pain, which was greatest immediately after the bath.<sup>[75]</sup> Bakera,

a steam bath prepared with various plants (commonly the essential oil plants) is traditionally used in Minahasa (Indonesia) mainly for recuperation after childbirth. It is based onthermotherapy with aromatherapy which attribute for its therapeutic effects. Thermoherapy soothes symptoms such as heaviness in limbs, edema, muscular strain, loss of appetite, and constipation. Essential oils of the plants used have antiseptic, antiphlogistic, and immunostimulant effect. Hence it can be an effective and safe method for recuperation after child birth.<sup>[76]</sup> In postnatal mothers, alternate (hot and cold) compress and cold cabbage leaves were equally effective in reducing breast engorgement, but in relieving breast engorgement pain, alternate compresses were more effective than cold cabbage leaves.<sup>[77]</sup>

Warm-SB (40-45°C) for 10 min, for at least 5 days immediately after the removal of Foley urethral catheter in patient undergone transurethral resection of prostate, significantly reduced urethral stricture compared with no SB group who had 1.13-fold increased risk of re-hospitalization within 1 month after surgery due to postoperative complications compared with warm-SB group.<sup>[78]</sup> Thirty healthy volunteers and 21 patients with urinary retention after hemorrhoidectomy underwent SB at 40°C, 45°C, and 50°C where the number of spontaneous micturitions increased with higher-temperature baths and it seems to be initiated by reflex (thermo-sphincter reflex) internal urethral sphincter relaxation. The urethral pressure both in normal and retention subjects showed significant reduction, which increased with higher temperature; and vesical pressure or EMG activity of the external urethral sphincter did not show significant differences.<sup>[79]</sup>

### Hematology/immunology

Subsequent CE induced increase of leukocytes, granulocytes, circulating levels of interleukin (IL)-6, and natural killer (NK) cells and its activity. Leukocytes, granulocyte, and monocyte responses were augmented by pretreatment with exercise in water (18°C) and thus acute-CE has immune-stimulating effects.<sup>[80]</sup>

Daily brief cold stress can increase both numbers and activity of peripheral cytotoxic T-lymphocytes and NK cells, the major effectors of adaptive and innate tumor immunity, respectively. It (for 8 days) improved survival of intracellular parasite *Toxoplasma gondii* infected mice, with consistent enhancement in cell-mediated immunity. The sustained/longer-term effects of cold stress repeated daily over the period of 5 days to 6 weeks increased plasma levels of tumor necrosis factor- $\alpha$ , IL-2, IL-6. A hypothesis describes, daily brief cold-water stress over many months could enhance antitumor immunity and improve nonlymphoid cancer survival rate. The

possible mechanism of nonspecific stimulation of cellular immunity might attribute to transient activation of SNS, hypothalamic-pituitary-adrenal (HPA) and hypothalamic-pituitary-thyroid axes. Though daily moderate cold hydrotherapy does not appear to have noticeable adverse effects on normal subjects, some studies showed that it can cause transient arrhythmias in patients with heart problems and can also inhibit humoral immunity. Sudden ice-cold WI can produce transient pulmonary edema and increase blood-brain barrier permeability, thereby increasing mortality of neurovirulent infections. Studies are required to warrant this hypothesis for immunotherapy development for some (nonlymphoid) cancers, including those caused by viral infections.<sup>[81]</sup>

Warm water (28°C) treatment could not only cure bacterial cold-water disease but also immunize against causative agent *Flavobacterium psychrophilum*.<sup>[82]</sup>

Head-out WI (38.41 ± 0.04°C) for 30 min decreased blood viscosity; red blood cells count; and mean hematocrit without significant changes in leukocytes and platelets count; mean corpuscular volume; plasma viscosity; erythrocyte filtration time and red cell deformability index.<sup>[13]</sup> Application of hyper-thermic water bath produced significant reduction of relative B-lymphocyte. Whole-body hyperthermic water bath reduced relative total T-lymphocyte counts; increased relative CD8+ lymphocyte; NK cell counts and its activity, which were probably dependent on increased somatotrophic hormone production.<sup>[83]</sup>

### Endocrine/hormonal system

During CE increase levels of circulating norepinephrine was observed<sup>[80]</sup> and exercising HPA system by repeated CE could potentially restore its normal function in chronic fatigue syndrome, or at least increase net HPA activity (without changing baseline activity).<sup>[84]</sup> It produces temporary increase in plasma levels of adrenocorticotrophic hormone (ACTH), beta-endorphin, and cortisol.<sup>[32]</sup> The sustained/longer-term effects of cold stress repeated daily produced increase in ACTH, corticosterone, and decrease in  $\alpha$ -1-antitrypsin and testosterone.<sup>[81]</sup> Cold stress reduces level of serotonin in most regions of brain (except brainstem).<sup>[32]</sup> Cold stress-induced analgesia might be mediated by increased production of opioid peptide beta-endorphin (an endogenous pain-killer).<sup>[85,86]</sup>

