

# Index

## A

- Acclimation in artificial environments, *see* Heat acclimatization
- Altered neuromuscular control theory, 122, 123
  - limitations of, 126
  - positive feedback loop, 123
  - support for, 124, 125
- American Conference of Governmental Industrial Hygienists (ACGIH), 248
- Apparent temperature/heat index, 228
- Arm immersion cooling system (AICS), 197, 198
- Armed Forces Health Surveillance Center (AFHSC), 182

## B

- Behavioral thermoregulation, 24, 25
- Body cooling, alternative methods of, 71, 72

## C

- Calsequestrin-1 (CASQ1), 158
- Cardiovascular disease, 238
- Carnitine palmitoyl transferase (CPT) II, 161
- Cellular heat shock response, 154, 155
- Chemical, biological, radiological, and nuclear (CBRN) warfare agents, 191–192
- Chronic disease, 238
- Classic heat stroke (CHS), 3
- Climate change and heat exposure
  - community adaptation programming for heat events, 245, 246
  - health advisory systems for heat events, 245, 246

- heat and impact on population health, 235
  - and children, 239
  - chronic disease, 238
  - geographic location, 240, 241
  - heat health and ageing, 237, 238
  - large-scale catastrophic effect of extreme heat, 236
  - short-term mortality, 236
  - social and community determinants, 239, 240
  - temperature-mortality relationship, 236, 237
- heat protection and management strategies for workers, 247
- heat stress, 229, 230
  - changes in climate related, 228, 229
  - environmental factors, 228
  - global surface mean temperatures, 230
  - limit greenhouse gases emissions, 229
- occupational heat stress
  - impact of, 242
  - indices of, 243, 244
  - management, 247–249
  - physiological strain during work, 242, 243
  - surveillance system, 245
  - worker productivity, 244
- planning and prevention, current state of, 245
- temperature regulation
  - inter- and intra-individual determinants of heat strain, 233–235
  - rest and physical activity in hot environments, 231, 232
- Cold-water dousing, 219

Cold water immersion (CWI), 69–71, 110, 200, 219, 222  
 Compensated heat stress (CHS), 186  
 Conduction, 20  
 Core temperature, 199, 218  
 Crampers, 121, 122  
 Cystic fibrosis, 40

## D

Danger associated molecular patterns (DAMPs), 152, 153  
 Dehydration, 38, 110, 193, 232  
 Dehydration/electrolyte imbalance theory, 119  
   exercise-induced sweating, 119  
   limitations of, 120–122  
   support for, 120  
 Dexamethasone, 155  
 Diabetes, 40  
 Dichotomy, 73  
 Disseminated intravascular coagulation (DIC), 150  
 DuBois equation, 22

## E

Eccrine gland sweat secretion, 21  
 Economic cost of excessive heat, 227  
 EHS, *see* Exertional heat stroke (EHS)  
 Electrically induced fatigue, 124  
 Emergency medical services (EMS), 170, 212, 216  
 Endothermy, 19  
 Endotoxemia, 63, 150  
 Epidemiology, EHI, 4  
   in athletic settings, 7–11  
   incidence, 4  
   in military settings, 4–7  
   in occupational settings, 11  
   physical activity, 4  
 European Food Safety Authority, 46  
 Evaporative heat loss, 21, 22  
 Evaporative requirements ( $E_{req}$ ), 21  
 Excessive heat stress, 226  
 Exercise-associated collapse (EAC), 94  
 Exercise-associated muscle cramps (EAMC), 117–119  
   in athletes, 118  
   caused by, 118  
   pathophysiology of, 119  
     altered neuromuscular control theory (*see* Altered neuromuscular control theory)

