Yoga in the Management of Arterial Hypertension

23

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23.1 Epidemiology of Hypertension

Hypertension occurs when blood pressure (BP) is high as measured on two different days. Blood pressure or BP, the force exerted by circulating blood against the walls of the body's arteries, is reflected in two parameters: systolic, the pressure in the arteries when the heart contracts or beats, and diastolic, the pressure in the arteries when the heart rests between beats. Hypertension is diagnosed when systolic blood pressure (SBP) ≥ 140 mmHg and/or diastolic blood pressure (DBP) ≥ 90 mmHg.

According to the World Health Organization [1], arterial hypertension affects 40% of adults aged 25 and above, worldwide. A pooled analysis of 1479 population-based measurement studies from 200 countries revealed that the number of people with hypertension doubled from 594 million in 1975 to 1.13 billion in 2015 worldwide with the increase largely in low- and middle-income countries [2]. A recent review by Mills et al. [3] confirmed that the prevalence of hypertension among adults was higher in low- and middle-income countries (31.5%, 1.04 billion people) than in high-income countries (28.5%, 349 million people). However, fewer than 1 in 5 people with hypertension have the problem under control [4]. Complications of hypertension accounted for 9.4 million global deaths every year [1]. In fact, hypertension is behind 45% of deaths due to heart disease and 51% of deaths due to stroke [1]. However, its prevalence is difficult to estimate since most hypertensive people don't perceive any symptoms at all, which is why it is called a "silent killer." Hypertension is a serious public health problem not only due to its high prevalence, but also because it is the most important risk factor for cardiovascular diseases (CVDs; [1]), which is the number one cause of death globally [5].

When arterial hypertension is not well controlled, it can cause very serious pathologies such as myocardial infarction, ventricular hypertrophy, and heart failure. High BP can also cause aneurysms, increasing the possibility of blockage and rupture of the blood vessels and the risk of suffering a stroke. Arterial hypertension can also lead to renal failure, blindness, and cognitive impair-

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ment. In many cases, arterial hypertension converges with other risk factors such as smoking, obesity, hypercholesterolemia, or diabetes mellitus, complicating health consequences, and augmenting the likelihood of suffering from all the mentioned pathologies. Since arterial hypertension is an asymptomatic disorder, early detection, treatment, and self-care are essential to reduce the risk of suffering from all these disorders.

The WHO [1] classified the risk factors of suffering arterial hypertension into behavioral, metabolic, socioeconomic, and other factors. Behavioral factors comprise consumption of food containing too much salt and fat, lack of enough fruits and vegetables in the diet, alcohol consumption, smoking, sedentary lifestyle, and poor stress management. Metabolic factors are obesity, cholesterol, and diabetes mellitus. Regarding socioeconomic factors, arterial hypertension is related to income, education, and housing; these factors have an impact on behavioral risk factors and can also delay early detection and treatment. Genetic factors and age can also play a role in the development of hypertension. Finally, other risk factors of hypertension are preeclampsia (hypertension during pregnancy) and "white coat syndrome" (anxiety experienced during visit to a clinic). The growth in the world's population, aging, and risk factors related to lifestyle, such as unhealthy diet, harmful and abusive use of alcohol, sedentary lifestyle, overweight, and stress are the main causes of the significant increase of hypertensive cases in recent years [1].

Complications of hypertension, including heart attack, stroke, and kidney failure lead to high spending for households on hospitalization and healthcare, driving millions into poverty [6]. According to the report on Global Economic Burden of Non-communicable Diseases [7], prepared by the World Economic Forum and the Harvard School of Public Health, over the period 2011–2025, the annual loss due to major non-communicable diseases for low- and middle-income countries is projected to be approximately US$500 billion and amounts to approximately 4% of their gross domestic product. CVDs including hypertension account for 51% of this annual loss [1].

23.2 Pathophysiology of Hypertension

Arterial hypertension is classified as essential (primary) or secondary. Between 90 and 95% of cases are essential hypertension in which there is no identifiable cause [8], while secondary hypertension represents only 5–10% of cases and it is due to known organic factors such as chronic kidney disease, renal artery stenosis, excessive aldosterone secretion, pheochromocytoma, and sleep apnea [9].

In the pathophysiological mechanism of hypertension, kidney, sodium-water balance, and the state of vasoconstriction of the arteries play an important role. The pathogenesis is multifactorial and not yet sufficiently clear. However, the influence of genetics and the over-activation of the sympathetic nervous and renin-angiotensin-aldosterone systems are generally accepted.

Mental and psychosocial stress is one of the major risk factors of hypertension. The reactivity of the cardiovascular system to psychological stress has been extensively associated with the development of arterial hypertension. Carroll et al. [10], in a 5-year longitudinal study with a sample of 453 Dutch participants, found a significant relationship between systolic reactivity to stressful tasks and the establishment of arterial hypertension disorder. The study of Phillips [11] also confirms the relationship between high cardiovascular stress reactivity and the development of arterial hypertension, systemic atherosclerosis, and cardiovascular disease markers, together with contribution from the interaction of genetic and environmental factors.

Gawlik et al. [12] carried out an online cross-sectional survey on 59,798 adult participants, who completed a Million Hearts community cardiovascular screening between 2013 and 2018, in order to estimate the effects of stress on hypertension and high cholesterol (parameters of cardiovascular health). The authors reported that higher stress was associated with higher prevalence of pre-hypertension/hypertension and elevated total cholesterol among all race/ethnic groups as well as all age groups. The estimation of the effect of stress on cardiovascular health,

adjusting for other relevant confounders (age, sex, race/ethnicity, smoking status, BMI, total cholesterol—for the model on pre-hypertension/hypertension, and blood pressure—for the model on elevated cholesterol), showed that compared to those with low stress, high stress was associated with significant higher odds of having pre-hypertension/hypertension and elevated cholesterol.

