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Review Article

Effect of Various Pranayama Practices in Competitive Swimmers: A Review

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Abstract

Pranayama (yogic breathing) an essential component of Yoga, is said to influence both physiological and psychological aspects of humans. But its effectiveness in the field of sports especially in swimmers are less explored. The online databases were searched for the citations with "*Pranayama, Yogic Breathing, competitive swimmers, competitive swimming, nadishudi pranayama, bhastrika pranayama, ujjayi pranayama, Bhramari Pranayama and Kapalabhathi*" as keywords from the date of inception of the databases till October 2020. Experimental papers in English, revealing the effects of yogic breathing in competitive swimmers, effects of yogic breathing in lung capacity, lung function and psychological system and also papers showing the effect of pranayama on metabolic pathway were included in the review. The studies that had used yogic breathing in combination with other Yoga practices, studies in languages other than English, and whose abstracts were unavailable were excluded from the review. From the data gathered it was evident that pranayama has positive health effect and performance enhancement in competitive swimmers. Regular practice provides physiological and psychological wellbeing. Pranayama or yogic breathing act as a physiological stimulation. It has a multi-systemic effect in the human body. The rhythmic, slow and forceful inspiration and expiration in pranayama strengthen respiratory muscles, improve the expiratory power, and decrease resistance to the airflow in the lungs and increase voluntary breath holding time. Moreover, it brings sympathetic and parasympathetic nervous system into balance. This paper intends to explore the effect of a set of pranayama practice in competitive swimmers.

Keywords: Pranayama; Yogic breathing exercises; Lung capacity; Anxiety; Competitive swimmers; Swimming

Introduction

Swimming is self-propulsion of animal through water with coordinated movements of limbs, the body or both. It is usually practiced for recreation, sports, exercise or even for survival [1]. Humans have the ability to hold breath underwater and achieves rudimentary locomotive swimming within a few weeks of birth. Unlike land-based sports, more resistance is offered to swimmers due to the greater density of water than that of air [2]. Compared to other athletes' competitive swimmers are anticipated to have certain specific anthropometrical features [3].

Swimming is an activity that greatly requires physical strength and endurance. It is usually related to a large lung volume and comparatively a reduced flow of air. Even though it represents a physiological variant of normal pulmonary functions, it can indicate an obstructive abnormality as well [4]. Increased workload on the respiratory system in competitive swimming can induce respiratory muscle fatigue, which in turn can reduce swimming endurance, performance, and breathing frequency of the athletes [5]. Evidence from studies suggests that serum lactate which is a metabolic by-product of the glycolytic pathway is increased during swimming and it contributes to stiffness and soreness of the muscles [6]. Moreover, increased serum lactate levels are shown to influence stroke rate and distance covered per stroke [7].

It is also important to note that an increase in the pre-competitive stress is accompanied by increased anxiety. Anxiety is a multidimensional construct that refers to the willingness to respond to stress and a tendency to perceive stressful situations. The main stress factor for athletes is competition itself [8]. Research has shown the negative influence of somatic and cognitive anxiety on performance outcomes in sports. Certain characteristics can increase competitive anxiety in swimming competition. This includes an athlete's eye contact with his opponent before competition commences, hearing announcer pronouncing his name etc [9]. In the process of competitive stress, there is the perception of a substantial imbalance between the environmental demand and one's capability to respond to the demand. This imbalance is thought to have greater consequences on the outcome of sports. An increase organic stress just before the competition is said to reduce muscle and cognitive performance. Thus, somatic anxiety can result in diminished performance in swimmers [10].

The conventional method of competitive swimming involves inhalation through the mouth in a short time and exhalation through the nose while underwater, which helps to reduce the resistance caused by turning the head. However, increased duration of exhalation could intensify fatigue of the respiratory muscles and a reduction in blood flow and oxygen supply to other muscles in action [1].

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Human body requires energy to function. Energy is derived from food and the initial product of food conversion is Adenosine Triphosphate (ATP). It acts as an energy currency and is inevitable for cellular functions [11].

The body utilize three main pathways to produce the ATP that fuels muscle contraction and swimming performance. These systems are:

- Phosphocreatine system
- Anaerobic glycolysis system
- Aerobic system

Phosphocreatine (CP) system

This system uses creatine phosphate which produce ATP rapidly and is fundamental in promoting rapid resynthesis of ATP. The amount of CP and ATP stored in muscle is comparatively low, as a result there is a limited energy available for muscle contraction. Although it is the instantaneous form of energy available which is essential at the onset of activity, lasting about 1-30 sec in duration. This system fuels intense swimming lasting from 0 to 12 sec. ATP production is limited by amount of CP present in the muscles [12,13].

