A Dissertation On

IMMEDIATE EFFECT OF HOT ARM AND FOOT BATH ON PULMONARY FUNCTION IN HEALTHY INDIVIDUALS

Submitted by

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I, Dr.D.Divya solemnly declare that this dissertation entitled **"IMMEDIATE EFFECT OF HOT ARM AND FOOT BATH ON PULMONARY FUNCTION IN HEALTHY INDIVIDUALS"** is a bonafide and genuine research work carried out by me at Government Yoga and Naturopathy Medical College and Hospital, Chennai from May 2018 - March 2019 under the guidance and supervision of

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The Institutional Ethical Committee of Government Yoga & Naturopathy Medical College and Hospital, Chennai reviewed and discussed the application for approval of**"IMMEDIATE EFFECT OF HOT ARM AND FOOT BATH ON PULMONARY FUNCTION IN HEALTHY INDIVIDUALS"**, project work submitted by Dr. D. DIVYA, 3rdyear M. D. Naturopathy, Post graduate, Government Yoga and Naturopathy Medical College and Hospital, Chennai.

The proposal is **Approved**.

The Institutional Ethical Committee expects to be informed about the progress of the study and adverse drug reactions during the course of the study and any change in the protocol and patient information sheet / informed consent and asks to be provided a copy of the final report.

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ABSTRACT

Background & Objectives:

Naturopathy is an art and science of healthy living and a drugless system of healing based on well-founded philosophy .It is a system of man building in harmony with the constructive principles of Nature on physical, mental, moral and spiritual planes of living. Hydrotherapy is one of the most important interventions in naturopathy. Water used at various temperatures enhances blood flow, which is thought to help dissipate all chemicals and facilitate muscle relaxation. Among various techniques of hydrotherapy, the arm bath and foot bath are used to treat both local and systemic illness. This study aims to explain the physiological effects of hot arm and foot bath on pulmonary function in healthy individuals before applying them as therapy.

Methods:

A total of 60 healthy volunteers of both the genders, were recruited from Govt. yoga and naturopathy medical college & hospital, Chennai, Tamil nadu. Subjects were randomly assigned into two groups. Study group (n=30) and control group (n=30), after satisfying the inclusion criteria. Study group was given hot arm and foot bath, for 20 minutes. Control group on the other hand was advised to sit quietly for 20 minutes. Both groups were assessed at baseline and immediately after 20 minutes for FVC, PEFR, FEV_1 and FEV_1/FVC%.

Results:

The study group showed significant improvement in the FVC ($p<0.002$), PEFR ($p<0.04$), FEV_1 ($p<0.03$), FEV_1/FVC% ($p<0.001$) and FEF 25-75% ($p<0.05$) as compared to that of control group.

Interpretation and conclusion:

Study group showed significant improvements in Forced vital capacity, peak expiratory flow rate, FEV_1 (Forced expiratory volume in 1 second) and FEV_1/FVC%. Hence, the immediate effect of hot arm and foot bath by healthy volunteers has shown a positive influence on the lung volumes and capacities.

Key words: Hydrotherapy, Arm and Foot bath, pulmonary function.

LIST OF ABBREVIATIONS USED

ECF	Extra Cellular Fluid
NCV	Nerve Conduction velocity
WI	Water Immersions
MR	Metabolic Rate
Tre	Rectal temperature
SBP	Systolic blood pressure
DBP	Diastolic blood pressure
BP	Blood Pressure
SNS	Sympathetic nervous System
QoL	Quality of Life
VC	Vital Capacity
VT	Tidal volume
MVV	Maximum voluntary ventilation
CSF	Cerebro Spinal Fluid
ANS	Autonomic Nervous system
FVC	Forced vital capacity
PEF	Peak Expiratory flow
FEV_1	Forced Expiratory Volume in 1 second.

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1. INTRODUCTION

Naturopathy is an art and science of healthy living and a drugless system of healing based on well-founded philosophy. It has its own concept of health and disease and also principle of treatment. Naturopathy is a system of man building in harmony with the constructive principles of Nature on physical, mental, moral and spiritual planes of living. It has great health promotive, disease preventive and curative as well as restorative potential. According to the manifesto of British Naturopathic Association, "Naturopathy is a system of treatment which recognizes the existence of the vital curative force within the body." It therefore, advocates aiding human system to remove the cause of disease i.e. toxins by expelling the unwanted and unused matters from human body for curing diseases.(1)

We can find a number of references in our Vedas and other ancient texts. Water Cure (Hydrotherapy) was synonymous with Nature Cure in those early days. Now, Hydrotherapy is a branch of Nature Cure. It is the treatment of disorders using different forms of water. These forms of water application are in practice since age-old days. Hydrotherapy additionally uses its temperature effects, as in hot & cold baths, saunas, wraps, etc. and in all its forms-solid, fluid, vapor, ice and steam, internally and externally. Water is without doubt the most ancient of all remedial agents for disease. This great healing agent has now been systematized and made into a science.(1)

Hydrotherapy is the external or internal use of water in any of its forms (water, ice, steam) for health promotion or treatment of disease. It was used widely in ancient cultures, including Egypt, Persia, China, India, and Israel, before it was well established as the traditional European water cure.(2)

Hydrotherapy is one of the most important interventions in naturopathy, which has been used since Ancient times. It can be defined as a naturopathic modality that involves the use of water at different temperatures, pressures, states and modes of application for the treatment of various disorders. The physiological effects and therapeutic applications of hydrotherapy are diverse. Water used at various temperatures enhances blood flow, which is thought to help dissipate all chemicals and facilitate muscle relaxation.(3) In addition, the hydrostatic effect may relieve pain by reducing peripheral oedema and by dampening sympathetic nervous system activity.(4) Hipbaths, enemas, hot and cold fomentation, hot footbaths, spinal baths, steam baths, immersion baths, application of hot and cold packs as well as advanced modalities like whirlpool baths, sprays and jets are some of the various forms of hydrotherapy.(5)

Studies have been conducted extensively in hydrotherapy and as evolved as a promising intervention in treating various systemic disorders.Many of the treatments can be applied at home, making them cost effective and participatory for the patient. Numerous studies have examined potential immune modulatory effects of hydrotherapy treatments with promising results.

Hydrotherapy stimulates the body's Natural healing mechanisms, which increases the circulation of blood and lymph.(3) Among various techniques of hydrotherapy, the arm bath and foot bath are used to treat both local and systemic illness. The arm and foot bath is used in pulmonary congestion, chronic bronchitis and chronic pneumonia(6)

A hot foot and arm bath which is used as a treatment of choice in naturopathy along with cold chest pack for bronchial asthma is believed to reduce pulmonary congestion, decrease pulmonary mucus membrane irritation and increase the depth of respiration.(7) It is found that the combination of hot foot and arm bath is much more useful than giving them separately. The temperature of the foot bath and arm bath will be initially fixed at a temperature of 400 C and gradually raised to 450 C. Duration of bath is 12 minutes. At the end of the bath, cold water should be dashed on the feet and arms and the body is quickly dried. This bath is found to be quickly relieving the congestion of the lungs and thus relieving the severe paroxysmal attacks within 8-10 minutes. It also causes dilation of the bronchioles and thus relieves the mucus, which is obstructing the airway passages(8).

However, hot arm and foot bath has been used along with other modalities for various respiratory disorders, its underlying mechanism are less understood. To the best of our knowledge there is no previous randomized control trial conducted to evaluate the effect of a hot arm and foot bath in isolation on pulmonary functions of both physiological as well as pathological conditions.

A study done by Syan et al on Migraine patients there was a significant increase in parasympathetic activity following hot foot and arm bath along with ice massage to head(9).

Hence, this study is conducted to explain the physiological effects of hot arm and foot bath on pulmonary function in healthy individuals before applying them as therapy.

2. AIM & OBJECTIVES

AIM:

- To study the effectiveness of hot arm bath and foot bath in temperature between 103^0 Fto110^0 F on pulmonary functions in healthy individuals.

OBJECTIVES:

- To observe the immediate effect of exposure of extremities to arm and foot bath at the same time in temperature between 103^0 – 110^0 Fon pulmonary functions in healthy individuals.

3. Review of Literature

3.1. Healing power of water:

Szent-Győrgi called water the “matrix of life” and claimed that there was no life without it. Water is a participant in the “life of the cell”, this statement is true, as far as we know, on our planet, but it is not clear whether it must hold throughout the cosmos(10). Water exhibits diverse structural and dynamical roles in molecular cell biology(11). Water can be used internally as well as externally as a therapy for preventing and treating the various disorders in human beings(2).

3.1.1Water as a vital nutrient:

Water is the major constituent of the human body and it has various intramural functions. Water is the main constituent of cells, tissues and organs and is vital for life. Following are some of the vital functions of water inside the human body(12).

- **Distribution of body water**

Water is the main constituent of our body, as about 60% of our body weight is made of water. In adults, about two-thirds of total water is in the intracellular space, whereas one-third is extracellular water. The constancy of the amount and composition of ECF is a necessity for the function of cells. This constancy

is due to the homeostatic mechanisms that monitor and regulate its composition, osmotic pressure, pH and temperature. These mechanisms rely on the function of the main systems of the body, such as the circulatory, respiratory, renal and alimentary systems. The monitoring and regulation of these systems are coordinated by the nervous and endocrine systems. The composition of the intracellular fluid is maintained by solute movement across the cell membrane by passive or active transport.(13)

- **Water as a building material**

  Water, present in each cell of our body and in the various tissues and compartments, acts first as a building material. This primary function leads to nutritional recommendations, as water needs are higher during the growth period of the body.(14)

- **Water as a solvent, a reaction medium, a reactant and a reaction product**

  Water has unique properties: it is an excellent solvent for ionic compounds and for solutes such as glucose and amino acids (Häussinger, 1996). Water as a macronutrient is involved in all hydrolytic reactions, for instance, in the hydrolysis of other macronutrients (proteins, carbohydrates, lipids and so on).

  Water is also produced by the oxidative metabolism of hydrogen-containing substrates in the body. (14)

- **Water as a carrier**

Water is essential for cellular homeostasis because it transports nutrients to cells and removes wastes from cells (Häussinger, 1996). It is the medium in which all transport systems function, allowing exchanges between cells, interstitial fluid and capillaries (Grandjean and Campbell, 2004). Water maintains the vascular volume and allows blood circulation, which is essential for the function of all organs and tissues of the body (Ritz and Berrut, 2005). Thus, the cardiovascular and respiratory systems, the digestive tract, the reproductive system, the kidney and liver, the brain and the peripheral nervous system, all depend on adequate hydration to function effectively (Häussinger, 1996). Severe dehydration therefore affects the function of many systems and is a life-threatening condition.(14)

- **Water and thermoregulation**

Water has a large heat capacity, which contributes to limiting changes in body temperature in a warm or cold environment. Water has a large capacity for vaporization of heat, which allows a loss of heat from the body even when ambient temperature is higher than body temperature (Montain et al., 1999). When sweating is elicited, evaporation of water from the skin surface is a very efficient way to lose heat.(14).

- **Water as a lubricant and shock absorber**

Water in combination with viscous molecules forms lubricating fluids for joints, for saliva, gastric and intestinal mucus secretion in the digestive tract, for mucus in airways secretion in the respiratory system and for mucus secretion in the genito-urinary tract.By maintaining the cellular shape, water also acts as a shock absorber during walking or running. This function is important for the brain and spinal cord, and is particularly important for the fetus, which is protected by a water cushion.(14)

3.1.2: Water as therapeutic agent:

Water is beneficial to human health even when it is administered externally. Water has the various effects on body tissues by means of heating, cooling, debridement, pain relief and relaxation of muscles when it is applied externally. Simply bathing itself has positive impacts on our health. Submerging ourselves in water, whether in a bathing receptacle or in a natural body of water is something we do for personal hygiene, leisure and health. There is nothing more enjoyable than going for a swim in the ocean on a warm day or having a hot fragrant bath in the cooler months. Both the use of hot and cold water can have beneficial effects on the body. Boiling water can be sourced naturally from a hot spring and many places like New Zealand and Iceland have naturally occurring hot pools that people can utilize to take advantage of the mineral rich

waters. Similarly, cryotherapy or taking ice baths can help to alleviate muscle strain and many athletes including runners will submerge themselves in freezing waters to counteract the damage or strain induced by exercise. Regardless of the temperature, the benefits of taking a bath have been scientifically proven and can ensure optimal health of the mind and body.(15)

Apart from bathing and showering water is used therapeutically probably as old as mankind. Hydrotherapy is the use of a water environment for therapeutic effects both internally as well as externally. 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 systems of the body.(2)

3.2. General Considerations to Hydrotherapy:(15)

In Hydrotherapy, sometimes water is applied for therapeutic purposes. Hydrotherapy, previously known as hydropathy, is a sector of medicine, specifically naturopathy. The title covers an expansive variety of therapeutic techniques and approaches which grasp benefits of water's physical properties for therapeutic purposes, namely stimulation of blood circulation and symptomatic treatment of certain diseases.