The stress response implies an activation of the Sympathetic Nervous System (SNS) with the corresponding secretion of adrenaline and norepinephrine. This neuroendocrine response accelerates the heart rate (HR) in order to supply more blood to the muscles. When the cardiovascular stress response is maintained over time, the cardiovascular system deteriorates substantially. The maintenance of high BP leads to the development of arterial hypertension, and subsequently, this deterioration may result in different cardiovascular pathologies such as atherosclerosis, ischemic heart disease, heart attack, and cerebrovascular accidents. Another hypothesis in the pathology of essential hypertension is rooted in the concept of allostasis, referring to the ability of our body in maintaining stability when facing stressful challenges through bodily change, adapting, and achieving a dynamic balance [13]. The persistence of high BP causes gradual adaptation in terms of arterial smooth muscle cells, thereby hypertrophy, thickening of the carotid sinus wall, and increase in the production rate of hormones related to BP, viz., renin, norepinephrine, cortisol, etc. [14].

The Polyvagal Theory [15] represents an interesting explanation about the role of the physiological activation process in the development of cardiovascular diseases. This theory exposed a complex and integrative vision of the Autonomic Nervous System (ANS) beyond the intervention of only the SNS in physiological activation. This theory proposes the Parasympathetic Nervous System (PNS) as a modulator of stress vulnerability and reactivity. According to this theory, the ANS consists of three hierarchically organized subsystems that support three different behavioral and emotional adaptation strategies as given below.

1. The dorsal branch of the vagus nerve (myelinated), called the "social engagement system" [16], regulates areas of the body related to social communication (facial expression, vocalization, listening, etc.). This system is the most recent and sophisticated, in evolutionary terms.
2. The sympathetic-adrenal system is related to mobilization behaviors and physiological activation (fight and flight behavior). This system is more primitive and less flexible than the dorsal branch of the vagus nerve.
3. The ventral branch of the vagus nerve is the most primitive neuronal circuit. This branch is activated because of hypoxia and enables immobilization related to survival (feigning death, vaso-vagal syncope, and behavioral shutdown).

First, the newest circuits come into play, and when these are insufficient, the older ones intervene. The myelinated vagus acts as a heart level inhibitor of the SNS, functioning as an active vagal brake and contributing to the modulation of cardiac output. This vagal brake provides a neural mechanism to rapidly change the visceral state, increasing or decreasing the HR, and thereby supporting either the metabolic needs of mobilization, communication behaviors or behaviors leading to the development of a calm state. Under stress conditions the SNS is activated and the social engagement system is inhibited. Therefore, the myelinated vagus becomes less active, and vagal tone decreases. In a situation of chronic stress, when the vagal brake does not work properly, the sympathetic-adrenal system, phylogenetically older than the myelinated vagus, would regulate the metabolic response facing the environmental challenges. Therefore, the cardiovascular system would be more exposed to the SNS activation with corresponding elevation of BP [15, 17].

23.3 Mechanisms of Yoga in Hypertension Management

23.3.1 Psycho-physiological Mechanisms

Yoga focuses on the attainment and maintenance of psycho-physiological balance, making available to the practitioner a set of techniques for coping with stress, reducing psycho-physiological activation, and facilitating mental calmness as a naturally positive state of mind. Besides that, yoga offers a holistic approach, which takes into consideration all the constitutive aspects of an integral health regimen, including aspects of healthy lifestyle, viz., a healthy diet, physical activity, invigorating breathing, a healthy thought process, the practice of conscious awareness in every daily activity, being surrounded by a healthy and natural environment, etc. In addition, yoga promotes a general attitude of respect, commitment, and personal responsibility in the care and maintenance of one's health.

The beneficial action of yoga practice in the prevention and management of arterial hypertension could be based on two main pathways: (1) Health behaviors: yoga practice is itself a physical activity and is based on maintaining healthy habits and lifestyle; and (2) Stress management: yoga involves a set of techniques to prevent and cope with stress.

Firstly, the practice of regular physical activity is generally associated with the reduction of BP. The protective effect of physical activity on the risk of developing hypertension was demonstrated in a prospectively-conducted study in Finland with a very large sample (8302 men and 9139 women) aged 25 to 64, during a mean follow-up of 11 years [18]. The practice of yoga too can be considered a healthy form of physical activity; however, the scope of yoga goes beyond the health benefits of a physical or sports training program. The practice of aerobic exercise has been compared with conscious activities, such as yoga and Feldenkrais Method, where the latter were more effective in reducing anxiety and increasing positive mood [19]. Besides that, the practice of yoga supports a holistic approach toward life and is associated with adopting and maintaining a healthy lifestyle. This was demonstrated in a study by Satish and Kumar [20] on the relationship between lifestyle and yoga practice with a sample of 870 young Indian people from Chennai (India), of which 368 were yoga practitioners for at least 6 months and 502 were non-practitioners. The researchers found that yoga practitioners scored higher on protective health factors and showed more control over risk behaviors than non-practitioners. Yoga practitioners also reported greater physical and psychological well-being. Likewise, the findings of the study by Butzer et al. [21], wherein the effect of yoga on prevention of adolescent substance use risk factors in a middle school setting was evaluated, suggested that school-based yoga can prevent willingness to smoke cigarettes in both males and females as well as improve emotional self-control in females.