    dehydration/electrolyte imbalance theory (*see* Dehydration/electrolyte imbalance theory)  
   prevention, 131, 132  
   recognition, 126  
   return-to-activity, 130, 131  
   treatment, 127, 129, 130  
     pickle juice, 127  
     questions to aid, risk factors identification, 128–129  
     static stretching, 127  
     volume of sports drink, 129, 130  
 Exercise-heat intolerance, 159, 160  
 Exercise-induced hypoxia, 152  
 Exertional collapse associated with sickle cell trait (ECAST), 160  
 Exertional heat cramps, 118  
 Exertional heat exhaustion ( $H_{EX}$ ), 81  
   characteristics of, 95–101  
   daily activities, return to, 112  
   etiology, 82, 83, 94, 102, 103  
   cumulative incidence of, 102  
   exercise-associated collapse, 94  
   water and salt (NaCl) losses, 103  
   history, 81  
   ICD-9 diagnostic code, 82  
   management, 110  
   paradigms and clinical features of, 82  
   pathophysiology, 83, 103–107  
   recognition, 105, 107–109  
   severe heat exhaustion, 110, 111  
   signs and symptoms, 83, 106  
   treatment, 83, 110  
   water and salt (NaCl) losses, 103  
 Exertional heat illness (EHI)  
   classification, 2, 3  
   definition, 1  
   nomenclature, 2, 3  
   risk of, 1  
 Exertional heat stroke (EHS), 3, 8, 10, 29, 34, 36, 38, 145, 214, 215  
   definition, 59, 149, 169, 218  
   etiology, 59–61  
   Falmouth Road Race protocol, 219–222  
   management and care, 67, 68  
     body cooling, alternative methods of, 71, 72  
     clothing/protective equipment, 71  
     cold water immersion (CWI), 69, 70  
     physical characteristics, 71  
     survivability rates in rat model, 68  
     water temperature, 69, 70  
   management, in Athletics

- best safety practice recommendations, 176
- in-hospital care and return to physical activity, 173, 174
- policy-based intervention, 175–177
- prehospital care, 172
- prevention, 170, 171
- specific information to document on medical chart, 173
- transport, 172, 173
- paradigm for care, 170
- pathophysiology, 61–63
- physical activity, return to, 72–76
- prognosis, 169
- recognition and assessment, 63, 67
- susceptibility
  - cellular heat shock response, 154, 155
  - immune function affects, 149–152, 154
  - malignant hyperthermia and EHS share genotype-associated, 155–159
  - metabolic disturbances, reduce tolerance to exercise-heat stress, 160–162
  - non-MH related heritability, exercise-heat intolerance, 159, 160
  - pharmacological treatments,
    - pathophysiological molecular mechanisms, 155
- Exertional hyponatremia, 129
- Exertional rhabdomyolysis (ER), 160, 161
- External cooling methods, 48
- Extreme heat, 226, 227, 236
  
- F**
- Falmouth Road Race protocol, 219–222
- Fatigue, 124, 131
- First Law of Thermodynamics*, 231
- Fitness, 45
- Fluid-electrolyte disorder, 104, 109
- Forced convection, 21
  
- G**
- Glycogen storage deficiency V, 161
- GSD7, 161
- GSD11, 161
- Gut associated lymphoid tissue (GALT), 151
  
- H**
- Healthy erythrocytes, 160
- Heat acclimatization, 24, 43–45, 171, 182, 193, 195, 223
  - lack of, 40, 41
- Heat balance equation, 18
- Heat cramps, 118
- Heat edema
  - definition, 138
  - pathophysiology, 138
  - recognition, 138
  - return to activity, 139
  - treatment, 139
- Heat intolerance, 38, 204
- Heat prostration, 82
- Heat rash
  - pathophysiology, 140
  - recognition, 140
  - return to activity, 141
  - treatment, 141
- Heat stress, 229, 230
  - behavioral thermoregulation, 24, 25
  - changes in climate related, 228, 229
  - classification, 18, 19
    - compensatory zone, 18
    - intolerable zones, 18
    - prescriptive zone, 18
  - environmental factors, 228
  - global surface mean temperatures, 230
  - limit greenhouse gases emissions, 229
  - physiologic control of, 22, 23
    - acclimatization, 24
    - glabrous (non-hair bearing) skin, 23, 24
    - peripheral sensation of thermal stress, 23
    - sweating, 23
  - thermoregulation, biophysical determinants of, 19
    - biophysical factors affect heat stress, 22
    - conduction, 20
    - convection, 20, 21
    - evaporative heat loss, 21, 22
    - heat balance equation, 18, 19
    - metabolic heat production, 19, 20
    - radiation, 20
- Heat syncope
  - pathophysiology, 143
  - recognition, 143, 145
  - return to activity, 145
  - ruling in, 144
  - treatment, 145
- Heat tolerance, 73, 203, 227
- Heat tolerance test (HTT), 73–76, 203–205
- High ambient heat, 235
- Homeostatic control of body temperature, 61, 62
- Homeothermy, 17

HTT, *see* Heat tolerance test (HTT)  
 Hydration, 41, 42, 45, 46  
 Hypertension, 238  
 Hyperthermia, 23, 110, 218, 220  
 Hypohydration, 23, 143  
 Hyponatremia, 40, 109, 110