Anaerobic glycolysis

Anaerobic glycolysis is the main metabolic pathway used in the setting of limited oxygen supply during exercise. This pathway occurs within cytoplasm of cell to break glucose down into pyruvate. It is an intermediate pathway between anaerobic phospho-creatinine pathway and aerobic pathway. It fuels high intensity swimming lasting up to 2-3 mins [13,14].

Aerobic glycolysis

This pathway which occurs in the mitochondria requires the presence of oxygen to produce ATP. It has a slow rate of ATP production and is utilized during lower intensity activity for a longer duration. It fuels performance lasting longer than 3min [13].

Yogic breathing practice is beneficial in improving the lung capacity as well as strengthening the respiratory muscles [15]. Moreover, Regulation of breathing is said to regulate the elevation in a sympathetic tone which is marked by anxiety and reduced Heart Rate Variability. Cognitive Behavioral Therapy (CBT) involving yogic breathing has been shown to reduce anxiety [16]. The capability to give out a good performance and to overcome pressure and anxiety is an important part of sports, especially among competitive swimmers. Thus, an increased lung capacity and a calm mind play a pivotal role in the performance of the swimmers.

In Sanskrit (an ancient Indian language) the conscious and controlled breathing practices or yogic breathing technique are called "*Pranayama*". Pranayama is not merely a breathing technique. It is one of the powerful yogic techniques used to regulate the flow '*prana*'- the vital energy. The technique of pranayama has got its influence over both body and mind. Breathing is a link in the chain activities of body physiology. As we pull one link, it will have an impact on all others. Hence when one tries to regulate breathing, he actually controls the muscle functions, brain function, and metabolic functions and in turn, the mind also gets controlled [17].

Traditional literature of yoga suggests four aspects of breathing patterns utilized in Pranayama. They are Puraka (inhalation), Rechaka (exhalation), Antharkumbhaka (Internal Breath Retention), and Bahir kumbhaka (External Breath Retention) [18].

In this article, the role of a set of selected pranayama in competitive swimmers are analyzed, which includes: Nadishudi pranayama (Alternate Nostril Breathing), *Bhastrika pranayama* (Yogic Bellows Breathing), *Bhramari Pranayama* (Humming bee breathing), Ujjayi pranayama (victorious breath) and Kapalabhathi.

Methodology

Search criteria

The online database, PubMed, PubMed Central and google scholar were searched for citations for keywords "*Pranayama, Yogic Breathing, competitive swimmers, competitive swimming, nadishudi pranayama, bhastrika pranayama, ujjayi pranayama, Bhramari Pranayama and Kapalabhathi*".

Selection of studies

Experimental papers in English, revealing the effects of yogic breathing in competitive swimmers, effects of yogic breathing in lung capacity, lung function and psychological system and also papers showing the effect of pranayama on metabolic pathway were included in the review. The studies that have used yogic breathing in combination with other Yoga practices, Studies in languages other than English, and whose abstracts were unavailable were excluded from the review.

Data extraction

The search yielded a total of 4,642 references from the date of inception of the databases till October 2020. Of these, 3832 were excluded by screening the title and the abstract for failure to meet the inclusion criteria. Of the remaining (810 articles) for 34 articles a full-text review yielded, 6 studies satisfying the inclusion/exclusion criteria.

Data synthesis

After applying the inclusion and exclusion criteria and removing the duplicates, a total of 6 studies were selected for the final review. Of these three studies were conducted in competitive swimmers (which showed the effects of yogic breathing practice on lung function, performing ability and breath holding capacity), fourth one is a study conducted in physically active men showing anaerobic power, muscle strength and physiological changes following yogic practice. Fifth one is an RCT showing the effects of yogic breathing on anxiety, and brain functional connectivity and activity. And the sixth one is a study that shows the effects of yoga (pranayama) on lung function and lactate kinetics. The data synthesis was done by categorizing the study findings under role of pranayama in competitive swimmers and effect of pranayama in energy systems. The numbers of studies were limited. Hence, meta-analysis could not be done and the data was summarized using a narrative method.