There is further evidence about yoga leading to healthy behavior. Speroni et al. [22] carried out an intervention program based on yoga practice, healthy habits, and nutrition education to reduce extra weight and promote a healthier lifestyle with a total of 217 nurses, self-selected to the intervention ($n = 108$) or control (no intervention; $n = 109$) groups. The intervention group experienced significant decreases in Body Mass Index and waist circumference measurement and also stated an increase in their level of physical activity as well as an improvement in eating habits after the program. Watts et al. [23] used data collected as part of wave 4 of Project EAT (Eating and Activity in Teens and Young Adults), a population-based cohort study in Minnesota (USA). A sample of 1820 young adults completed the Project EAT survey and a food frequency questionnaire, and a subset, who reported practicing yoga additionally, participated in semi-structured interviews ($n = 46$). Young adult yoga practitioners reported healthier eating behaviors and higher levels of physical activity than non-practitioners. Yoga also supported healthy eating through motivation to eat in a healthier manner, greater mindfulness, management of emotional eating, more healthy food

cravings, and the influence of the yoga community, as assessed by the interviews. Additionally, yoga supported physical activity through activity as part of yoga practice, motivation to do other forms of activity, increased capacity to be active, and by complementing an active lifestyle.

Secondly, stress leads to alterations in the regulation of the hypothalamic-pituitary-adrenal (HPA) system, which gets reflected in various psycho-neuro-endocrinological processes, such as an increase in cortisol levels and decrease in serotonergic activity [24, 25]. In addition, stress also reduces the Gamma Aminobutyric Acid (GABA) and Parasympathetic Nervous System (PNS) activity. A reduction in brain GABA levels and an increase in cortisol levels are biologic markers of stress [26]. Impairments in serotonin neurotransmission have been strongly linked to stress and depression [27, 28] and a meta-analysis revealed that serotonergic activity moderates the relationship between stress and depression [29]. There is also evidence of the relation between low levels of GABA and depression and anxiety [30]. The reduction in the PNS activity leads to decreased heart rate variability (HRV) and reduced cardiac control by the vagal brake. Reduced PNS activity also creates a higher dependence on the Sympathetic Nervous System (SNS) led excitation of the cardiovascular system among other systems, and thereby negative cardiovascular health consequences such as arterial hypertension [31]. Yoga practices serve to reduce the effects of stress through increasing the PNS and GABA activity, reducing the reactivity of the HPA system and the allostatic load, in turn, balancing the Autonomic Nervous System (ANS) [31, 32]. Streeter et al. [33] additionally demonstrated that yoga practices decreased depressive symptoms in participants with major depressive disorder.

The positive effect of yoga practice on stress management has been demonstrated in healthy population as well as in chronic disease patients. A systematic review of 1469 studies, published between 2104 and 2018, selected from the databases of PubMed and Scopus, investigated the effect of different types of yoga (e.g., Hatha Yoga, Bikram Yoga, Kundalini Yoga, Sudarshan Kriya Yoga, Kripalu Yoga, Yin Yoga) on stress in healthy population. After a step-by-step thorough filtration process, only 12 studies were finally included in the review, which, in turn, revealed that most types of yoga reduced stress in healthy population [34]. Likewise, a rigorous systematic review and meta-analysis examined the benefits of yoga interventions on psychological distress among people living with HIV/AIDS (PLWHA). Seven studies sampling 396 PLWHA met inclusion criteria. The review showed that PLWHA who followed yoga interventions reported significant improvements in perceived stress, positive affect, and anxiety compared to controls [35].

Innes et al. [36] hypothesized primarily two mechanistic pathways underlying the beneficial effects of yoga interventions on cardiovascular risk profiles after conducting a systematic review of yoga therapy publications on CVD risk indices including hypertension. According to the authors, in the action of the first pathway, yoga may alleviate the effects of stress and foster multiple positive downstream effects on neuroendocrine status, metabolic function, and related inflammatory responses by reducing the activation and reactivity of the sympatho-adrenal system and the HPA axis, and promoting feelings of well-being. In the action of the second pathway, yoga may enhance parasympathetic output by directly stimulating the vagus nerve, and thereby shift the autonomic nervous system balance from primarily sympathetic to parasympathetic, leading to positive changes in cardiac-vagal function, in mood and energy state, and in related neuroendocrine, metabolic, and inflammatory responses.

23.3.2 Psychological and Neurocognitive Mechanisms

Perception is personal and subjective. During perception, reality is filtered and determined by "top-down" processing [37], or what Siegel [38] calls the "construction" function, as opposed to a "bottom-up" or "conduction" function of the mind. According to Siegel [38], "top-down" processing refers to how we have experienced things

in the past and created mental models and schemas of those experiences. Therefore, our perceptions are shaped by top-down learning from prior experience. However, in the "bottom-up" processing, the sensory experience is conducted as an energy flow. The senses capture the energy of the body and the outside world and send the information to the brain. Although the senses have limitations, the conduction process provides information closest to the objective and actual reality. In this way, we can experience the subjective sense of energy flow before it is transformed into structured information, living in the "here and now," seeing and perceiving with beginner's eyes and mind.