Water therapy involves the modulation of body temperature like delivery of hot and cold to the body. It encompasses submerging of all or part of the body in water and may involve many types of equipment, namely full body immersion tanks; neutral baths; sitz baths; contrast sitz baths; foot baths; arm baths; cold mitten friction rub; steam inhalation; hot compresses, cold compresses; alternating hot and cold compresses; and arm, hip, and leg whirlpool.

Immersion of the body in water or the application of water or ice to the body is external hydrotherapy. The variable effect of hot or cold water on the skin and underlying tissues is involved in temperature-based hydrotherapy. Application of hot water relaxes muscles and is used to treat arthritis, rheumatism, and sore muscles while cold water therapy stimulates the flow of blood in the skin. Fomentation is the application of moist heat and is used in chest cold and flu. Ice packs or cold compresses are used for sprains and headaches.

Water jets, underwater massage, and mineral baths (Swiss shower, balneotherapy) are used in existing hydrotherapy. Preinstalled jets are present in hydro machines, which shoot water on the body in specified time intervals. Specifically, water affects chakras of the body, i.e., gradually cleansing and opening the desired chakras. Hydro therapists may utilize it for vasodilation and vasoconstriction purposes. Ultimately, alteration in blood flow occurs through physiological mechanisms like thermoregulation. Sometimes, for the treatment

of wounds, tissue removal becomes necessary which is performed by direct wound irrigation or therapeutic irrigation with suction(15).

The advantages of hydrotherapy comprise of detoxification (helps in elimination of waste), loosening tense muscles and assisting relaxation, enhancing metabolic rate, respiration and digestion activity and improving skin and muscle tone. In addition, it also boosts the immune system by its efficient functioning and also improves internal organs functioning by stimulating blood supply.

Hydrotherapy achieves its desired effects through the physical properties of water, temperature and agitation. It may be applied in its solid (ice), liquid or vapor (steam) state for health promotion or treatment of various diseases with various temperatures, pressure, duration and site.(16)

3.3. Physical Properties of Water in Relation With Hydrotherapy(16)

Water has the inherent following forces which play a role in the effects produced on the body from hydrotherapy:

1. Buoyancy
2. Pressure
3. Cohesion
4. Viscosity

1. Buoyancy:

The most important principle is *Archimede's principle* of buoyancy. This principle state that a body immersed in a liquid experiences an upward force equal to the weight of the displaced liquid. Thus, the body will appear to weigh less in water than in air.

Buoyancy may be affected by:

- The postural alignment.
- The surface area immersed.
- The weight of the bones in relationship to muscle and fat.
- The vital capacity.

The buoyancy of the water can be used to assist with exercise of the extremities and to minimize stress of joints and muscles. Work can be done in the opposite direction, against the assist of buoyancy, so that resistance to motion can be exerted.In addition, by varying the speed of exercise in water, the difficulty of exercise may be graded or changed.

- The principle of *relative density* is used to provide support of the body and its limb in the water.
- The *specific gravity* is the ratio of the weight of a volume of substance to the weight of an equal volume of water. The specific gravity of a body is approximately 0.974. Objects with a specific gravity less than 1.0 will float in water. The specific gravity of a body can be advantageous to exercise in water.

2. Pressure:

Water exerts a perpendicular pressure against the surface of the body. This *hydrostatic pressure* is the ratio of the magnitude of the force exerted by the fluid per body surface area. This pressure is dependent on the depth of the submerged part and the density of the liquid. Hydrostatic pressure increases as depth and density of the liquid increase. Therefore, motion is performed more easily near the surface of the water than at greater depths.

3. Cohesion:

Water molecules are cohesive; they have the tendency to attract each other. This results in an increase in viscosity of the medium, as compared to that of air, and an increase in resistance to range of motion.

4. Viscosity:

Viscosity is internal friction, the property of liquids that resist relative motion within it. The greater the speed of the liquid, the higher it's viscosity. Resistance to motion is also dependent on the shape of the body. The more streamlined the body or object, the less force is required to move it through the water. The larger or more spread out the object moving through water, the greater the resistance to motion. As discussed earlier, viscosity and pressure will play a role in *turbulence* created by the whirlpool agitation.

3.3.1.Water temperature:(16)

As seen in the previous points, water is applied for its thermal effect. We have to be aware of the temperature ranges. Water at 92F to 97F (33.5 to 35.5C) gives the sensation of being natural (neither hot nor cold).

Table 1: General classification of temperature – ranges

Very cold	34° – 55°F	1° – 13°C
Cold	55° – 65°F	13° – 18°C
Cool	65° – 80°F	18° – 27°C
Tepid	80° – 92°F	27° – 33.5°C
Neutral	92° – 96°F	33.5° – 35.5°C
Warm	96 °– 98°F	35.5° – 36.5°C
Hot	98° – 104°F	36.5° – 40°C
Very hot	104° – 115°F	40 °– 46°C

Factors that affect the results of hydrotherapy:

- Water temperature
- Difference between the skin and water temperature
- Methods of application
- Suddenness of application
- The extend of the surface covered
- The duration of treatment
- The frequency of treatment
- The weight, age, and general condition of the patient.

3.3.2. Methods of heat transfer(16)

- Conductive heat is the transfer of heat between two objects in contact, and at different temperatures, heat being transferred by conduction from the warmer object to the cooler one.
- Convective heat is the transfer of heat energy by means of convection currents which arise due to temperature and density differences in various parts of a fluid.
- Specific heat of a substance is the heat required per unit of mass to change the temperature one degree Celsius.It is expressed as a ratio of the amounts of heat required to raise the temperature of equal masses of the substance and water by the same amount. The value for water is taken as one.
- Thermal conductivity is the ability of a tissue to absorb heat and conduct in across the tissue.

1. **Heat Exchange by Conduction**:(16)

As heat is a form of energy motion, the transfer of heat on a molecular scale is affected by the transfer of kinetic energy during the collision of molecules.Conduction is the diffusion of this energy from one body to another. Conduction is an exchange of thermal energy in which there is physical contact between two surfaces. If the water temperature is higher than the skin temperature, heat will be conducted to the skin and the temperature will rise. When an object is heated by a source in contact with it, the speed at which the

heat will flow will and cause a rise in temperature will depend upon the thermal conductivity of the source and substance. The thermal conductivity of water is greater than that of fat.

Tissues with high water content will conduct faster than tissues with low water content. The specific heat of the tissue will also govern the amount of heat needed to raise temperature by any particular amount. Fat has a specific heat of only 0.6 and can therefore be heated with less expenditure of energy than of water (specific heat = 1.0).Since fat acts more as an insulator, than as a conductor, it has a tendency to hold heat in or to keep it out.

This point is important for two reasons:

- The effect of superficial heating by conduction will be lessened as the body fat composition increases.
- Higher body fat content compromises the body's ability to dissipate heat, which may cause an increase in body-core temperature to dangerous levels.

With the obese person, therefore, superficial heating with the whirlpool may not achieve the intended effects. Caution must be taken when a large body surface area is immersed; the person may not be able to dissipate internal heat and maintain a proper core temperature. This may present a dangerous situation, requiring other methods of heat loss, such as evaporation and convection, to work overtime causing dehydration and increased cardiac output. A particular

patient’s medical condition may not tolerate this situation, such as a patient with cardiac or peripheral vascular diseases.

Sources of conductive heating include:

- Solids- mud and peat packs, and electric heating pads;
- Liquids- thermal water baths, and contrast baths, hot packs, paraffin wax.
- Gasses- hot air, hot vapor baths.

2. **Heat Transfer by Convection**(16)

Convection which occurs when a portion of the fluid moves from one place to another is a more rapid process of thermal energy exchange than conduction. Energy transfer by convection occurs when the patient is moving in the water or when the water swirls across the skin surface. Convection plays an important role in heating or cooling tissues, as well as in dissipating or retaining body heat.Convection occurs between the core and the shell of the body. Surface body heat can be carried by the venous blood toward the core, thus potentially increasing the core temperature.

Conversely, convection will help with heat dissipation by carrying heat away from areas of the body that are being heated. This method of heat transfer is compromised when the patient has cardiovascular or peripheral vascular disease. In this case, heating an entire extremity or full body may create dangerous overheating because the extremity or body is unable to dissipate heat from the treated area to maintain tissue temperature at safe levels.

These two methods of heat transfer are used to transport heat in either direction in the body. Two other methods of heat transfer, radiation and evaporation, help to dissipate heat from the body during or following a hydrotherapy treatment. Evaporation occurs through the loss of fluid from sweating and by the pulmonary system during exhalation. Any disturbance with the autonomic nervous system or pulmonary system's functions may interfere with loss of heat by evaporation. Therefore, when administering hydrotherapy, sufficient body surface must be exposed to the air to allow heat loss. Otherwise water temperatures must be kept below a body temperature between 33.3°C and 36.6°C.

Heat loss is affected by:

- The medical condition of the patient and his/her ability to cope with heat.
- The environmental factors of humidity and temperature.

If either humidity and /or ambient room temperature are too high, the body will have great difficulty with heat loss. On the other hand, should the ambient temperature be too low and the area dry, heat loss may occur to a greater extent than needed causing a chill. Therefore, muscle and joint stiffness secondary to the reduction in peripheral circulation could occur. Strong consideration should always be given to the design and environment of the hydrotherapy area.

3.4. BIOPHYSIOLOGICAL EFFECT OF WATER(16)

The health effects of hydrotherapy generally appear as thermal, mechanical, and chemical effects, either alone or as mixed effects.

Thermal Effects

- One of the principal reasons for using hydrotherapy is to gain the therapeutic value of heat or cold. As with hydrotherapy, a larger body surface is usually immersed in water, the exposure of the body to varying temperatures will have not only a local effect but also systemic effects on the cardiovascular and other organs systems. The greater the difference in temperature between the water and skin, the more intense the reaction is.

- Cold application to the whole body decreases the heart rate and lengthens diastole. The tone of the cardiac muscle is enhanced, and blood pressure is raised, as a result of peripheral vasoconstriction. The increase in peripheral resistance requires the heart to work harder to maintain adequate blood flow to the periphery.
- The application of heat to the entire body will cause an initial increase in blood pressure, followed by a decrease in blood pressure as a result of vasodilatation. The initial rise in blood pressure may be quite marked and prolonged if the temperature of the bath is very high, above 40°C.
- Respiratory rate will increase with the application of heat or cold, although the increase might be less marked with the application of heat.

- In addition sweating will increase; the amount is dependent on the temperature, the size of body surface exposed, and the length of treatment.
- Whether the use of hydrotherapy bath increases diuresis remains controversial, but diuresis is affected by the hydrostatic pressure, which increases with the depth of immersion.

Cold Water Effects:(16)

- Short application of cold water has a stimulating effect and results in peripheral vasoconstriction, pallor of the skin, chilliness, increased muscle tone, increased pulse rate, increased respiratory rate, rise in blood pressure and involuntary shivering, which in turn is responsible for more heat production in the body.
- Removal from water results in peripheral vasodilatation, redness of the skin, a feeling of warmth, a decrease of blood pressure, relaxation and a decrease in pulse and respiratory rate.

Hot Water Effects:(16)

Local application of mild heat has a sedative effect upon irritating conditions and in cramps and spasms. Heat applied to a large portion of the body in sufficient dosage results in an increase in body temperature and general physiologic changes.

- There is an increase of the circulatory rate and metabolism.

- A rise in blood volume and oxygen consumption and a change in the pH of urine, blood and sweat to the alkaline side.

Clinical Effects of Mild General Body Heating:(16)

- Increased heat elimination and perspiration.
- Increased circulation.
- A rise of the pulse rate in the ratio of about 10 beats for every degree Fahrenheit, just as in fever.
- A lowering of blood pressure in contrast to the effects of cold.
- Increased elimination through the kidneys.
- Increased respiration.
- Loss of water, salt, urea and other nitrogenous substances with a relative excess of alkali remaining in the blood and the tissues.
- A temporary loss of body weight.
- General nervous sensibility is markedly lessened.

Psychological Effects:

The smallest amount of voluntary motion which might not be possible in air helps the patient retain a “body image” of movement and gives him/her the hope of one day moving the part without the help of water(16).

3.5. Effects of Hydrotherapy on human body:

3.5.1. General effects of Hydrotherapy

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(17).

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%(16).

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(16).

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. 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)(16).