Analysing the Role of Pranayama in Competitive Swimmers

Nadishudipranayama (Alternate nostril breathing)

Nadishudi pranayama is inhalation through the same nostril with which exhalation was done, having retained the breath so long as

Table 1: Search results.

Author, Year, Country	Objective	Study design	Gender	Age	Intervention	Result
Hakked CS, Balakrishnan R and Krishnamurthy MN, 2017. India	To study effects of yogic breathing practices on lung functions of swimmers.	RCT	Not mentioned	13-20 years	Yogic breathing practice was advised for thirty minutes, five days a week for a period of one month.	There was a significant improvement in the YBP group as compared to control group in maximal voluntary ventilation (p = 0.038), forced vital capacity (p = 0.026) and number of strokes per breath (p = 0.001).
ABAJI PP, 2019. India	To study the effect of pranayama on psycho-physiological aspects and performance of swimmers.	RCT	Male	18-25 years	Pranayama was advised for a duration of 30 minutes for eight weeks	There was a significant improvement on psychological aspects of swimmers.
Bera T, Chourasia K, Shete SU and Verma A, 2017. India	To study the influence of pranayama on breath holding capacity and reaction time of junior state level elite swimmers.	Single group study design	Male	16-18 years	Pranayama was advised for 11/2 hrs for 6 weeks	The result shows that swimming plus pranayama training leads to significant increase in breath holding capacity whereas reduction in reaction time.
Pal R, Saha M, Chatterjee A, Halder K, Tomer OS, Pathak A and Basavaraddi IV, 2013. India	To study anaerobic power, muscle strength and physiological changes in physically active men following yogic practice.	Clinical study	Male	21-33 years	Pranayama along with other yoga practices were advised for 90min for 3 months	There was a significant decrease in systolic blood pressure and mean blood pressure.
Novaes MM, Palhano-Fontes F, Onias H, Andrade KC, Lobão-Soares B, Arruda-Sanchez T, Kozasa EH, Santaella DF and de Araujo DB, 2020. Brazil	To study the effects of yoga respiratory practice on anxiety, affect and brain functional connectivity and activity.	RCT	Not mentioned	18-40 years	Pranayama was advised for 30 min for 30 days	This study provides evidence that pranayama reduced anxiety and increase positive affect associated with the activity and connectivity of a brain network involved in emotion processing, particularly the amygdala, anterior cingulate, anterior insula, and the prefrontal cortex.
Benavides-Pinzón WF and Torres JL, 2017. Colombia	To describe the effects on lung function assessed by rest spirometry -vital forced capacity (VFC), forced expiratory volume in one second (FEV1), and FEV1/VFC ratio- in a group of apparently healthy adults, as well as to explore the effects of pranayama techniques in lactate kinetics.	Quasi-experiential study	Both genders	Not specified	Pranayama was advised for 12 weeks	Significant differences were found in FVC, FEV1 and lactate among YG and CG ($p<0.05$), and before and after the stimulus in the Pranayama group ($p<0.05$).

it can be done without suppressing the impulse to exhale, and then slowly exhale through the other nostril without any hurry [17].

The main focus of this pranayama technique is slow and deep breathing, which is essential as it decreases the dead space ventilation. Shallow breathing refreshes air only at the base of the lungs compared to which nadishudi pranayama refreshes the air throughout the lungs. A study conducted in thirty competitive swimmers of age range 15.27 ± 1.66 years, who were randomly allocated to Yogic Breathing Pattern (YBP) or waitlist control groups, showed a significant change in Maximal Voluntary Ventilation, forced vital capacity as well as in swimming performance based on number of strokes per breath were observed in Yogic Breathing Pattern as compared to the controls following one month of intervention [1].

Bhastrika pranayama (Yogic bellows breathing)

Bhastrika pranayama is a practice of exhaling by contracting the abdominal muscles quickly and forcefully, followed with a quick diaphragmatic inhalation, letting the abdominal muscles relax completely [17].

A study conducted to determine the effects of Anulom-Vilom and *Bhastrika Pranayama* on vital capacity and maximal ventilatory volume in 30 randomly selected males aged 18 to 26 years assigned to two groups of experimental and control revealed that the vital capacity and maximal ventilatory volume significantly improved in the experimental group compared to the control [19]. Thus, the practice of *Bhastrika Pranayama* can be employed among competitive swimmers, which could help in improving their ventilatory functions.