## I

Inflammatory bowel disease, 152  
 Inter- and intra-individual determinants of heat strain, 233–235  
 International Association of Athletics Federations (IAAF), 217  
 International Classification of Diseases (ICD), 2  
 Intestinal barrier dysfunction, 151  
 Intestinal ischemia, 152  
 In vitro contracture test (IVCT), 156

## J

Joint Service Lightweight Integrated Suit Technology (JS-LIST), 191

## L

Lipopolysaccharide (LPS), 150–154  
 Low physical fitness, 41  
 LPS, *see* Lipopolysaccharide (LPS)

## M

Malignant hyperthermia (MH), 40, 155–159  
 Maximum evaporative heat loss ( $E_{max}$ ), 21  
 McArdle disease, 161  
 Medical disorders involving environmental heat, 3  
 Medical Surveillance Monthly Report (MSMR), 182  
 Melatonin, 155  
 Metabolic endotoxemia, 151  
 Metabolic heat production, 19, 20  
 Methylphenidate (Ritalin), 37  
 Mild hyperthermia, 108, 220  
 Mild orthostatic hypotension, 110  
 Miliaria rubra, *see* Heat rash  
 Military, EHI
 

- epidemiology, 182–184
- history, 181, 182
- military unique populations
  - basic training, 188, 189
  - officer training, 189, 190

special operations and other high-risk, 190  
 physiologic considerations, 183–186  
 prevention of
 

- operational risk management, 194, 195
- primary, 195–197
- secondary, 196–198
- tertiary, 198–200

 return-to-play/return to duty (RTP/RTD) decisions, 201
 

- assessment of recovery, 202, 203
- current army guidance for, 205–206
- heat tolerance, 203
- heat tolerance testing, role of, 203–205
- risk of recurrent heat injury, 201, 202

 risk factors of heat-related illness
 

- acclimatization, 193
- dehydration, 193
- dietary supplements, 192
- infectious disease, 194
- intrinsic vs. extrinsic motivation, 192
- leadership factors, 194
- military gear and equipment, 191, 192
- sleep deprivation, 193
- solo training/remote operational missions, 193, 194

 Minor heat illnesses

heat edema
 

- definition, 138
- pathophysiology, 138
- recognition, 138
- return to activity, 139
- treatment, 139

 heat rash
 

- pathophysiology, 140
- recognition, 140
- return to activity, 141
- treatment, 141

 heat syncope
 

- pathophysiology, 143
- recognition, 143, 145
- return to activity, 145
- treatment, 145

 sunburn
 

- pathophysiology, 141
- recognition, 141
- return to activity, 142
- treatment, 142

 transient heat fatigue
 

- pathophysiology, 139
- recognition, 139
- return to activity, 140
- treatment, 140

Mixed-method cooling strategy approach, 48  
 Moderate-to-severe heat illness, 106–107  
 Multi-organ dysfunction (MOD), 150  
 Muscle afferents, 124

**N**

National Institute for Occupational Safety and Health (NIOSH), 247  
 Non-crampers, 120, 121, 124  
 Non-malignant hyperthermia related heritability, 159, 160  
 Non-steroidal anti-inflammatory drugs (NSAIDs), 43, 142, 151

**O**

Obesity, 238  
 One size fits all approach, 227  
 On-site medical care, 211

**P**

Pathogen associated molecular patterns (PAMPs), 152, 153  
 Peripheral sensation of thermal stress, 23  
 Physical exhaustion, 94  
 Physiologic status monitoring (PSM) technology, 198  
 Pre- (before activity) and per-cooling (during activity) methods, 47, 48, 171  
 Predisposing factors (PDF), 150  
   heat illness mitigation strategies, 43  
     education and communication, 50  
     fitness, 45  
     heat acclimation, 43–45  
     hydration, 45, 46  
     pre and per cooling, 47, 48  
     pre-participation examination, 49, 50  
     WBGT monitoring, activity modifications based on, 48, 49  
 modifiable risk factors, 30  
   alcohol, sleep, and supplements, 42, 43  
   hydration, 41, 42  
   lack of heat acclimation, 40, 41  
   low physical fitness, 41  
 non-modifiable risk factors, 30, 31, 38  
   age, 33, 34  
   anthropometrics, 35  
   environmental conditions, 32, 33  
   febrile events, 38  
   history of heat illness, 38, 39  
   medical and recreational drugs, 37

medications, 36, 37  
 motivation, culture and risk tolerance, 35, 36  
 peer, coach and organization pressure, 36  
 programmed clothing and exercise demands, 31, 32  
 sex, 34, 35  
 sickle cell trait, 39  
 skin and sweat gland disorders, 39, 40  
 spinal cord injury, 39