Regular winter swimming significantly decreased tension, fatigue, memory, and mood negative state points with the duration of swimming period; significantly increased vigour-activity scores; relieved pain who suffered from rheumatism, fibromyalgia, or asthma; and improved general well-being in swimmers(18).

3.5.2. Effect of Hydrotherapy Techniques on Temperature Regulation:

Rectal temperature has been reported to increase by about 1.0°C in 30 min in heat-adapted individuals in Finnish saunas with air temperatures of 80°C (Leppaluotoet al. 1986). As air temperatures are typically in the range 80–100°C in Finnish saunas, the rectal temperature ranges from 1.0 to 1.5°C in

individual's sauna bathing for > 19 min per session(19). Whole body immersion in moderately cold water is effective cooling manoeuvre 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(20). Significant less BT variability and an overall higher BT were observed in late preterm infants following tub bathing procedure(21).

Exercising while submerged in warm water lowers the heart rate and enhances thermoregulatory responses, thereby prolonging the PWSCI's ability to exercise and thus increasing their aerobic capacity(22).

3.5.3. Effect of hydrotherapy Modalities on respiratory system:

WI up-to shoulder levels at different temperatures (25°C, 34°C, and 40°C) showed increased MR, oxygen (O_2) consumption (VO_2) only at 25°C. Two main factors affecting O_2 transport during immersion are temperature and hydrostatic pressure. O_2 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_2 transport is altered. At any of the temperatures tested, the pulmonary tissue volume and arterial blood gases were not significantly affected(18).

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(23).

CWI was associated with increase in respiratory minute volume and decrease in end tidal CO_2 partial pressure(24). 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(25).

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(26). Inhaling hot air while in a sauna produced no significant impact on overall symptom severity of common cold(27). 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(28).

Among various techniques of hydrotherapy, the arm bath and foot bath are used to treat both local and systemic illness. The arm and foot bath is used in pulmonary congestion, chronic bronchitis and chronic pneumonia(29). A hot foot and arm bath which is used as a treatment of choice in naturopathy along with cold chest pack for bronchial asthma is believed to reduce pulmonary

congestion, decrease pulmonary mucus membrane irritation and increase the depth of respiration(30).

A study evaluated the usefulness of Naturopathy intervention (a combination treatments including massage, hydrotherapy, color therapy, fasting and diet therapy, mud application and yoga therapy) in bronchial asthma patients. The results suggested that there was a significant improvement in PEFR, VC(vital capacity), FVC, FEV1, MVV (Maximum Voluntary Ventilation) and absolute eosinophil count. The patients reported a feeling of wellbeing, freshness and comfortable breathing. Hence it was concluded that Naturopathy and yoga helps in inducing positive health, alleviating the symptoms of disease by acting at physical and mental levels(31).A study reported that Hydrotherapy has positive effect on increasing muscle strength, peak expiratory flow and muscular endurance in individuals with Down syndrome(32).

A study reported that when a person is submersed in water, the hydrostatic pressure against the body increases, thereby decreasing their lung volume(33). Becker etal reported that the patient's vital capacity is reduced by 6% – 9% because of compression by external hydrostatic pressure which counteracts inspiratory muscle action. Energy expenditure at rest increases by 60% during neck-level submersion which in turn enhances inspiratory muscle strength and endurance, serving as an effective respiratory rehabilitative exercise medium

able to counteract respiratory diseases. Pachalski and Mekraskiet al reported that PWSCI gained a greater cardiorespiratory fitness improvement by following an aquatic exercise programme as compared to land-based exercises. An another study reported that respiratory muscle rehabilitation conditioning programmes increase the expiratory muscle strength, vital capacity and residual volumes of PWSCI(34).

A study concluded that when a person is submerged in water, blood is displaced towards the heart, thereby enhancing central venous return, which in turn increases arterial and ventricular filling and results in a subsequent decrease in heart rate. There is a significant increase in end-diastolic volume, producing a larger stroke volume. During aquatic exercising, maximal oxygen consumption is greater than that of land-based exercise, allowing for greater energy expenditure at slower speeds and prolonged activity. During neck-level submersion, there is a decrease in sympathetic nervous activity which reduces peripheral resistances, thereby allowing greater venous return. Stevens and Morgan et al reported that habitual underwater treadmill walking reduces PWSCI heart rate, suggesting enhanced cardiorespiratory function(13).

Bunt et al. explained that warm water immersion may reduce the progress of vascular pathologic changes, such as atherosclerosis. Furthermore, warm water immersion increased oxy-hemoglobin levels to improve tissue oxygenation, and also contributed to an improved short-term brain function by increasing the levels of substances involved in brain-cell genesis(35).

Wijayanto et al. explained that the improvement of blood flow rate by warm water immersion therapy can, in turn, improve the function of important organs such as the brain by facilitating the transport of substances in the blood(35). In other articles, partial immersion applied to elderly subjects was found to be effective in partially improving the quantity and quality of sleep(36).

In conclusion, the physiological changes induced by warm water immersion, such as vasodilation, increased blood flow, reduction of arterial stiffness, vascular endothelial function, oxygenation, and decreased sleep-related stress, may result in improvements in the cardiovascular function. These physiological changes due to water immersion are similar to the cardiovascular effects of physical activity(37). Exercise has a variety of effects, particularly the improvement of cardiovascular function, increased cardiac output, decreased atherosclerotic plaque formation, decreased vascular resistance, increased organ perfusion, improved insulin-sensitivity, increased oxygen carrying capacity, and improved plasma lipid profile(30).

3.6. ANATOMY AND PHYSIOLOGY OF THE RESPIRATORY SYSTEM

3.6.1Anatomy of the Respiratory System(38)

The respiratory system consists of the respiratory tract, the chest wall (with the diaphragm and intercostal muscles), bronchial circulation, the

pulmonary circulation and central nervous system. The respiratory tract consist of the upper and lower respiratory tracts. The upper respiratory tract consists of the nose, oral cavity, pharynx and the larynx. The lower respiratory tract consists of the tracheobronchial tree, right and left lung. The tracheobronchial tree consists of series of branching airways commonly known as generations or orders of bronchioles. These airways progressively becomes narrower and shorter and more numerous as they branch throughout the lungs. After a total of about 23 divisions, the bronchioles end at alveolar ducts. Each alveolar duct ends in clusters of alveoli (alveolar sac).

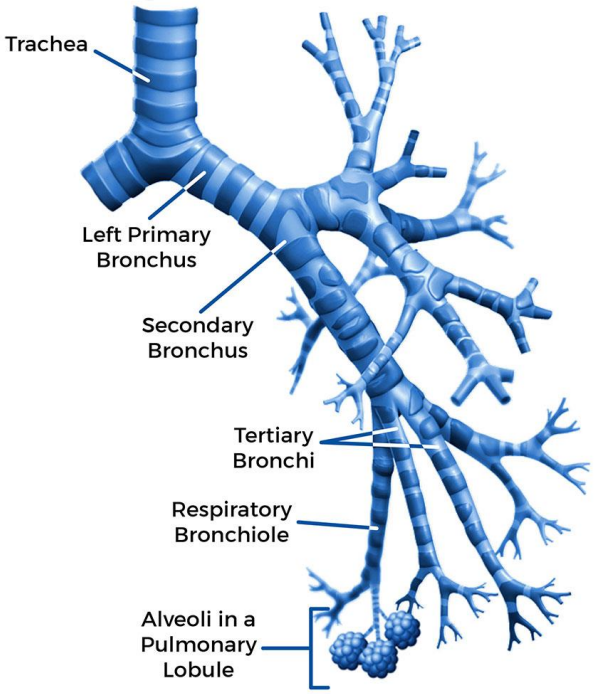


Figure 1: Bronchial Tree

Blood Supply:

The lung is supplied by Bronchial arteries and Pulmonary arteries. Bronchial artery arises from the aorta and follows the tracheobronchial tree as far as the terminal bronchioles. Beyond the terminal bronchioles, the bronchial arteries lose their identity and merge with the pulmonary arteries and capillaries, which are part of the pulmonary vascular system.

Pulmonary circulation is involved in cardiac output and oxygenation of the blood. These blood vessels in turn branch into smaller units, ending with capillaries, which are in direct contact with each alveolus (Respiratory Unit). Gas exchange occurs through the alveolar membrane. The air we breathe contents oxygen, carbon dioxide and nitrogen. Oxygen moves from the alveoli into the blood stream in exchange for carbon dioxide which moves out of the bloodstreams into the alveoli. The alveoli have a surface area, for gas exchange, that is equivalent to the size of a tennis court.

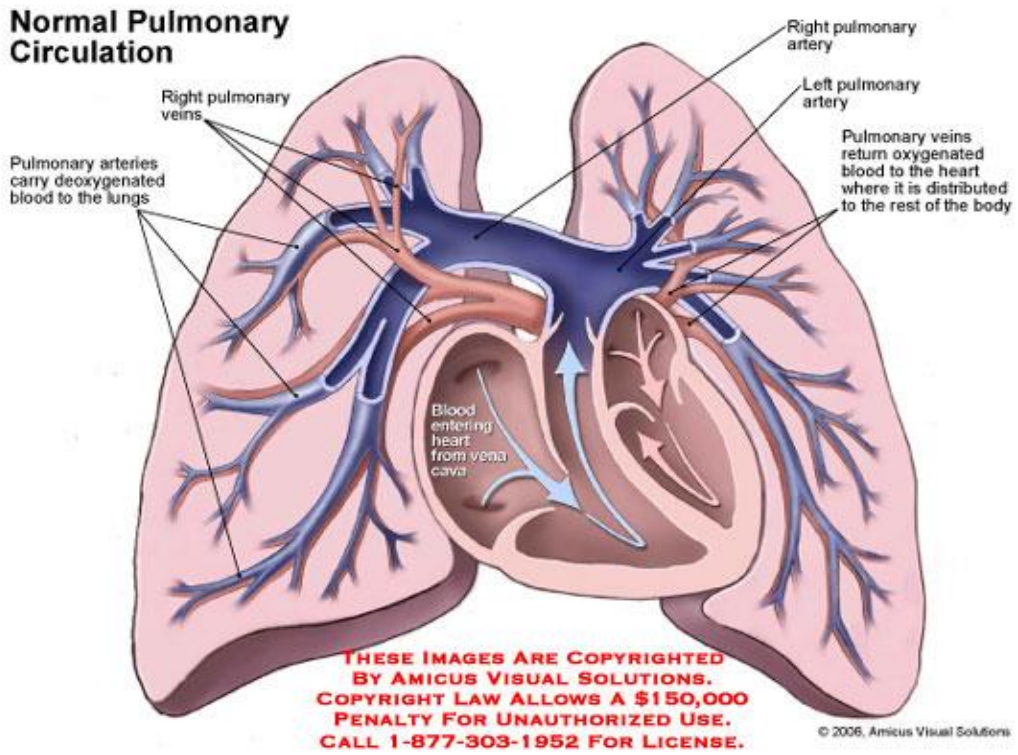


Figure 2: Pulmonary circulation

3.6.2. Physiology of the Respiratory System(38).

The main function of the respiratory tract is the exchange of gases (oxygen from the air is exchanged with carbon dioxide in the blood). If there is any change in the anatomy or physiology of the respiratory tract, there will disturbance (changes) in respiratory function i.e exchange of gases. The respiratory function is affected at three levels:

The disturbance can occur due to

1. Disturbance of ventilatory function,
2. Disturbance of pulmonary circulation
3. Disturbance at gas exchange level.

1. MECHANICS OF BREATHING:

INSPIRATION:

Inspiration is the active part of the breathing process, which is initiated by the respiratory control centre in medulla oblongata (Brain stem). Activation of medulla causes a contraction of the diaphragm and intercostal muscles leading to an expansion of thoracic cavity and a decrease in the pleural space pressure. The diaphragm is a dome-shaped structure that separates thethoracic and abdominal cavities and is the most important muscle of inspiration.

When it contracts, it moves downward and because it is attached to the lower ribs it also rotates the ribs toward the horizontal plane, and thereby further expands the chest cavity. In normal quite breathing the diaphragm moves downward about 1 cm but on forced inspiration/expiration total movement could be up to 10cm. When it is paralysed it moves to the opposite direction (upwards) with inspiration, paradoxical movement.

The external intercostal muscles connect adjacent ribs. When they contract the ribs are pulled upward and forward causing further increase in the volume of the thoracic cavity. As a result fresh air flows along the branching airways into the alveoli until the alveolar pressure equals to the pressure at the airway opening.