Bhastrika pranayama use the action of the abdominal muscles and diaphragm to draw air in and out of the lungs, resulting in the generation of heat in the body by squeezing blood through the digestive organs, toning the liver, spleen, stomach, and pancreas, and increasing digestive capacity [17]. It was well established that optimal nutrition and digestion are important for improving endurance and athletic performance. In-order to sustain energy, weight and muscle strength, athletes must consume large calories. But digestion may be compromised when stress is experienced [20,21]. *Bhastrika pranayama* is helpful in establishing optimal nutrition and digestion by enhancing the functions of digestive organs.

Few other evidences suggest that a regular practice of *Bhastrika pranayama* reduced anxiety which is associated with the activity and connectivity of a brain network involved in emotion processing, particularly the amygdala, anterior cingulate, anterior insula, and the prefrontal cortex [22]. So, it could help reduce precompetitive stress and anxiety in swimmers.

Bhramari Pranayama (Humming bee breathing)

Bhramari Pranayama is named because of the humming sound produced during expiration which mimic the sound of a wasp. The literature describes reduction of anxiety and stress as the benefits of practicing this breathing [23]. In a study, Paroxysmal Gamma Waves

(PGW) were observed using EEG in eight subjects practicing a yoga technique of breathing control called *Bhramari Pranayama* [24]. These gamma brain waves are related to the performance of high mental activities and perceptual task. It was noted that the heart rate and blood pressure was influenced in healthy subjects immediately after 5min of the practice of *Bhramari Pranayama* because of the parasympathetic dominance. This suggests that *Bhramari Pranayama* improves the resting cardiovascular parameters in healthy adolescents [25]. Hence, the implementation of *Bhramari Pranayama* practice among competitive swimmers will be beneficial in reducing their stress and anxiety.

Swimming is a sport that induces relative load on respiratory muscles resulting in fatigue [1]. The increased Peak Expiratory Flow (PEF), Forced Expiratory Flow (FEF), and Maximal Voluntary Ventilation (MVV) during *Bhramari Pranayama* practice may attribute to voluntary prolongation of inspiration and expiration which stretches the respiratory muscles to their full extent. Thus, the respiratory apparatus can work to their maximum capacity. Increased maximal sustained ventilatory capacity and reduction in the relative load on the muscles are achieved through the improvement of respiratory muscle functions [26]. So, the practice of *Bhramari Pranayama* among swimmers could strengthen the respiratory muscles and reduce the relative load on the muscles and help them deliver a good performance.

Ujjayi pranayama (victorious breath)

Ujjayi is a breathing practice that reduces airflow during inspiration and expiration due to slight contraction of the glottis muscles. It increases the intra-thoracic pressure which potentially results in intensified vagal activity [17]. Ujjayi pranayama practice along with a slow breathing pattern improves oxygen saturation and Baroreceptor Sensitivity (BRS) in blood [27]. This helps to improve the oxygen saturation levels in swimmers, thus helping them to perform without much exhaustion.

Kapalabhati

Kapalabhati a breathing technique, which is one among the shat kriya (Six cleansing process) can be employed along with the pranayama practice. As athletes experience frequent digestive stress due to prolonged training environmental toxicity exposure, the forceful exhalation during kapalabhati creates a venturi effect in the nasal passage which creates a partial vacuum resulting in sucking off the inhaled pollutant particles out of the olfactory lobes thus cleansing the lungs and brain [28].

Effects of Pranayama on Energy Systems

Anaerobic phosphocreatine

In this pathway ATP production is limited by the amount of creatine phosphate (PCr) present in the muscles. In swimming, sprint training is done to enhance the capacity to produce energy through the phosphocreatine system. An increased amount of PCr present in muscle is favorable for increased production of ATP through anaerobic phosphocreatine pathway [3]. Individuals with an elevated aerobic power are said to be able to resynthesis PCr at a rapid rate. Studies show that Pranayama improves aerobic power and physical endurance. Thus, a regular practice of Pranayama can enhance the PCr synthesis at a rapid rate by enhancing the aerobic power. Yoga practice along with Nadishudi Pranayama and *Bhastrika Pranayama* are beneficial in enhancing aerobic power. For a study of yoga (including pranayama) in relation to body composition, cardiovascular endurance and anaerobic power conducted in 40 male high school students, age 12-15 years, the result revealed that a significant improvement in ideal body weight, body density, cardiovascular endurance and anaerobic power was observed [29].