Once the sensation reaches the brain, the "construction" or "top-down" processing comes into play, resulting in perception, awareness of what is being perceived and, subsequently, construction and narration of the experience. This process connects the perceived information with some previous experiences, "labeling" them and creating models that fit those past experiences and transforms the energy of the primary and original perception (the more objective one) to a secondary one, one that is more subjective and processed. The reinterpretations of experiences shape the "own stories" of living reality, which are stored in memory and, in turn, determine new experiences and provide new sources of distortion of perceived reality, which in a kind of vicious circle, reinforces and perpetuates internal dissonance and imbalance. According to the yogic and meditative philosophies this state of dissonance is called *dvandva* (in Sanskrit) or *klesa* (in Pali) and in modern science is understood as stress [39].

In general, the "construction" or "top-down" processing predominates in the human being. In fact, the brain circuit associated with this process has been called the "default mode network" because of activation without performing any specific task [40]. Therefore, promoting the development of the "conduction" function and achieving a balance between both functions could be fundamental in personal integration and that with the outside world, as well as in establishing and maintaining well-being [38].

Yoga and meditative practices propose coming fully into contact with the sensation, the experience derived from the pure experience of what is actually being felt and perceived, and feeling and perceiving without interpretations or explanations, without categorizations or evaluations, or in other words, without any conceptualization. In neurofunctional terms, this means to reinforce the "conduction" manner of processing of the mind. This process of awareness of actual experience would facilitate a more objective knowledge of the reality and a harmonious and balanced integration of the internal experience, in all corporeal, cognitive, and relational (with others and the environment) aspects.

Through observation and development of awareness, yoga practices, including meditation, provide a greater understanding of the nature of internal thoughts and representations, and enable one to detect physical, mental, and emotional habits. Continued yoga practice and the development of awareness of the present moment help to avoid or minimize judgments and assessments, thereby approaching the true nature of experience. When the experience is observed in an objective way, one realizes that everything is in a continuous process of change, and sensations, emotions, and thoughts are continuously transforming. The understanding of this impermanent nature of everything (within and outside oneself) allows oneself to overcome identification with what is happening, reduces reactivity, and improves acceptance. As a consequence, a state of internal equilibrium can be achieved, feeling more independent of changing external circumstances and potential internal fluctuations, and when these happen, being more able to understand and accept them.

Specifically, yoga practices involve a process of integration of perceptions, feelings and thoughts, leading to restoration of the psychophysiological balance. The capacity for integration has been proposed as the central mechanism that underlies adaptive regulation and health [41, 42]. Starting from a visceral, sensorial, and motor awareness, through an embodiment process, yoga practices act on emotional and cognitive levels in a "bottom-up" process. Likewise, awareness of

the body and its related processes would act from the cognitive to the emotional and physiological levels in a "top-down" awareness pathway, facilitating not only the control of certain autonomic processes, but also the integration of physiological, emotional, and cognitive levels of experience and its interaction with the environment.

Furthermore, neuroplasticity is the inherent ability of the central nervous system (CNS) to adapt and reorganize its structure and function in response to internal and/or external stimuli. The high-level of plasticity of the CNS suggests that it is modifiable by any sort of training or intervention, and this neuroplastic ability can be leveraged in a clinical sample as well [43]. In this regard, yoga interventions have shown a positive impact, improving systemic biomarkers of neuroplasticity in healthy [44] and stressed individuals [45], as well as in major depressive disorder [43]. Although no study has as yet been undertaken on the role of yoga and neuroplasticity in essential arterial hypertension, taking a cue from the Tolahunase et al. [43] study on a clinical sample, it may be possible to hypothesize that yoga interventions carry the potential to capitalize on brain plasticity in hypertension as well.

23.4 Types of Yoga Studied

The modality, dosage, and duration of the yoga interventions in the study of the effect of yoga on management of arterial hypertension vary widely. The variety of the types of yoga used in the interventions has been a difficulty to compare the studies in most of the rigorous reviews. Although interventions based on different types of yoga have demonstrated their effectiveness, a combination of methods such as *asana, pranayama*, and relaxation practices (mainly *Shavasana*) has been proven to be more efficacious [46].

Despite the diversity in the type of yoga used in the interventions, in a systematic review conducted subsequently, the same authors reported that, among all the reviewed studies mentioning different types of yoga (*Hatha Yoga*, yoga with supervised exercise, unspecified yoga, yoga consisting of *asana* and *pranayama*), the emphasis on mind-body therapies reinforcing meditative states and breathing-focused techniques (in addition to other mind-body practices) was similar throughout [47].

In a comprehensive bibliometric analysis of publications about yoga therapy research inclinical populations, Jeter, Slutsky, Singh, and Khalsa [48] pointed out the need for standardized yoga protocols in randomized controlled trials to determine efficacy/effectiveness. This expressed need may conflict with the clinical practice of yoga, wherein yoga as a form of therapy needs to be tailored to individual needs, specific symptoms and severity of disease.

There exist limited studies comparing the effectiveness of different types of yoga on management of hypertension. In a three-armed randomized controlled trial (RCT) comparing the BP-lowering effect of yoga interventions with and without yoga postures in patients with arterial hypertension, Cramer et al. [49] found that a yoga intervention even without postures (comprising breathing, meditation, relaxation techniques, and some educational-interactive activities) was successful in lowering the ambulatory systolic blood pressure (short-term) significantly better than the controlled condition as well as the condition of yoga intervention with postures. The authors concluded that their obtained results were in accordance with the findings of earlier studies, that yoga is safe and effective in patients taking medications for arterial hypertension, and therefore, can be recommended as an additional treatment in this condition.