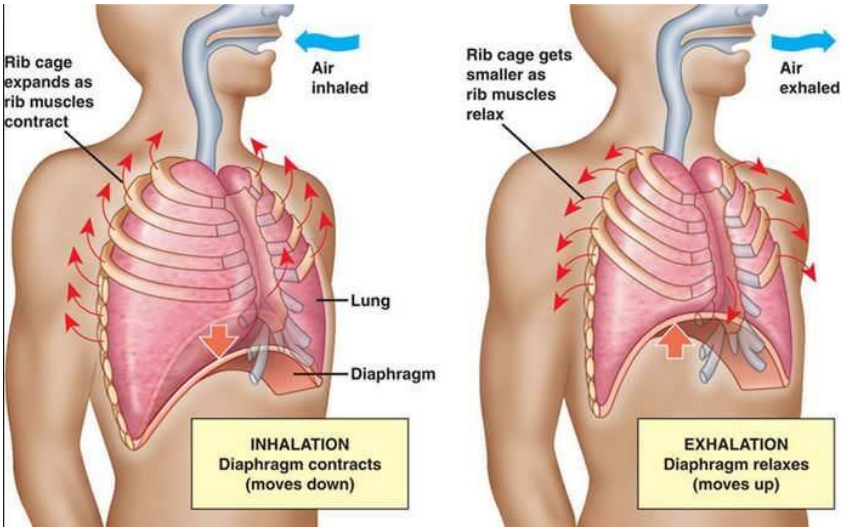


Figure 3: Mechanism of breathing

EXPIRATION:

Expiration is a passive event due to elastic recoil of the lungs. However, when a great deal of air has to be removed quickly, as in exercise, or when the airways narrow excessively during expiration, as in asthma, the internal intercostal muscles and the anterior abdominal muscles contract and accelerate expiration by raising pleural pressure.

COUPLING OF THE LUNGS AND THE CHEST WALL:

The lungs are not directly attached to the chest wall but they change their volume and shape according to the changes in shape and volume of the thoracic cavity. Pleura covering the surfaces of the lungs (visceral) or the thoracic cavity (parietal) together with a thin (20 μm) layer of liquid between them create a liquid coupling.

2. REGULATION AND CONTROL OF BREATHING:

In order to maintain normal levels of partial oxygen and carbon dioxide pressure both the depth and rate of breathing are precisely regulated. Basic elements of the respiratory control system are

(1) Strategically placed sensors

(2) Central controller

(3) Respiratory muscles.

SENSORS:

1.Mechanoreceptors:

These receptors are placed in the walls of bronchi and bronchioles of the lung and the main function of these receptors is to prevent the overinflation of the lungs.

Inflation of the lungs activates these receptors and activation of the stretch receptors in turn inhibits the neurones in inspiratory centre via vagus nerve. When the expiration starts activation of the stretch receptors gradually ceases allowing neurones in the inspiratory neurones become active again. This phenomenon is called Hering-Breuer Reflex. It is particularly important for infants. In adults it is functional only during exercise when the tidal volume is larger than normal.

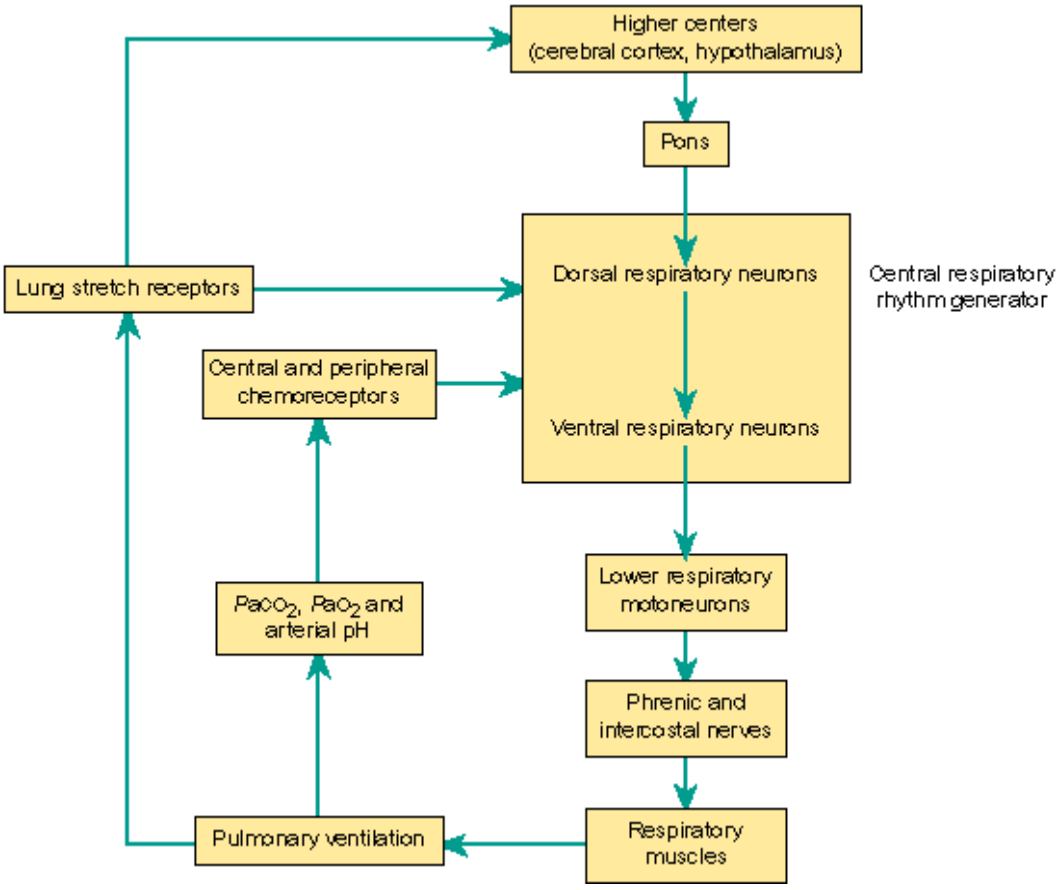


Figure 4: Regulation of breathing

2.Chemoreceptors:

The respiratory system maintains concentrations of O2, CO2 and the pH of the body fluids within the normal range of values. Any deviation from these values has a markedinfluence on the respiration. Chemoreceptors are specialised neurones activated by changes in O2 or CO2 levels in the blood and the brain tissue, respectively. They are involved in the regulation of respiration according to the changes in PO2 and pH. O2-sensitive chemoreceptors (Peripheral chemoreceptors) are located at the bifurcation of the carotid artery in the neck and the aortic arch. They are small vascular sensory organs encapsulated with the connective tissue. They are connected to the respiratory centre in the

medulla by glossopharingeal nerve (carotid body chemoreceptors) and the vagus nerve (aortic body).

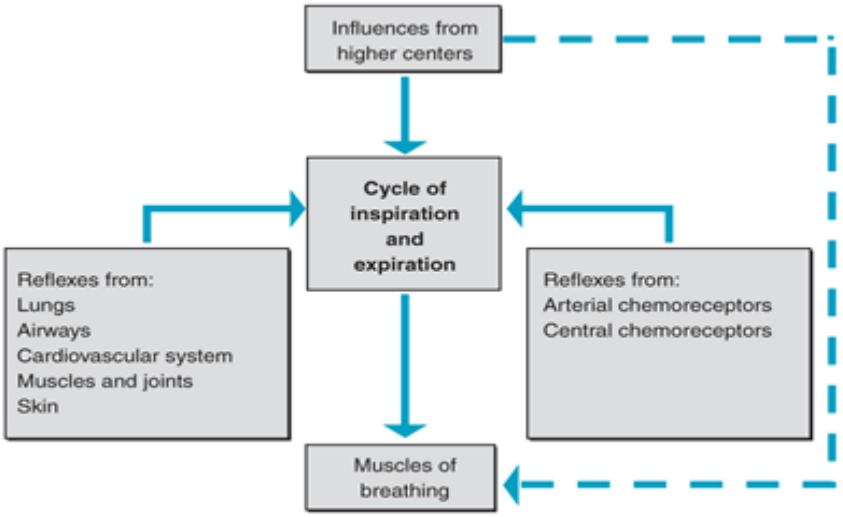


Figure 5: Control of breathing

Central chemoreceptors are located bilaterally in the chemosensitive area of the medulla oblongata and exposed to the cerebrospinal fluid (CSF), local blood flow and local metabolism. They actually respond to changes in H+ concentration in these compartments. When the blood partial PCO2 is increased CO2 diffuses into the CSF from cerebral vessels and liberates H+. (When CO2 combines with water forms carbonic acid and liberates H+ and HCO3-).

$$CO2 + H2O \leftrightarrow H2CO3$$

$$H2CO3 \leftrightarrow HCO\text{-}3 + H+$$

An increase in H+ stimulates chemoreceptors resulting in hyperventilation which in turn reduces PCO2in the blood and therefore in the CSF. Cerebral vasodilatation always accompanies an increased PCO2and enhances the diffusion of CO2 into the CSF. Because CSF has less protein than blood it has

amuch lower buffering capacity. As a result changes in pH for a given change in PCO2 is always biggerthan the change in blood.

CENTRAL CONTROLLER:

Breathing is mainly controlled at the level of brainstem. The normal automatic and periodic nature of breathing is triggered and controlled by the respiratory centres located in the pons and medulla. These centres are not located in a special nucleus or a group of nuclei but they are rather poor defined collection of neurones.

1. Medullary respiratory centre:

-Dorsal medullary respiratory neurones are associated with inspiration: It has been proposed that spontaneous intrinsic periodic firing of these neurones responsible for the basic rhythm of breathing. As a result, these neurones exhibit a cycle of activity that arises spontaneously every few seconds and establish the basic rhythm of the respiration. When the neurones are active their action potentials travel through reticulospinal tract in the spinal cord and phrenic and intercostal nerves and finally stimulate the respiratory muscles.

-Ventral medullary respiratory neurones are associated with expiration. These neurones are silent during quite breathing because expiration is a passive event following an active inspiration. However, they are activated during forced expiration when the rate and the depth of the respiration is increased e.g. exercise. During heavy breathing increased activity of the inspiratory centre neurones activates the expiratory system. In turn, the increased activity of the

expiratory system inhibits the inspiratory centre and stimulates muscles of expiration. The dorsal and ventral groups are bilaterally paired and there is 8 cross communication between them. As a consequence they behave in synchrony and the respiratory movements are symmetric.

2.Apneustic Centre:

It is located in the lower pons. Exact role of this centre in the normal breathing is not known. Lesions covering this area in the pons cause a pathologic respiratory rhythm with increased apnoea frequency. What is known is nerve impulses from the apneustic centre stimulate the inspiratory centre and without constant influence of this centre respiration becomes shallow and irregular.

3.Pneumotaxic centre:

It is located in the upper pons. This centre is a group of neurones that have an inhibitory effect on the both inspiratory and apneustic centres. It is probably responsible for thetermination of inspiration by inhibiting the activity of the dorsal medullar neurones. It primarily regulates the volume and secondarily the rate of the respiration. Because in the lesions of this area normal respiration is protected it is generally believed that upper pons is responsible for the fine-tuning of the respiratory rhythm. Hypoactivation of this centre causes prolonged deep inspirations and brief limited expirations by allowing the inspiration centre remain active longer than normal.Hyperactivation of this centre on the other hand results in shallow inspirations.

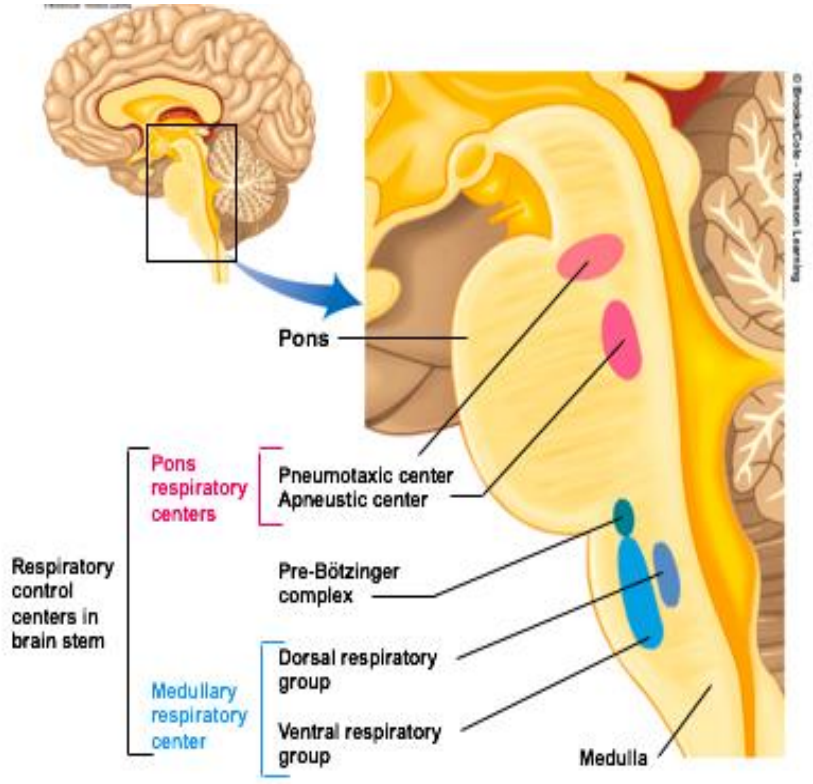


Figure 6: Higher centres of respiration

The apneustic and pneumotaxic centres function in co-ordination in order to provide a rhythmic respiratory cycle: Activation of the inspiratory centre stimulates the muscles of inspiration and also the pneumotaxic centre. Then the pneumotaxic centre inhibits both the apneustic and the inspiratory centres resulting in initiation of expiration. Spontaneous activity of the neurones in the inspiratory centre starts another similar cycle again. Breathing in some extent is also controlled consciously from higher brain centres (e.g. cerebral cortex).This control is required when we talk, cough and vomit. It is also possible voluntarily change the rate of the breathing.