Anaerobic glycolytic pathway

This pathway, which occurs in the cytoplasm, does not use oxygen to breakdown glucose. In swimmers, middle distance training is used to enhance the ability of producing energy anaerobically [3]. The practice of Nadishudi Pranayama and Ujjayi Pranyama is said to improve the anaerobic capacity. A targeted practice of these pranayama has shown to stimulate blood oxygenation and glycolytic capacity, which has a favourable impact on anaerobic glycolytic capacity. This happens due to the stimulation of the fibers that use glycolytic pathway [30].

Aerobic pathway

In this pathway the percentage of energy is derived from the breakdown of fats and carbohydrate. In swimming, distance training enhances lactate removal and improve VO_{2max} (the maximum rate of oxygen consumption measured during incremental exercise), thus stimulating aerobic pathway [3]. Pranayama like Nadishudiand breathing techniques like Kapalabhati has the potency improve aerobic capacity (VO_{2max}). Studies showed that yogic exercises done for one hour daily including these pranayama seem to improve VO_{2max}. Pranayama practice is thus said to enhance aerobic pathway [31].

Discussion

Pranayama, the branch of yoga practice is extremely beneficial to mankind in maintaining sound physical and mental health. The breath is the most important sign of energy in the body. To get control over the energy, initially one has to regulate the breathing [32]. Breathing is regulated by the expansion and contraction of the lung. Expansion happens in 2 ways: By the downward and upward movement of the diaphragm, by elevation and depression of ribs [17]. Contraction takes place by elastic recoil of the respiratory muscles. The Rate and pattern of breathing are regulated by the pneumotaxic center in the brain. The dorsal respiratory group in the medulla is causing the inspiration and a ventral respiratory group of neurons is controlling expiration [33]. The overall level of respiratory center activity is controlled to match the ventilatory needs of the body. This is achieved in two different ways: By excitatory signals from other parts of the nervous system and by feedback excitation of respiratory center activity in response to changes in the chemical composition of the blood. The chemical composition of blood depends on the metabolic activity in the body [17].

The entire energy requirement of the body which is spend to perform physical and mental functions is met through metabolic activity. Breathing is one of the links of chain of activities in the body physiology. So, a control in breathing can regulate muscle functions, brain functions and metabolic functions. This multi-systemic effect of breathing eventually turns to control the vital energy which controls the whole function i.e. Prana. This in turn controls the mind

too. Pranayama practices cleanses airway secretions and acts as a major physiological stimulus for the release of lung surfactant and prostaglandins into alveolar spaces and promote lung compliance. Even though, breath holding induces transient phases of hypoxia, Pranayama practices promote the production of lung surfactants, reduce surface tension and promote exchange of gases in alveolar membrane. The oxygen carrying capacity of RBCs are enhanced by practicing pranayama [34]. Moreover, a study that compared the effects of yoga and physical exercises in athletes showed that the subjects who practiced pranayama could achieve higher work rates with reduced oxygen consumption per unit work and without increase in blood lactate levels. The blood lactate levels were significantly low at rest in these subjects [35].

Nadishudi pranayama is proved to be effective in cardio-pulmonary functioning and improving vital capacity in healthy individuals. This, when practiced along with *bhastrika pranayama*, showed to improve maximum ventilatory volume and vital capacity [1]. Regular practice of *bhastrika pranayama* along with other breathing practices showed a reduction in basal heart rate and respiratory rate suggesting a better cardiac autonomic reactivity and parasympathetic activity [19].

Studies are suggesting the effect of Ujjayi pranayama (victorious breath) in balancing the autonomic nervous system through enhanced activation of the parasympathetic system. Therefore, it could also be practiced for mental relaxation. As there is a reduction in stress and anxiety there will be a reduction in over-expenditure of energy [17,27]. This reduction in turn lower the over expenditure of energy, preventing exhaustion. Thus, it will have positive effect on swimming.

Kapalabhati strengthens the respiratory muscles. It also prepares one for advanced pranayama practices. Studies substantiate that the practice of Kapalabhathi is beneficial for pulmonary function in healthy individual. It also has positive results in anxiety and depressive symptoms in the patients with treatment resistant generalized anxiety disorder [28,36].

Conclusion

In the light of evidences from different studies, it could be understood that the selected pranayama practices have a positive effect on physiological and psychological aspects of health, especially lung capacity and anxiety. So, it would be beneficial to practice pranayama as daily routine among competitive swimmers. The practice is effective and safe when done under proper guidance. Large scale studies with rigorous designs to understand the mechanism involved will substantiate the worth of yogic breathing.

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