Pre-race runner education, 223

Prickly heat, *see* Heat rash

Pyrokines, 38

**Q**

Quasi-heat-acclimated state, 41  
 Quick sequential organ failure assessment (qSOFA), 151

**R**

Radiation, 20  
 Recommended Alert Limits (RALs), 247  
 Recommended Exposure Limits (RELs), 247  
 Regional heat safety guidelines for low-risk acclimatized individuals, 48  
 Rehydration, 46  
 Representative concentration pathway (RCP), 230  
 Reserve Officer Training Corps (ROTC) programs, 189  
 10<sup>th</sup> Revision of the ICD Clinical Modification document (ICD-10-CM), 2, 3  
 Rhabdomyolysis, 160, 162  
 Road race medicine, 211  
   admittance of exertional heat stroke (EHS) patients, 214, 215  
   adverse conditions, 222, 223  
   communications system, 212  
   duties of the medical director, 212  
   education of runners, 223  
   emergency medical services, 212, 216  
   medical care area, 216  
     equipment for, 212, 216  
     location of, 214  
   medical tent set-up, 215  
   protocols/procedures, 218, 219  
     cold-water dousing, 219

- Road race medicine (*cont.*)  
 cold-water immersion, 219  
 Falmouth Road Race protocol,  
 219–222  
 medical plan, 219  
 rotating cold, wet towels, 219  
 tarp-assisted cooling, 219  
 recommended medical team structure, 213,  
 214  
 staffing, 217
- S**  
 Salt-depletion (SD), 103–105, 110  
 Salty sweaters, 120, 122  
 SCT, *see* Sickle cell trait (SCT)  
 SD, *see* Salt-depletion (SD)  
*Second Law of Thermodynamics*, 231  
 Sepsis, 151, 153  
 Severe heat exhaustion, 110, 111  
 Sickle cell hemoglobin (HbS), 159  
 Sickle cell trait (SCT), 39, 159, 160  
 Skin and sweat gland disorders, 39, 40  
 Skin wettedness ( $\tau_{\max}$ ), 21  
 Spinal cord injury, 39  
 Sunburn  
 pathophysiology, 141  
 recognition, 141  
 return to activity, 142  
 treatment, 142  
 Survival, Evasion, Resistance, and Escape  
 (SERE), 193  
 Sweaty Sooners Study, 120
- T**  
 Tactical athletes, 181  
 Tarp-assisted cooling, 219  
 Temperature regulation  
 inter- and intra-individual determinants of  
 heat strain, 233–235  
 rest and physical activity in hot  
 environments, 231, 232  
 Thermal tolerance, molecular mechanisms of  
 cellular heat shock response, 154, 155  
 malignant hyperthermia, 155–159  
 metabolic disturbances, reduce tolerance to  
 exercise-heat stress, 160–162  
 non-MH related heritability, exercise-heat  
 intolerance, 159, 160  
 pharmacological treatments,  
 pathophysiological molecular  
 mechanisms, 155  
 Thermoafferent feedback, 231  
 Thermoeffectors, 41  
 Thermoreceptors, 231  
 Thermoregulation, 30, 169  
 biophysical determinants of, 19  
 biophysical factors affect heat stress, 22  
 conduction, 20  
 convection, 20, 21  
 evaporative heat loss, 21, 22  
 heat balance equation, 18, 19  
 metabolic heat production, 19, 20  
 radiation, 20  
 during exercise, 17  
 Toll-like receptor 4 (TLR4), 152, 154  
 Transient heat fatigue  
 pathophysiology, 139  
 recognition, 139  
 return to activity, 140  
 treatment, 140  
 Type 2 diabetes, 238
- U**  
 Uncompensated heat stress (UCHS), 186  
 United Nation's Intergovernmental Panel on  
 Climate Change (IPCC), 225  
 Universal Thermal Climate Index (UTCI), 228  
 Urban density, 241  
 US Army Institute of Environmental Medicine  
 (USARIEM), 196, 197
- V**  
 Very long chain acetyl-CoA dehydrogenase  
 deficiency (VLCAD), 161
- W**  
 Water-depletion (WD), 103–105  
 Wet-bulb globe temperature (WBGT), 21, 32,  
 48, 49, 171, 198, 222, 229, 247  
 Whole-body cold-water immersion, 47