Hyperventilation can decrease blood partial carbon dioxide pressure (PCO2) due to loss of CO2 resulting in peripheral vasodilatation and decrease in blood pressure. One can also stop breathing voluntarily.

That results in an increase in arterial partial oxygen pressure (PO2), which produces an urge to breathe. When eventually PCO2 reaches the high enough level it overrides the conscious influences from the cortex and stimulates the inspiratory system. If one holds his breath long enough to decrease PO2 to a very low level one may loose his consciousness.

In an unconscious person automatic control of the respiration takes over and the normal breathing resumes. Other parts of the brain (limbic system, hypothalamus) can also alter the breathing pattern e.g. affective states, strong emotions such as rage and fear. In addition, stimulation of touch, thermal and pain receptors can also stimulate the respiratory system.

RESPIRATORY MUSCLES:

Diaphragm, intercostal muscles and the other accessory respiratory muscles work in co-ordination for normal breathing under central controller. There is evidence suggesting that in premature new-born babies this co-ordination is not mature enough and this could be responsible for the sudden infant death syndrome.

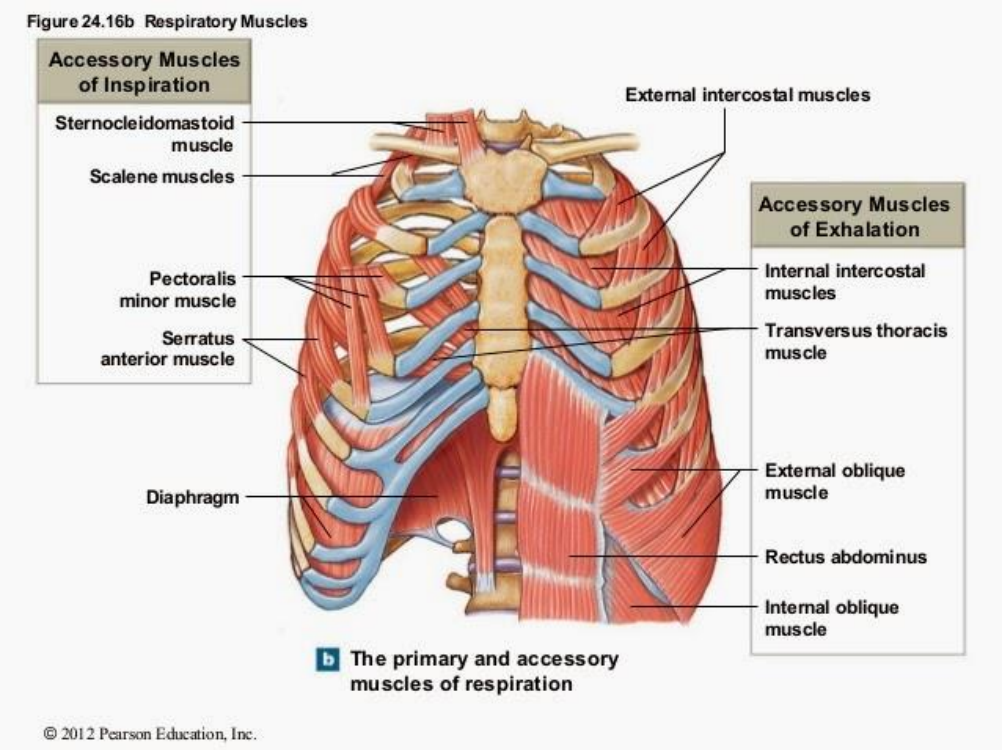


Figure :7 Muscles of respiration

3.6.3. Overview of the autonomic nervous system (39)

The autonomic nervous system (ANS) regulates physiologic processes. Regulation occurs without conscious control, i.e., autonomously. The 2 major divisions are the

- Sympathetic system
- Parasympathetic system

Anatomy

The ANS receives input from parts of the CNS that process and integrate stimuli from the body and external environment. These parts include the hypothalamus, nucleus of the solitary tract, reticular formation, amygdala, hippocampus, and olfactory cortex.

The sympathetic and parasympathetic systems each consist of 2 sets of nerve bodies:

- Preganglionic: This set is located in the CNS, with connections to another set in ganglia outside the CNS.
- Postganglionic: This set has efferent fibers that go from the ganglia to effector organs.

Sympathetic

- The preganglionic cell bodies of the sympathetic system are located in the intermediolateral horn of the spinal cord between T1 and L2 or L3.
- The sympathetic ganglia are adjacent to the spine and consist of the vertebral (sympathetic chain) and prevertebral ganglia, including the superior cervical, celiac, superior mesenteric, inferior mesenteric, and aorticorenal ganglia.

Long fibers run from these ganglia to effector organs, including the following:

- Smooth muscle of blood vessels, viscera, lungs, scalp (piloerector muscles), and pupils
- Heart
- Glands (sweat, salivary, and digestive)

Parasympathetic

The preganglionic cell bodies of the parasympathetic system are located in the brain stem and sacral portion of the spinal cord. Preganglionic fibers exit the brain stem with the 3rd, 7th, 9th, and 10th (vagus) cranial nerves and exit the spinal cord at S2 and S3; the vagus nerve contains about 75% of all parasympathetic fibers.

Parasympathetic ganglia (eg, ciliary, sphenopalatine, otic, pelvic, and vagal ganglia) are located within the effector organs, and postganglionic fibers are only 1 or 2 mm long. Thus, the parasympathetic system can produce specific, localized responses in effector organs, such as the following:

- Blood vessels of the head, neck, and thoracoabdominal viscera
- Lacrimal and salivary glands
- Smooth muscle of glands and viscera (eg, liver, spleen, colon, kidneys, bladder, genitals)
- Muscles of the pupil

Physiology

The autonomic nervous system controls BP, heart rate, body temperature, weight, digestion, metabolism, fluid and electrolyte balance, sweating, urination, defecation, sexual response, and other processes. Many organs are controlled primarily by either the sympathetic or parasympathetic system, although they may receive input from both; occasionally, functions are reciprocal (eg, sympathetic input increases heart rate; parasympathetic decreases it).

The **sympathetic nervous system** is catabolic; it activates fight-or-flight responses.

The **parasympathetic nervous system** is anabolic; it conserves and restores

Two major neurotransmitters in the ANS are

- **Acetylcholine:** Fibers that secrete acetylcholine (cholinergic fibers) include all preganglionic fibers, all postganglionic parasympathetic fibers, and some postganglionic sympathetic fibers (those that innervate piloerectors, sweat glands, and blood vessels).
- **Norepinephrine:** Fibers that secrete norepinephrine (adrenergic fibers) include most postganglionic sympathetic fibers. Sweat glands on the palms and soles also respond to adrenergic stimulation to some degree.

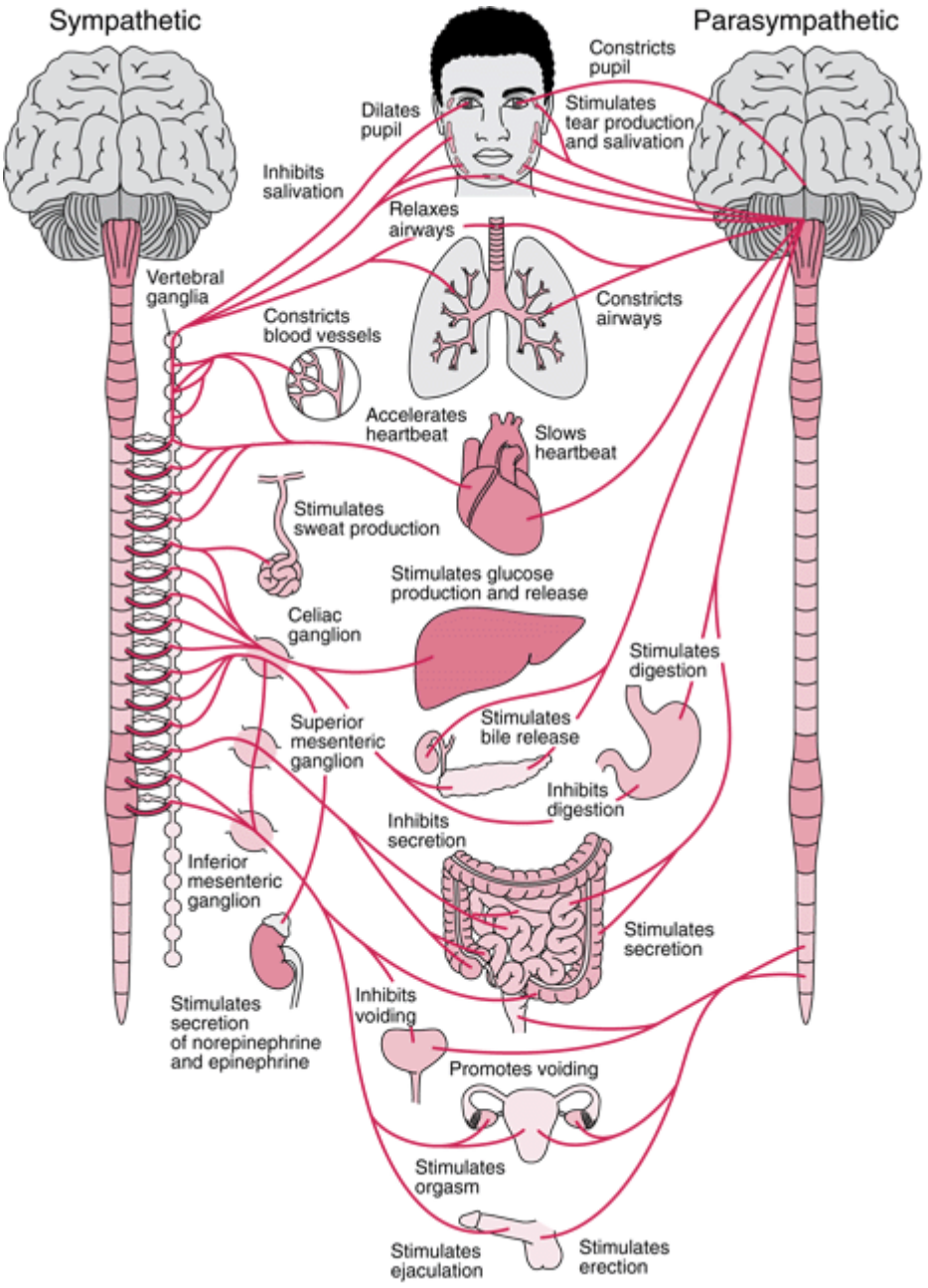


Figure -8: Autonomic nervous system

3.6.4. Thermoregulation and abnormal elevation of body temperature

Body temperature is closely regulated by homeostatic mechanisms that strike a balance between heat production and heat dissipation(40) Heat is a product of all metabolic processes and it is dissipated over the body surface. The skin accounts for about 90% of

heat loss, with the lungs contributing most of the remaining 10%. In the basal state, about 70% of the body's thermal load is dissipated by conduction; 30% is removed by the evaporation of insensible perspiration. Radiation and convection are less important mechanisms of heat removal. When the ambient temperature rises or metabolic heat production increases, evaporation accounts for the major share of heat dissipation (41)

In humans, controlling centre for thermoregulation is located in hypothalamus. Hypothalamus detects changes in the body´s thermal state directly from changes in blood temperature and indirectly by peripheral inputs from thermosensitive receptors located in the skin and in the muscles. (42)The preoptic nucleus of the anterior hypothalamus functions as the thermal control centre and acts to maintain the body temperature at a set value. Thus, it serves as so-called hypothalamic thermal set point.(43) Abnormal elevation of body temperature, or pyrexia, can occur as a result of hyperthermia or fever. In hyperthermia, thermal control mechanisms fail, so that heat production exceeds heat dissipation.