Exposure to sauna and ice-WI significantly elevated epinephrine levels in winter swimmer.<sup>[87]</sup> Steam bath produced increase in blood serum concentrations of gastric and aldosterone, with decrease in concentrations of cortisol in athlete-fighters.<sup>[88]</sup> Whole-body hyperthermic bath increased STH activity in 8 out of 10 volunteers.<sup>[83]</sup>

### Eye, skin, and hair

Warm moist air device seems to be safe and produced improvement in tear stability and symptomatic relief in ocular fatigue in patients with meibomian gland dysfunction.<sup>[89]</sup> Sauna (80°C) produced stable epidermal barrier function; increase in stratum corneum hydration; faster recovery of both elevated water loss and skin pH; decrease in casual skin sebum content on skin surface of forehead; increase in ionic concentration in sweat and epidermal blood perfusion in volunteers. It suggests protective effect of ST on skin physiology.<sup>[90]</sup> Clinical remission of atopic dermatitis has been reported after intake of low-salt water.<sup>[57]</sup> Application of heated mustard compress produced second-degree, partial-thickness burn followed by hyperpigmentation and hypertrophic scarring.<sup>[91]</sup> Persistent use of cold pillow compress could reduce hair follicles inhibition or damage caused by chemotherapeutic agents. So alopecia can be decreased or prevented.<sup>[92]</sup>

### Temperature regulation

Very-HC applied to lumbar region of healthy female for 10 min increased back Tsk to 41.1-43.1°C under HC, followed by decreased rapidly but no changes observed in BT.<sup>[56]</sup> A case of 20% of 2<sup>nd</sup> degree burns and severe heat stroke followed by temperature rose up to 40.5°C and patient developed severe multiorgan failure and critical polyneuropathy was reported after exposure to extreme heat in sauna for unknown period of time.<sup>[93]</sup> The most effective method of reducing body core temperature appears to be immersion in iced water, main predictor of outcome in exertional heatstroke is the duration and degree of hyperthermia where possible patients should be cooled using iced-WI, but if it is not possible, combination of other techniques may be used to facilitate rapid cooling<sup>[94]</sup> such as fan-therapy, CWI, iced-baths, and evaporative cooling.<sup>[95]</sup>

Wet-ice, dry-ice, and cryogen packs applied to skin overlying right triceps surae muscle for 15 min on 10 females decreased mean Tsk 12°C, 9.9°C, and 7.3°C, respectively. None of the modalities produced Tsk cooling below 17°C and no cooling was demonstrated 1 cm proximal or distal to any modalities after 15 min of application. Significant mean Tsk reduction in between pretreatment rest interval (time 0) and 15 min after removal of modality (time 30) was observed only in wet-ice. It suggests wet-ice was significantly more efficient in reducing Tsk than dry-ice and cryogen packs.<sup>[96]</sup>

After exercise at 65% maximal oxygen consumption at ambient temperature of 39°C until Tre increased to 40°C produced no difference in cooling rate between WI at 8°C, 14°C, and 20°C but cooling rate was significantly greater during 2°C, which was almost twice as much

as other conditions. It suggests that 2°C WI is the most effective treatment for exercise-induced hyperthermia.<sup>[97]</sup> When hyperthermic individuals are immersed in 2°C water for approximately 9 min to Tre cooling limit of 38.6°C negated any risk associated with overcooling.<sup>[98]</sup>

Whole body immersion in moderately cold water is effective cooling maneuver for lowering BT and body heat content of approximately 545 kJ at the end of immersion in absence of severe physiological responses generally associated with sudden cold stress.<sup>[99]</sup> Significant less BT variability and an overall higher BT were observed in late preterm infants following tub bathing procedure.<sup>[100]</sup>

## Conclusion

Based on available literature, this review suggests that hydrotherapy was widely used to improve immunity and for the management of pain, CHF, MI, chronic obstructive pulmonary diseases, asthma, PD, AS, RA, OAK, FMS, anorectal disorders, fatigue, anxiety, obesity, hypercholesterolemia, hyperthermia, labor, etc. It produces different effects on various systems of the body depending on the temperature of water and though these effects are scientifically evidence based, there is lack of evidences for the mechanism on how hydrotherapy improves these diseases, which is one of the limitations of hydrotherapy, and further studies are required to find the mechanism of hydrotherapy on various diseases.

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