Tolbaños-Roche et al. [50] analyzed the differential effectiveness of three yoga interventions, specifically designed for essential arterial hypertension treatment: (1) "Yoga Practice" which included *asana*, *pranayama,* and relaxation, (2) only "*Pranayama"* and, (3) only "Meditation." Although a clinically significant decrease in BP was found in all the yoga interventions, the results showed a differential effect of improvement in self-regulation and emotional symptomatology, as well as a decrease in physiological parameters related to essential hypertension, specifically in the "Meditation" intervention.

Pranayama practices used in the management of hypertension have also demonstrated a significant decrease of SBP and DBP parameters, as well as an enhancement of HRV [51–55]. Meditation interventions (transcendental meditation and mindfulness techniques) have shown more effectiveness in decreasing BP in patients above 60 years, whereas yoga (mainly focused on postural and breathing practices but also including meditative physical relaxation) contributed to the decrease in BP of patients aged less than 60 years [56].

23.5 Evidence About the Efficacy of Yoga in Hypertension Management

23.5.1 Efficacy of Yoga and Allied Interventions

The practice of yoga induces a coordinated psycho-physiological response that can be considered the antithesis of the stress response. This relaxation response consists of a reduction in cognitive and somatic excitation that involves a modification in the activity of the HPA axis and of the ANS [57], with reduction in SNS activity and a corresponding improvement in PNS activity, resulting in decreased systolic blood pressure (SBP), diastolic blood pressure (DBP), heart rate (HR), and increased heart rate variability (HRV) [58, 59]. Furthermore, a reduction in cardiovascular reactivity to stress induced by physical activity, with better recovery in the cardiovascular parameters of SBP, DBP, and HR was found after a 2-month yoga training program [60].

The effect of yoga interventions in reduction of BP in hypertension patients has also been widely confirmed [60–64]. Patel [65] also demonstrated the efficacy of yoga practice in hypertensive patients, with significant decreases in BP, and reduced intake of antihypertensive medication. Compared to treatment with antihypertensive drugs, the greater efficacy of yoga therapy in the reduction of SBP and HR opens the doors for considering yoga therapy as a substitute for pharmacological therapy (see [66]). Likewise, a 21-day naturopathy and yoga intervention program in hypertensive patients taking antihypertensive medication significantly lowered SBP and DBP, improved blood lipid profile, and reduced body weight. After withdrawing medication in the most favorable cases, who reached normal BP values, approximately 26% of them maintained BP within these normal limits even after 1 year without medication [67]. In a review of studies conducted (1972–2012) on the efficacy of yoga in arterial hypertension, with a total of 19 studies analyzed, 12 of them reported significant decreases in the BP of the participants [46]. Another study by Metri et al. [68] carried out a 1-week residential yoga-based lifestyle program (Integrated Approach of Yoga Therapy, IAYT), with 20 hypertensive patients in India, which consisted of sessions of *asana*, breathing practices, meditation and relaxation techniques, low salt, low-calorie diet, devotional session, and counselling. A significant improvement in SBP, baroreflex sensitivity and total peripheral vascular resistance was found in the study group after the intervention compared to the control group. This study revealed the relevance of the holistic approach of yoga in the management of hypertension.

A recent systematic review and meta-analysis of RCTs assessed the efficacy and safety of yoga by comparing it with usual care or nonpharmacological interventions in secondary prevention of CVD. Results from 7 finally shortlisted RCTs comprising 4671 participants revealed that although no mortality benefits of yoga in CVD patients were observed, it could be a promising alternative for CVD patients as it significantly improved health-related quality of life, BP, BMI, triglycerides, and high-density lipoprotein cholesterol (HDL) without causing severe adverse events, and was associated with a lesser number of composite cardiovascular events [69].

In the Park and Han [56] systematic review (mentioned earlier), which included 510 indexed publications (1946–2014) on the effect of mindfulness meditation and yoga on hypertensive patients, only 13 studies qualified the rigorous selection criteria when the Cochrane risk-of-bias tool was applied to assess the validity of the stud-

ies. The meta-analysis indicated that the practice of meditation and yoga significantly decreased SBP and DBP in patients with similar baseline BP ranges. However, they found different results depending on the baseline range of BP and age of participants; the practice of meditation was more effective in decreasing BP in patients above 60 years, while the practice of yoga was more effective in patients below 60 years. Despite these differences, the authors concluded that both practices proved to be effective alternatives to pharmacotherapy. Further, the practice of yoga can also reduce the impact of age on cardiovascular function. Significantly lower BP and HR were found in yoga practitioners over 40 years with 5 years of experience in yoga, compared to a control group [70].

In yet another systematic review (mentioned earlier) by Innes et al. [36], 70 eligible original studies (1970–2004; including 22 RCTs, 21 non-randomized controlled clinical trials, 26 uncontrolled clinical trials, and 1 observational study) evaluating the effects of yoga on CVD or CVD risk indices associated with insulin resistance syndrome (IRS) were identified. Despite methodological and other limitations, these authors reported that the results of these reviewed studies indicated beneficial changes overall in several IRS-related indices of CVD risk, including glucose tolerance and insulin sensitivity, lipid profiles, anthropometric characteristics, BP, oxidative stress, coagulation profiles, sympathetic activation, and cardiovagal function, as well as improvement in several clinical endpoints.