3.6.5. Breathing pattern and neural control in thermal stress

The body temperature changes are accompanied with marked alterations in breathing pattern. These changes are evoked by alterations in the peripheral temperature, or modified by shifts in the central body temperature, eventually by other mechanisms. Hyperpnoea associated with elevated core temperature was described for the first time by Haldane in 1905(44) and since then numerous studies have been focused on investigation of breathing control in elevated-body temperature conditions.

For many animals an elevation in body temperature enhances respiratory frequency but decreases inspiratory amplitude and its duration. The increase in respiration helps to cool the body and restore its temperature to a normal range. In fact, the temperature-dependent modulation of respiratory frequency (e.g. panting) is a major mechanism to dissipate heat and avoid heat-stroke. The scale is extensive as hyperventilation was shown to be mediated by increase output from structures of central nervous system, through increase in peripheral output from skin receptors, by increases in output of central or/and peripheral chemoreceptors or changes in their sensitivity and through changes in thermoregulatory mechanisms.(45)

Effects of the Autonomic Nervous System

Organ	Sympathetic	Parasympathetic
Heart	↑ rate, force	↓ rate
Blood Vessels	constriction	no effect
Lung Bronchi	dilated	constricted
Gut Lumen	↓ peristalsis	↑ peristalsis
Liver	↑ glucose	↑ glycogen
Kidney	↓ urine output	no effect
Appetite	decreased	no effect
Blood	↑ glucose, lipids	no effect
BMR	↑ up to 100%	no effect
Skeletal Muscle	↑ strength	no effect
Mental activity	increased	no effect
Fat cells	lipolysis	no effect
Pupil	dilated	constricted
Pancreas Glands	↑ secretion	↑↑↑ secretion

Figure-9: Effects of Autonomic nervous system

Sensors, centers and effectors involved in control of breathing. Several studies confirmed a crucial role of hypothalamus in modulating respiratory frequency with changes in body temperature.(46) In some species, a specialized breathing pattern known as panting is mediated by the thermoregulatory system in the preoptic area of the hypothalamus.

However, temperature can also directly affect the activity of the respiratory neural network located in the medulla, in sensitivity of central chemoreceptors and second, a change in the threshold of that response. Besides central mechanisms, elevated body temperature can evoke a change of breathing pattern also by peripheral feedback control or by a combination of both. Slowly adapting pulmonary stretch receptors and vagal afferent fibres from lungs play an important role in the regulation of respiration rate and tidal volume in mammals.(47)

Activation of pulmonary slowly adapting stretch receptors elicits Hering-Breuer reflex, that is defined by inhibition of inspiratory and prolongation of expiratory phases of respiratory cycle. Crucial importance of this reflex is to accomplish inspiratory to expiratory switching and to prevent over inflation of the lungs.(48)

4. METHODOLOGY:

4.1. Subject Selection:

- Healthy subjects are recruited from the general public and students of Arignar Anna Hospital of Indian Medicine & Homeopathy, Chennai – 106.
- Subjects who satisfied the following inclusion & exclusion criteria were recruited for the study.

4.1.1. Inclusion Criteria:

- Age group: 18 to 35 years
- All Genders
- Participants who signed the written consent form.
- Body mass index(kg/m^2): 18.5 to 28.0

4.1.2. Exclusion Criteria:

- Habits of tobacco chewing, smoking, alcoholism
- Any systemic diseases including respiratory tract infections within previous 6 weeks
- History of regular medication for any diseases, psychological disorder
- Regular practices of physical activity/ sports/ breathing practices at present and for past 6 weeks
- Women during pregnancy and lactation

4.1.3. Withdrawal Criteria:

- All subjects are free to withdraw from participation in the study at any time, for any reason, specified or unspecified, and without prejudice to further nature cure practices. Subjects who are withdrawn from the study will not be replaced.

4.2. Study design:

A randomized control trial study is adopted in this study.

4.2.1 Randomization:

Seventy potential subjects were screened initially based on the inclusion criteria. Among 70 subjects, sixty subjects who met the selection criteria were participated in the study. Subjects were assigned as two groups i.e., Study group (n=30) and Control group (n=30).

4.3. Ethical Consideration:

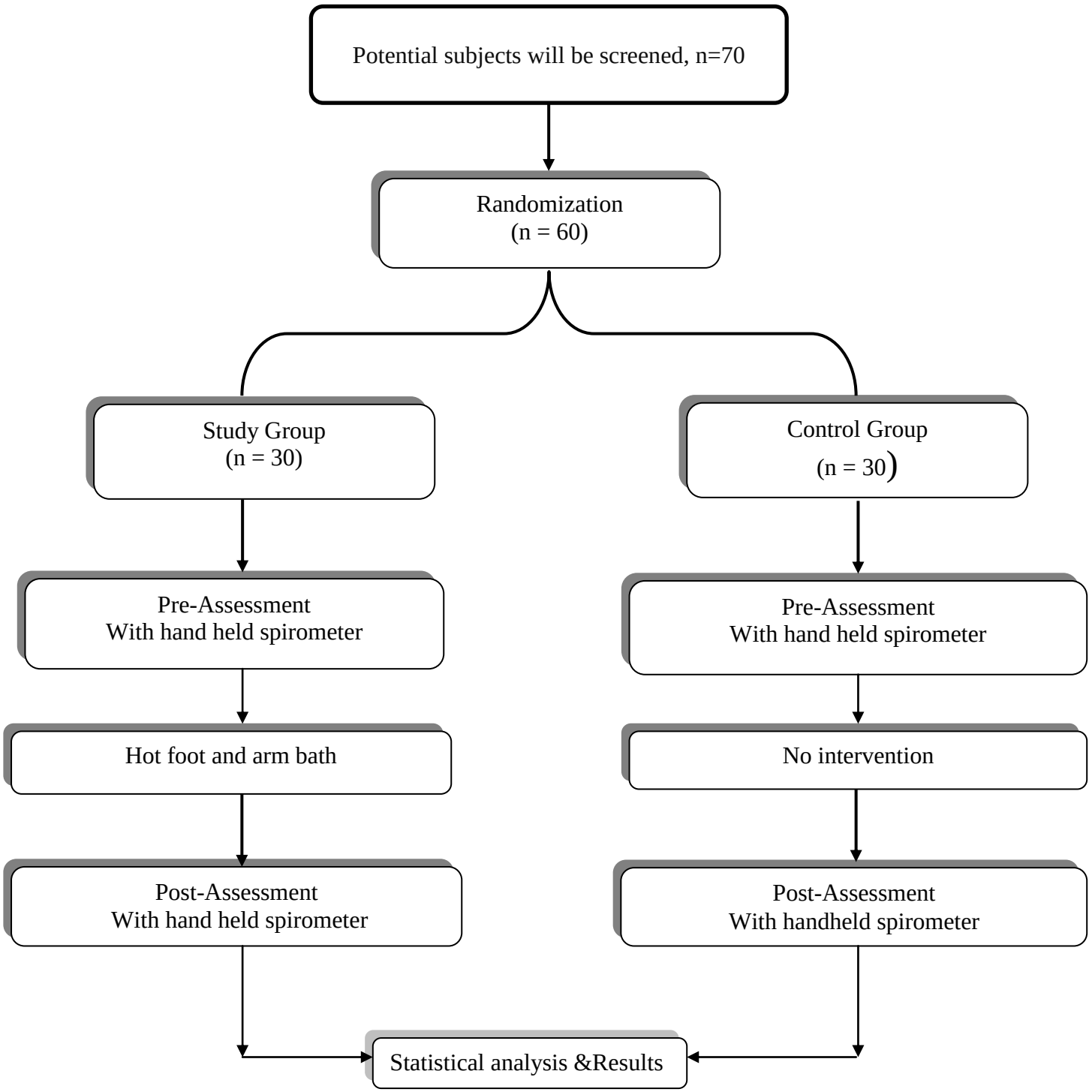
Subjects who full fill inclusion criteria were appraised about the purpose of the study and their rights as research subjects. Informed consent form was administered in local language i.e., Tamil and English as well. Adequate time was given to the participants to go through the information sheet and their queries were answered. Their rights to withdraw anytime from the study and the need for willingness to participate voluntarily in the study were explained. All the subjects expressed their willingness to participate in the study by giving a signed informed consent. (A sample information sheet and consent form is

enclosed as Annexure-1) Ethical clearance was obtained from the Institutional Ethical Committee prior to the start of the study and the approval for the same was granted.

4.4. Study setting:

The subjects were divided into two groups-study group and control group. The study group was given Hot Arm and Foot bath for 20 minutes. Whereas, control group received no intervention.

Figure-10: Illustration of the study plan



4.5. Assessments:

The baseline and post –intervention assessment was done for two groups- five minutes before and five minutes after the intervention.

4.5.1. Primary outcome variables:

Spirometry.(14)

Spirometer is an instrument which measures the volume of air that is contained in the lung and also the rate at which the gas is expelled from the lungs. Hence, the information that can be obtained by performing the spirometry is the Volume and Flow rate of gases.

Lung volume provides information on the size of different compartments of the lung; flow rate provide information on the rate of airflow within the airways. Spirometry is performed by using a spirometer. The tracings are called Spirograms. Spirometer Measures Lung Volumes and airflow rates.

The Essential Lung volumes that can be recorded with simple spirometry are:

FVC – Forced Vital Capacity:

The FVC is defined as the maximum volume of air which can be exhaled as forcefully and rapidly as possible after maximal inspiration.

Peak Expiratory Flow (PEF):

It is the maximum expiratory flow that is achieved from maximum forced expiration from the point of maximal inspiration. (Expressed in liters/seconds).

Forced expiratory volume in 1 second (FEV1):

Volume of air which can be forcefully expired out during the first expiration and is expressed in litres.

FEV_1/FVC%:

This is a calculated value. It is the Forced expiratory volume in 1 second, as a percentage of forced vital capacity. The ratio expresses the volume of air that the patient exhales in the first second, of the total volume of air that he/she exhales.

FEF 25-75% (Forced Expiratory Flow) or MMEF (Maximum Mid Expiratory Flow):

FEF (25-75%) is Forced expiratory flow during the middle half of the FVC. The $FEF_{25-75\%}$is defined as the average rate of flow during the middle two quarters of the forced expiratory effort, i.e., from 25% to 75% of the vital capacity.

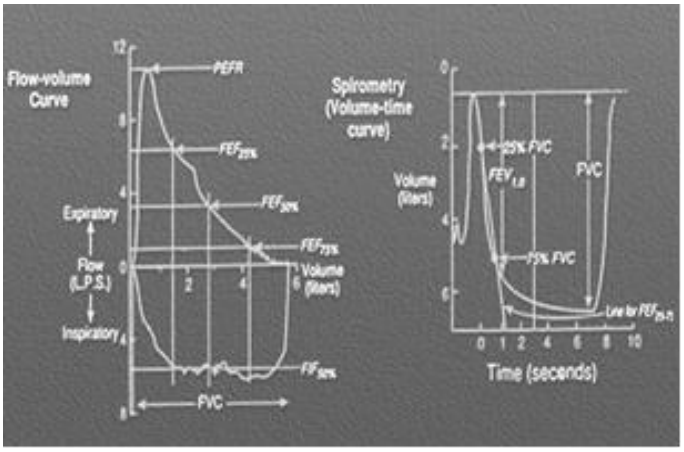


Figure-11: Lung volumes and capacities.

4.5.2. Technique for performing spirometry (breathing test)

Spiro metric tests require the subject to exhale as forcibly as possible after taking a full deep breath. This effort of the subject is called Forced Expiratory Effort (Maneuver).

Figure-12: Technique of Spirometry.

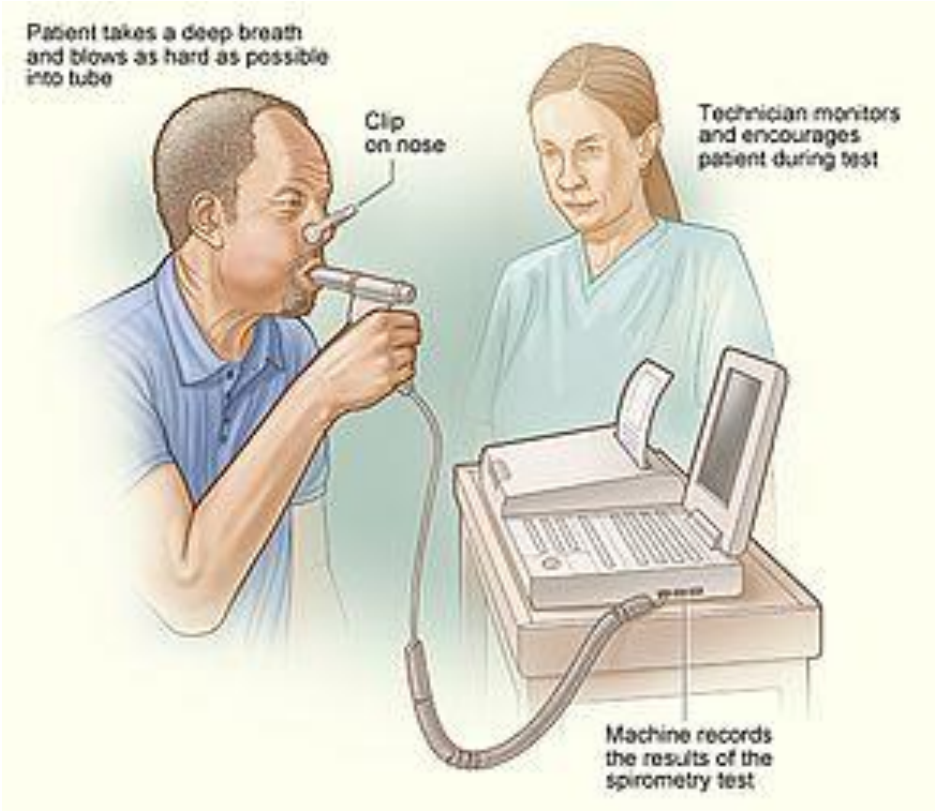


Figure-13: Spirometry

- **Proper positioning of mouth piece**

  Place the mouth piece about 1 inch deep inside the mouth. Bite the mouth piece with the teeth and make an air tight seal with the help of the lips. The tongue should not block the opening of the mouth piece. The mouth piece is connected to a tube which is connected to the spirometer.

Enter the subject's name, age, sex, height, weight and race in the computer.

1. **Get the confidence of the subject by talking to him/her in a pleasing manner.**

   a. Greet the subject by saying "hello"

   b. Explain to the subject the purpose of the test !

   "This is to measure the maximum amount of air that he/she can breathe in and out of the lungs and also to measure the speed (rate of flow) of air that goes in and out of the lungs, after taking in a deep breath"

2. **Precautions to be taken before doing a test by the subject**

   a. Do not smoke for one hour before test

   b. Do not drink alcohol within four hours of test

   c. Do not eat a large meal within two hours of test

   d. Do not perform vigorous exercise within 30 minutes of test

   e. Do not use drugs like salbutamol for atleast 4hrs prior to the test

   f. Do not perform if there are contraindications to conduct the test

   g. To avoid caffine containing products before the test

3. **Subject preparation:-**

    a. The subject has to remove any loose dentures, and also if there are light fitting dentures.

    b. Loosen tight clothing

    c. Nose clips may be applied

4. **Positioning**:-

    a. Position to perform the test. Upright posture to be maintained

Figure-14: Position of mouth for Spirometry.

- **Testing procedure**

As the subject to breaths in normally for 3 to 4 times, then asked to take a deep breath to fill the lungs as much as he/she can. When he/she reaches the total lung capacity immediately, asked to blowout continuously to a point till his/her lungs are almost empty. Then he/she can take a deep breath immediately without a gap. After the procedure mouth piece was removed[32]. The following spirometric measures were assessed with the use of digital spirometer (RMS Helios 401) such as forced vital capacity (FVC), Percentage of Forced expiratory volume in first second (FEV1%),forced expiratory flow $FEF_{25-75\%}$ and peak expiratory flow (PEF) expressed in liter/second; FVC maneuver was repeated at least thrice during each measurement and the highest of three acceptable readings were taken as the final value(8)

4.6. Intervention:

Study Group: The study group was given 20 minutes of Hot Arm and Foot bath.

Intervention procedure:

Hydrotherapy procedure was as follows. Subjects were instructed to drink a glass of tepid water and sit in an arm and foot bath by Immersing arms in arm bath and legs in foot bath tub. The temperature of the bath was maintained between 103°F and 110°F. A blanket was enveloped around the person and bath to prevent cool air from contact with skin and prevent

dissipation of heat from the bath. Simultaneously, wet compress placed over head. The duration of this arm and foot bath was for 20 min(9).

Figure-15: Arm and foot bath

Control group:

The control group besides doing their regular work schedule did not receive any intervention for the same period. They were instructed to sit simply without any disturbance.

4.7. Data Analysis:

4.7.1. Data Extraction:

The data was collected as self-reported observations using primary outcome variables. The assessment was done on the 5 minutes before the intervention (baseline data) and 5 minutes after the intervention (post data).the data was organized in Microsoft Excel sheets(Version 2010).

5. RESULTS

The data for the above study were statistically determined for FVC (Forced vital capacity), PEFR (peak expiratory flow rate), FEV_1 (Forced expiratory volume in 1 second) and FEV_1/FVC%. The following data for each subsets were expressed in Mean± SD. Parametric test had been used since the data fall on normal distribution ($P>0.05$). Comparison of Mean difference for inter group done by using unpaired *t* test and intra group difference was done by using paired *t* test. P value set as $P<0.05$ significant. R statistical software version 3.1.1 was used for the statistical analysis and Graph pad version 5 used for the graphical representation.

Table 2: - Anthropometric variables between the groups

Variable	Study group	Control group	P value
Height (cm)	154.4±13.88	152.87±10.34	0.45
Weight (kg)	56.24±4.12	58.34±10.15	0.88
BMI (kg/m^2)	22.10±1.90	21.8±2.12	0.71
Male/Female	10/20	8/22	0.22*

Note: Data expressed as Mean ±SD for continuous data and frequency (n) for categorical data. Unpaired t tests and Chi-square test (*) was done.P<0.05 set a significant.

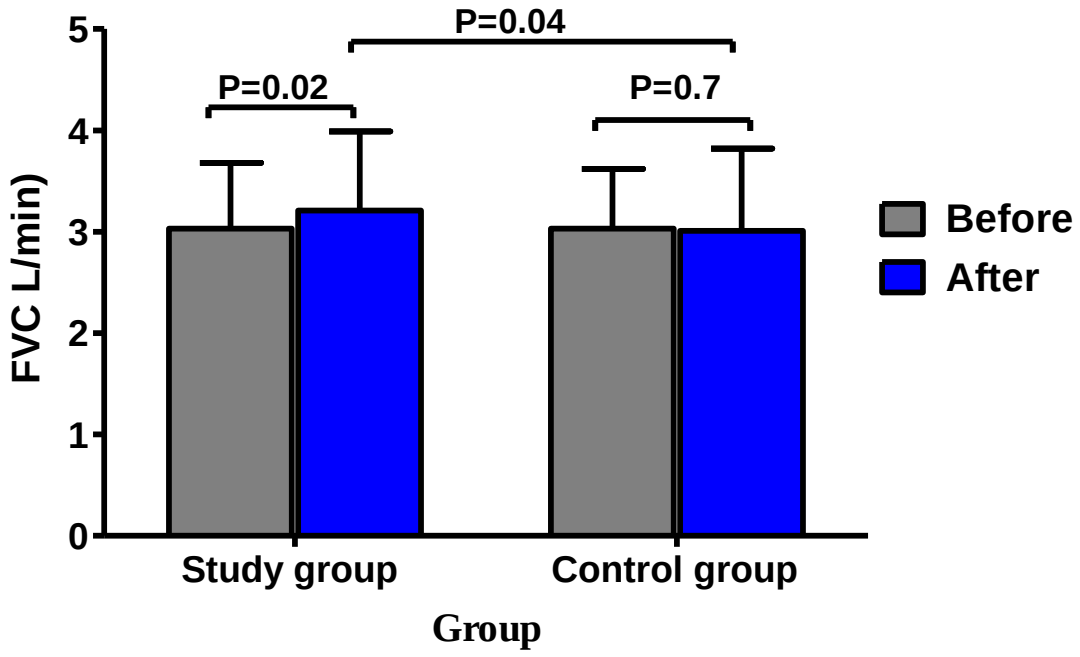
FVC (Forced vital capacity): Unpaired t testshowed thatthe study group (*p<0.002*) had significantly improved forced vital capacity than the control group.

Table 3: Effect of Hot Foot and Arm bath on Forced Vital capacity (FVC) parameter in between study group and control group.

variable	SG		p value	CG		P value
	Before	After		Before	After	
FVC(l/min)	3.03±0.65	3.21±0.78*	0.02	3.032±0.59	3.07±0.81	0.7

Note: *Data expressed as Mean ±SD. Paired and unpaired (*) t test was done to compare the mean difference. P<0.05 set as significant.*

Figure-16: Effect of Hot Foot and Arm bath on Forced Vital capacity (FVC) parameter in between study group and control group.



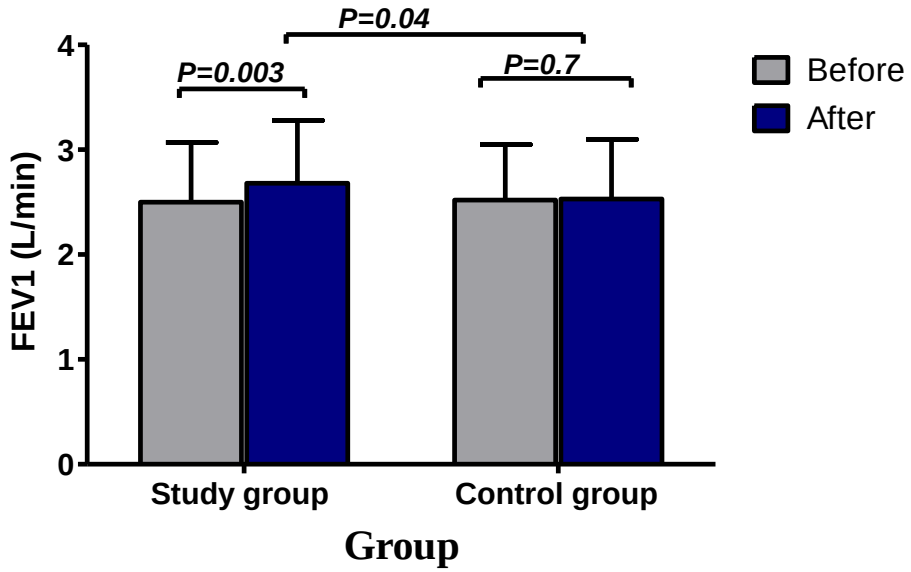
FEV_1 (Forced expiratory volume in 1 sec): Between group comparison, forced expiratory volume showed a significant changes , *(p<0.03)* in study group.(Table-)

Table-4: Effect of Hot Foot and Arm bath on Forced Expiratory Volume in 1 second (FEV1) parameter in between study group and control group.

Variables	**Study group**		P value	**Control group**		P value
	Before	**After**		**Before**	**After**	
FEV1(L/min)	2.50±0.57	2.68±0.60*	0.03	2.60±0.53	2.57±0.57	0.7

Data expressed as Mean ±SD. Paired and unpaired (*) t test was done to compare the mean difference. P<0.05 set as significant.

Figure-17: Effect of Hot Foot and Arm bath on Forced Expiratory Volume in 1 second (FEV1) parameter in between study group and control group.



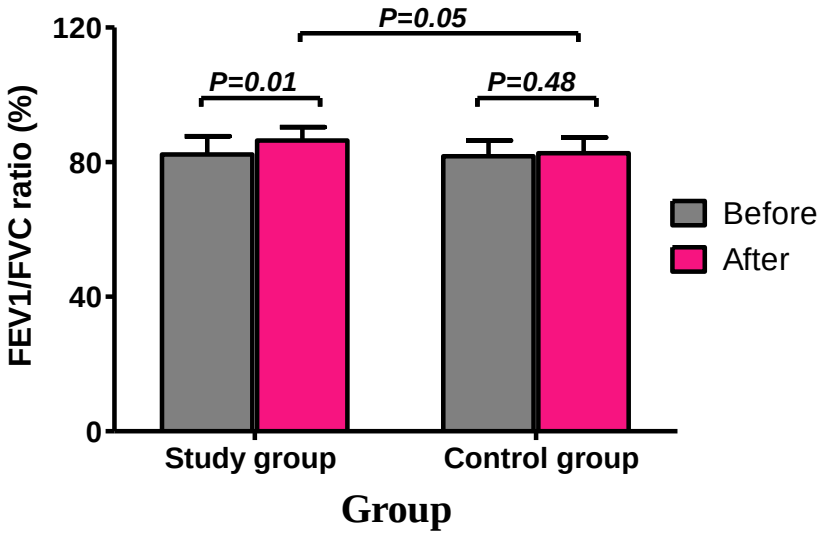
FEV_1/FVC%: There was a significant difference across the study group following FEV ratio *(p<0.01)* for both comparison.