23.5.2 Efficacy of Pranayama-Specific Interventions

Pranayama practices, which involve voluntary slow and deep yogic breathing, can significantly contribute to the management of hypertension. This was confirmed by a systematic review and meta-analysis, which investigated the efficacy of yoga as an antihypertensive lifestyle therapy and included 49 qualifying controlled trials. In this study, Wu et al. [71] compared interventions which included yogic breathing techniques and meditation/mental relaxation with those that did not, and demonstrated that yoga is a viable antihypertensive lifestyle therapy that produces the greatest BP benefits when yogic breathing techniques are included together with meditation/mental relaxation.

Pranayama practices have also shown a balancing effect on the ANS activity. The practice of various *pranayama* practices increases HRV [72] and decreases BP [73]. Some research has focused on analyzing the effects of yogic breathing techniques based on the use of a single nostril (*surya pranayama*—breathing through the right nostril; *chandra pranayama*—breathing through the left nostril), as well as both nostrils alternatively (*anuloma-viloma pranayama*). The function of naturally occurring nasal respiratory cycles had been analyzed in *Shivasvarodaya*, the ancient Indian text which deals with the relation between a person's mental state and the accompanying breath [74]. The left *swara* (the flow of air as well as *prana*, the subtle aspect of breath) through the left nostril presides over mental actions (*soumya karya*—quieter activities; [51]), the right *swara* through the right nostril presides over physical actions (*roudra karya*—exertional activities; [52]), and both *swara* through both nostrils together preside over spiritual actions (meditative activities) [75]. *Shivasvarodaya* states that the *swara* changes at regular intervals in a person, and advises correct action for the appropriate *swara* [75].

In healthy subjects, right nostril breathing increases SBP and DBP, while left and alternate nostril breathing decreases BP. There is also a greater increase in HR when breathing through the right nostril than with the other two practices. The effects of right nostril breathing may be due to sympathetic activity increasing, while the BP and HR decreasing in left and alternate nostril breathing may be due to a combination of effects, such as changes in cardiac output and peripheral vascular resistance [54]. In essential arterial hypertension patients, a statistically significant decrease of SBP and HR and a slight decrease of DBP (statistically non-significant) with left nostril breathing were found [51]. The authors attri-

bute the statistically significant results to the normalization of autonomic cardiovascular rhythms, with an increase of vagal modulation and/or a decrease of sympathetic activity. The authors reasoned that the non-significant change in the DBP may have been because the DBP was maintained within normal values by the medication, rendering little possibility for a significant change after performing these *Pranayama* practices. In another study with essential arterial hypertension patients, Bhavanani et al. [52] found a non-significant decrease in SBP and HR after right nostril breathing, attributing this small improvement to the role of yogic practices in restoration of homeostasis. In healthy subjects, right nostril breathing increases BP and HR; however, as sympathetic reactivity is already higher than normal in hypertensive patients, right nostril breathing would contribute to bringing the cardiovascular parameters to normal, in a kind of homeostatic or balancing effect.

Recent studies have demonstrated the effect of specific *Pranayama* practices such as *Shitali Pranayama* (yogic breathing with the tongue curled up like a bird's beak) as a solitary intervention on cardiovascular and autonomic changes in hypertension with a significant reduction in blood pressure as well as an improvement in HRV [55]. Similarly, a single short session of *Bhramari Pranayama* (yogic breathing with the sound of a bumble-bee) significantly augmented the parasympathetic tone as indicated by a significant improvement in HRV parameters, with a significant increase in the HF (high frequency) power and decrease in the LF (low frequency) power values immediately after the practice [53]. This practice, however, did not demonstrate a significant reduction in BP.

23.5.3 Efficacy of Yoga in Other Psycho-physiological Parameters Associated with Hypertension

Some studies have focused on the effect of yoga on the psychological parameters associated with hypertension along with the BP parameters [50, 76]. These authors found an increase in interoceptive awareness and improvements in emotional symptomatology related to hypertension, such as anxiety and depression symptoms, distress, and perceived stress, as well as perception of happiness and satisfaction with life along with statistical or clinical improvements in SBP, DBP, and HR in a group of Spanish hypertensive patients, who followed a yoga intervention, compared with a control group.

Carlson et al. [77] demonstrated that mindfulness-based interventions have other positive physiological effects, viz., improvements in immune function and cortisol levels, along with a reduction in BP. Positive emotional changes such as reduction in the degree of stress [78] and improvement in anxiety and depression symptoms [79] have also been found. A brief mindfulness training session was also shown to be effective, with reductions in BP, fatigue and anxiety symptoms, and improvement in visuospatial processing and memory in the participants compared to a control group, who listened to a book recording [80].

23.5.4 Feasibility of Yoga as an Adjuvant Therapy in Hypertension Management

It is important to note that, although BP is usually well controlled by antihypertensive drugs, some studies have questioned the risks and damages that pharmacotherapy can cause in patients with mild hypertension. A Cochrane systematic review [81] based on four randomized controlled trials revealed that the total mortality of 8912 hypertensive patients, who were treated with antihypertensive drugs for 4–5 years, was not lowered when compared to a control group. Also, drug treatment did not reduce the incidence of coronary heart disease, stroke, and general cardiovascular problems in 7080 participants compared to the control group. Moreover, the study reported that the withdrawal rate of patients from medication substantially increased as a consequence of adverse effects of drug therapy.

The growing interest in nonpharmacological interventions to treat blood pressure in hypertensive and pre-hypertensive patients at low cardiac risk led Chaddha et al. [82] to carry out the recent meta-analysis of RCTs which assessed the impact of device-guided and non-device-guided slow breathing on blood pressure reduction in hypertensive and pre-hypertensive patient populations. The review included 17 studies from 103 citations eligible for full-text review searching PubMed, EMBASE, CINAHL, Cochrane CENTRAL, Cochrane Database of Systematic Reviews, Web of Science, BIOSIS (Biological Abstracts) Citation Index and Alt HealthWatch. Although the included studies showed high heterogeneity, slow breathing showed reductions in SBP and DBP in this patient population. The authors concluded that it may be a reasonable first treatment for low-risk hypertensive and pre-hypertensive patients, who are reluctant to start medication.

A recent RCT by Sharma et al. [83] analyzed the feasibility of introducing the integrated approach of yoga therapy (IAYT) in a cardiac rehabilitation center in Bengaluru in southern India. This study was conducted to determine the efficacy of yoga in improving cardiac conditions and managing the cardiac risk factors in patients aged 30–65 years having acute myocardial infarction with left ventricular dysfunction. The results revealed that, compared to the standard cardiac care treatment, although the 12-week yoga intervention provided no added benefit in improving the primary outcome measure of left ventricular ejection fraction (LVEF; a powerful predictor of cardiac mortality), the yoga group was not significantly different on the LVEF parameter from the control group. The authors reasoned that significant improvement in the LVEF parameter is more likely when yoga therapy is coupled with standard medical therapy in patients with cardiac failure. Further, the cardiac patients practicing yoga demonstrated a favorable profile compared to controls in terms of reduced cardiac depression, anxiety, and improved quality of life and metabolic equivalents. Additionally, the authors reported the integration of yoga practice in a cardiac rehabilitation (CR) program to be feasible, thereby offering support to the feasibility of yoga as an adjuvant therapy in cardiovascular conditions.

Exercise is routinely prescribed to cardiac patients for its multiple benefits. Cardiac patients may typically have co-morbidities that prevent them from participating in traditional exercise. The lower metabolic demand of yoga is flexible, ranging from chair based to continuous flow, presenting an option for cardiac patients to participate in an exercise intervention with a sense of mastery, rather than difficulty [84]. The implementation of yoga practices in the management of arterial hypertension may also have cost savings, both for patients and health systems. On the one hand, direct cost savings due to reduction in the need for medication and in hospitalizations arising out of complications, and on the other hand, savings on indirect cost due to loss of productivity, can both be achieved by implementing evidence-based yoga practice modules along with adopting yoga's holistic approach to an individual and the environment [85].

23.6 Clinical Practice of Yoga in Hypertension Management

As was explained earlier, evidence about the efficacy and beneficial effects of lifestyle changes (yoga and allied practices) in the treatment of chronic diseases like hypertension either in combination with drugs and surgery or as an alternative therapy has been accumulating over the past years. This led Dr. Dean Ornish, founder and president of the Preventive Medicine Research Institute and a Clinical Professor of Medicine at the University of California (San Francisco, USA), to study the clinical application of lifestyle interventions in coronary heart disease and related conditions along with risk factors such as high levels of cholesterol, BP, and blood sugar. For the last four decades, Dr. Ornish and colleagues have been developing a lifestyle program based on wholefoods and plant-based diet, stress-management techniques including yoga and meditation, moderate exercise, and social support

[86]. The Ornish Lifestyle Medicine program [87] offers intensive cardiac rehabilitation (CR) based on the model of a structured class at different centers across the USA. The program is conducted by a multidisciplinary team which includes a nurse, exercise physiologist, stress management specialist (such as a certified meditation/yoga teacher, psychologist or clinical social worker), and a dietitian. All therapeutic decisions (e.g., medications, revascularization) are under the clinical supervision of a referring physician [88].

A systematic review from the American Heart Association (AHA) on the potential benefits of meditation on cardiovascular risk concluded that, given the low costs and low risks of this intervention, meditation may be considered as an adjunct to guideline-directed cardiovascular risk reduction [89]. However, the AHA stated that the benefits of such interventions will have to be better established as the reviewed studies on the effect of meditation on BP in the clinical context were inconclusive. The HARMONY (Hypertension Analysis of Stress Reduction Using Mindfulness Meditation and Yoga) trial also could not find benefit to patients in the initial stage of hypertension, who had followed an 8-week mindfulness-based stress reduction program, compared to wait-list controls [90]. In contrast, in the pilot study of Palta et al. [91], wherein an 8-week RCT on BP-control was conducted on female hypertensives with mindfulness-based versus social support interventions, a 11/4 mmHg decrease in SBP/DBP was observed in the mindfulness intervention group. These interventions were provided in residence for lowincome, urban, African-American predominantly hypertensive females aged 62 years or older. Multivariate regression analysis revealed significantly lower SBP (21.92 mmHg) and DBP (16.70 mmHg) in the mindfulness group compared to the social support control group.

Raghuram et al. [92] investigated the long-term effects of a yoga-based CR intervention versus a physiotherapy-based active control condition, in addition to conventional CR provided to both groups after coronary artery bypass grafting (CABG). Results demonstrated improvements in LVEF (cardiac mortality predictor), BMI, serum glucose, and lipid profile, and a decrease in perceived stress, anxiety, and depression. This RCT done with a total of 250 males, aged 35–65 years, over a period of 1 year at a CR center in Bengaluru, South India, demonstrated the importance of a long-term yoga intervention to produce a significant effect in LVEF (cf. [83]) and other hypertension-associated risk factors. The authors also concluded that the addition of yoga-based relaxation to conventional post-CABG CR can help in better management of risk factors in those with abnormal baseline values and may help in preventing recurrence.

The Advanced Centre for Yoga Therapy Education and Research (ACYTER), a collaborative venture between Jawaharlal Institute of Postgraduate Medical Education and Research (JIPMER; Puducherry, India) and Morarji Desai National Institute of Yoga (MDNIY; New Delhi, India) has been focusing primarily on the role of yoga in the prevention and management of cardiovascular disorders and diabetes mellitus since 2008. Between 2008 and 2012, more than 36,000 patients attended individual and group therapy sessions for these two conditions [93]. A study with 130 heart-failure patients recruited from the cardiology outpatient department of JIPMER, examined the effects of a 12-week yoga therapy program on BP, HR, HRV, and rate pressure product (RPP). After a total of 36 supervised yoga sessions over 12 weeks, the yoga intervention group showed a significant decrease in HR, BP, and RPP compared to a control group of heart-failure patients, who were only on the standard-of-care treatment. Also, normalized Low Frequency power (LFnu) and LF:HF ratio decreased significantly and normalized High Frequency power (HFnu) increased significantly in the yoga group compared to the control group, showing a significant improvement in the parasympathetic activity and reduction in the sympathetic activity in heart-failure patients [94].

From 2010 onwards, the Center for Yoga Therapy, Education and Research (CYTER) of Sri Balaji Vidyapeeth (SBV), a reputed private university in southern India, has been training and helping medical educators and administra-

tors for setting up integrative health centers in their respective institutions. CYTER has also been conducting a scientifically established Yoga Therapy program offered by Dr. Ananda Balayogi Bhavanani (a certified medical doctor as well as a yoga therapist) and team. This team has been developing individualized therapeutic yoga protocols for patients with various medical conditions such as diabetes, hypertension, musculoskeletal and psychiatric disorders, and also receiving excellent feedback from the program's participants [95, 96].

Other Indian medical institutions offer integrative yoga programs for the management of chronic diseases including arterial hypertension. An observational cohort study involving pre–post-comparative analysis of patients, enrolled between April and July 2015, was carried out in a hospital in South India, which has been offering an "Integrated Naturopathy and Yoga" (INY) program. The INY program includes a highly structured 15-day routine of natural-food diet, daily yogic exercises, meditation, relaxation, and patient counselling and health education. Among the 80 patients, who underwent a 3-month follow-up, 79 (99%) achieved the recommended clinical BP target (<140/90 mmHg), 45 (56%) achieved normal BP (<120/80 mmHg), 66 (83%) achieved more than 50% reduction in the dosage of antihypertensive medication, and 8 patients (10%) showed remarkable recovery with all medications withdrawn while maintaining normal BP. In addition, the patients achieved significant reductions in body weight, BMI, percentage of body fat, blood triglycerides, and mild increase in HDL cholesterol. Additionally, in patients with diabetes as a co-morbidity, there was a significant reduction in glycosylated hemoglobin levels [85].

Recently, the International Society of Hypertension (ISH) developed worldwide practice guidelines for the management of hypertension in a practical format that is easy-to-use particularly in low, but also in high resource settings—by clinicians, but also nurses and community health workers, as appropriate. These guidelines have included yoga (under regular physical activity) and meditation/mindfulness practices (for stress reduction) as a part of lifestyle modifications in the management of hypertension [97]. This inclusion in the ISH guidelines may provide added impetus for yoga and meditation practices to be adopted in mainstream healthcare. Safety and benefits considered, yoga is a promising alternative and complementary choice for conventional CR programs in patients with CVD, especially for patients in low- and middle-income countries where such programs may be unavailable or too expensive [69].

23.7 Conclusion

Yoga and meditative practice have proved effective not only in regulation of high BP but also in the improvement of related emotional symptomatology. As has been argued, yoga practice is a process of integration and attunement of the systemic unity of the organism: body, mind, and environment. This integrative capacity has been proposed as the central mechanism underlying adaptive regulation and health. In addition, yoga leads to changes in lifestyle, promoting healthy behaviors and habits that include a healthy diet, avoiding consuming toxic substances, and a general attitude of care for one's health, and respect, commitment, and personal responsibility in health maintenance, as well. Consequently, it provides a framework within which patients can learn new ways to take care of themselves and their health, complementing medication intake, or at times, having the opportunity to avoid dependence on medication.

The attitude of self-awareness offers patients the possibility of a new way of being with themselves. By learning to be aware, they come into contact with the experience arising from physical and mental stillness, being able to generate a non-judgmental and non-reactive space, that is, a space of acceptance. Beyond the physical practice, yoga is a practice of awareness in every daily activity, self-observation, and recognition of own feelings, thoughts and emotions, and the links between them. Through specific yoga practices, patients learn to reduce their psychophysiological activation, promote a state of

mental calmness, as well as that of positive and healthy changes in their body postures, emotions, attitudes, and relationship with the environment. In this way, the awareness process itself could act as a process of transformation for the patients.

The result of a systematized and continual yoga intervention could lead to the regulation and, even to the normalization of BP in these patients, with corresponding health benefits and decrease in demand for medical treatments, as well as a probable reduction or cessation of medication intake. More broadly, these positive effects of yoga could be extended to the prevention and treatment of many other pathologies related to stress and psycho-physiological imbalances. Therefore, the time is ripe to implement evidence-based yoga practices accompanied with yoga's holistic approach in mainstream healthcare.

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