Table-5: Effect of Hot Foot and Arm bath on Forced Expiratory Volume in 1 second (FEV1) / Forced Vital capacity (FVC) ratio in between study group and control group.

Variables	Study group		P value	Control group		P value
	Before	After		Before	After	
FEV1/FVC ratio	82.31±5.4	86.40±4.01*	0.01	81.80±4.6	82.67±4.64	0.48

Note: Data expressed as Mean ±SD. Paired and unpaired (*) t test was done to compare the mean difference. P<0.05 set as significant.

Figure-18: Effect of Hot Foot and Arm bath on Forced Expiratory Volume in 1 second (FEV1) / Forced Vital capacity (FVC) ratio in between study group and control group.



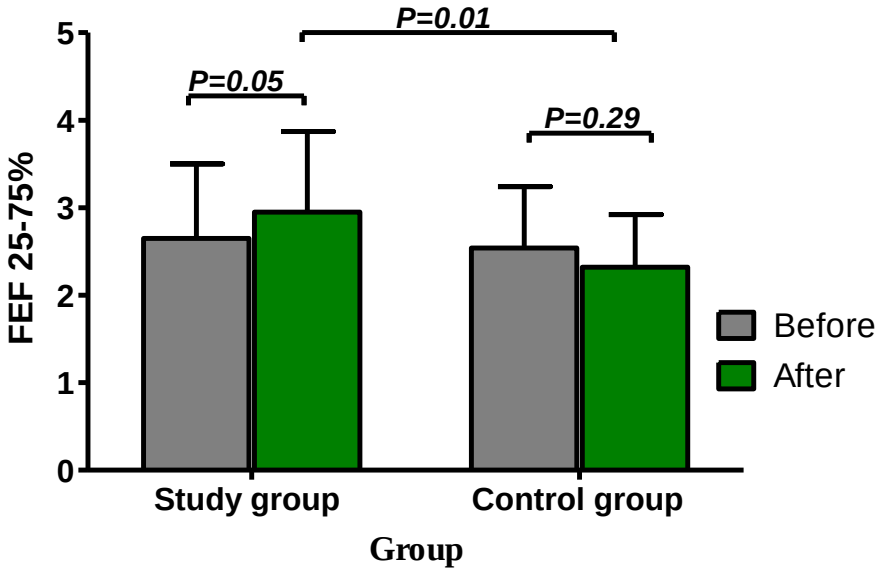
FEF 25-75 %: Compared to that of the control group, FEF 25-75% values are significantly higher in study group. ($p<0.05$, for both comparison)

Table-6: Effect of Hot Foot and Arm bath on Forced inspiratory flow *25–75%* (FEF 25-75%) in between study group and control group.

Variables	**Study group**		P value	**Control group**		P value
	Before	**After**		**Before**	**After**	
FEF 25-75%	2.65±0.85	2.95±0.92*	0.05	2.54±0.7	2.32±0.6	0.29

Note: Data expressed as Mean ±SD. Paired and unpaired (*) t test was done to compare the mean difference. P<0.05 set as significant.

Figure-19: Effect of Hot Foot and Arm bath on Forced inspiratory flow *25–75%* (FEF 25-75%) in between study group and control group.



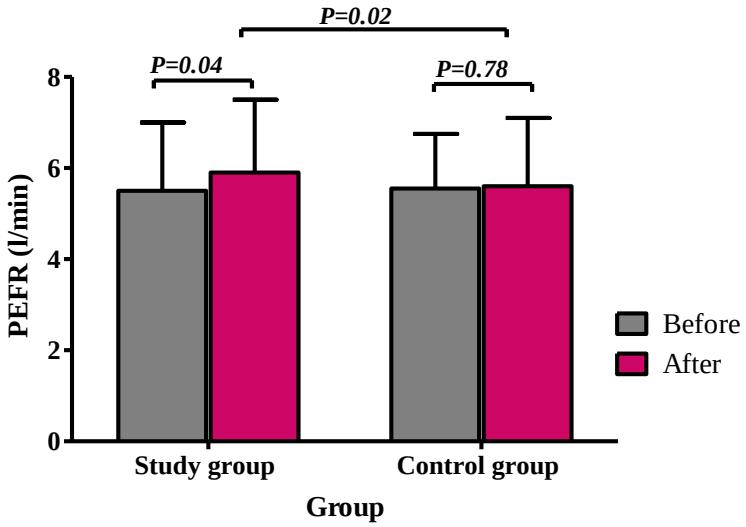
PEFR (Peak expiratory flow rate): when compared to control group, the study group shows significant difference *(p<0.04*) in peak expiratory flow rate.(Table-)

Table-7: Effect of Hot Foot and Arm bath on Peak Expiratory Flow Rate (PEFR) in between study group and control group.

Variables	Study group		P value	Control group		P value
	Before	**After**		**Before**	**After**	
PEFR (L/min)	5.50±1.5	5.90±1.6 *	0.04	5.55±1.2	5.60±1.5	0.78

Data expressed as Mean ±SD. Paired and unpaired (*) t test was done to compare the mean difference. P<0.05 set as significant.

Figure-20: Effect of Hot Foot and Arm bath on Peak Expiratory Flow Rate (PEFR) in between study group and control group



6. DISCUSSION

The present study results shows that immersion of all extremities to water in a temperature of 104^{O}f – 110^{0}f for 20 minutes has significant improvement in pulmonary function tests such as FVC, FEV_1, FEV_1/FVC % , FEV_{25-75}(Maximum mid expiratory flow) and PEFR. This indicates that there is some degree of Broncho-dilatation, which is leading to better oxygenation of the alveoli.

A study conducted by zila et.,al concluded that respiration and thermoregulation affects each other due to the influence of elevated body temperature .(49)

Another study reported that in humans, hyperthermia leads to activation of a set of thermoregulatory responses that includes cutaneous vasodilation and sweating. Hyperthermia also increases ventilation in humans, but the physiological significance and characteristics of the hyperventilatory response in humans remain unclear. Because hyperthermia causes hyperventilation, temperature input should be an important factor causing hyperthermia-induced hyperventilation in humans(50). Hence, for humans, maintaining body temperature represents an important homeostatic phenomenon and it can be greatly influenced by water immersion according to the water temperature.(51)

Thus, our study indicates that hot arm and foot bath may increases the body temperature which is influenced by sympathetic activation. It may leads to hyperthermic hyperventilation for shorter duration which is evident by significant changes in pulmonary function tests outcomes.

7. CONCLUSION

This study shows that immediate effect of hot arm and foot bath had improvements in Lung volumes and Lung capacities among healthy individuals. Based on this finding hot arm and foot bath for 20 minutes can be applied for respiratory disorders such as bronchial asthma, chronic obstructive pulmonary disease, Restrictive lung disease.

LIMITATIONS

1) The sample size is relatively smaller. Hence, generalizing the study outcome to a larger population would not be definitely conclusive.
2) Variables like Body Temperature, Blood Pressure, Respiratory Rate and Heart rate variation with respiration have not been used in our study.
3) All the subjects were healthy volunteers.

DIRECTION FOR FUTURE RESEARCH

1) This study should be replicated with a larger sample size.

2) Implementation of the therapy for the longitudinal follow up for clinical interpretation.

8. SUMMARY

Naturopathy is an art and science of healthy living and a drugless system of healing based on well-founded philosophy .It is a system of man building in harmony with the constructive principles of Nature on physical, mental, moral and spiritual planes of living. Hydrotherapy is one of the most important interventions in naturopathy. Water used at various temperatures enhances blood flow, which is thought to help dissipate all chemicals and facilitate muscle relaxation. The beneficial effects of water are being studied scientifically recent years. Among various techniques of hydrotherapy, the arm bath and foot bath are used to treat both local and systemic illness. Attempts are being made to understand the effects of arm and foot bath. Hence, the present study adopts an immediate approach in comparing the effect of hot arm and foot bath on lung volumes and capacities.

Two groups of 30 subjects each with age ranging from 18-35 years, belongs to both genders and healthy volunteers were recruited.the subjects of study grouphad hot arm and foot bath for 20 minutes and control group had to sit for 20 minutes. Subjects were assessed for Forced vital capacity, peak expiratory flow rate, FEV_1 (Forced expiratory volume in 1 second) and FEV_1/FVC%. at baseline

and immediately after 20 mins.

The data were found to be normally distributed across groups. Results were compared between the groups, whereas data was extracted at both baseline and post -intervention. Study group showed significant

improvements in Forced vital capacity, peak expiratory flow rate, FEV_1 (Forced expiratory volume in 1 second) and FEV_1/FVC%. Hence, the immediate effect of hot arm and foot bath by healthy volunteers has shown a positive influence on the lung volumes and capacities.

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ANNEXURE

Informed Consent Form

Title of the study: Immediate effect of Hot Arm and Foot Bath on pulmonary function in healthy individuals.

Name of the Participant: _____

Name of the Principal Investigator: Dr. D. Divya

Name of the Institution: Government Yoga & Naturopathy Medical College & Hospital, Chennai – 600 106

Documentation of the informed consent

I _____ have read the information in this form (or it has been read to me). I was free to ask any questions and they have been answered. I am over 18 years of age and, exercising my free power of choice, hereby give my consent to be included as a participant in the study titled, "Immediate effect of Hot Arm and Foot Bath on pulmonary function in healthy individuals"

1. I have read and understood this consent form and the information provided to me.
2. I have had the consent document explained to me.
3. I have been explained about the nature of the study.
4. I have been explained about my rights and responsibilities by the investigator.

5. I have been informed the investigator of all the treatments I am taking or have taken in the past _____ months including any native (alternative) treatment.

6. I have been advised about the risks associated with my participation in this study.

7. I agree to cooperate with the investigator and I will inform him/her immediately if I suffer unusual symptoms.

8. I am aware of the fact that I can opt out of the study at any time without having to give any reason and this will not affect my future treatment in this hospital.

9. I am also aware that the investigator may terminate my participation in the study at any time, for any reason, without my consent.

10. I hereby give permission to the investigators to release the information obtained from me as result of participation in this study to the sponsors, regulatory authorities, Govt. agencies, and IEC. I understand that they are publicly presented.

11. I have understood that my identity will be kept confidential if my data are publicly presented.

12. I have had my questions answered to my satisfaction.

13. I have decided to be in the research study.

I am aware that if I have any question during this study, I should contact the investigator. By signing this consent form I attest that the information given in this document has been clearly explained to me and understood by me, I will be given a copy of this consent document.

For adult participants:

Name and signature of the participant

Name _____ Signature_____

Date_____

Name and Signature of the investigator or his representative obtaining consent:

Name _____ Signature_____

Date_____

INFORMATION TO PARTICIPANTS

Investigator: Dr. D. Divya

Name of Participant:

Study title: Immediate effect of Hot Arm and Foot Bath on pulmonary function in healthy individuals

You are invited to take part in this research study. The information in this document is meant to help you decide whether or not to take part. Please feel free to ask if you have any queries or concerns. You are being asked to participate in this study being conducted in Government Yoga & Naturopathy Medical College & Hospital,Chennai – 600 106

The purpose of the researchstudy is to observe the immediate effect of Hot Arm and Foot Bath on pulmonary function in healthy individuals

Study Procedure:

Study group will drink a glass of cold water and sit in an arm and foot bath by immersing arms in arm bath tub and legs in foot bath tub. The temperature of the bath will be maintained between 103°F - 110°F. A blanket was enveloped around the

person and bath to prevent cool air from contact with skin and prevent dissipation of heat from the bath. The duration of this arm and foot bath was for 20 min.

Control group will not receive any intervention

Possible Risks to you: Nil

Possible benefits to you: Nil

Confidentiality of the information obtained from you

You have the right to confidentiality regarding the privacy of your medical information (personal details, results of physical examinations, investigations, and your medical history). By signing this document, you will be allowing the research team investigators, other study personnel, sponsors, IEC and any person or agency required by law to view your data, if required.

The information from this study, if published in scientific journals or presented at scientific meetings, will not reveal your identity.

How will your decision to not participate in the study affect you?

Your decisions to not to participate in this research study will not affect your studies or your relationship with investigator or the institution.

Can you decide to stop participating in the study once you start?

The participation in this research is purely voluntary and you have the right to withdraw from this study at any time during course of the study without giving any reasons.

However, it is advisable that you talk to the research team prior to stopping the participation.

The results of the study may be intimated to you at the end of the study period.

Signature of investigator Signature of participant

Date: