

A review of the physiological effects of Suryanamaskar in children

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Abstract

Increasing physical inactivity in children necessitates the exploration of physical activities that can confer health benefits. The purpose of this study was to review the literature regarding the physiological benefits of Suryanamaskar, a composite yogasana on physical fitness in children. Primary source articles in English, published between 1980 and 2020, in peer-reviewed journals were included. A literature review was carried out using PubMed, Cochrane-Library, Science Direct, and Google Scholar databases. Keywords used were "Suryanamaskar," "physical fitness," "sun-salutation," "physiological effects," "physical activity," "health promotion," "yoga," and "children." The methodological quality of the studies was assessed using the Physiotherapy Evidence Database scale. The effect of Suryanamaskar training on physical fitness components, namely flexibility, muscle strength, cardiorespiratory endurance, and cognition, was reviewed. Seven studies matched the inclusion criteria. All seven studies were randomized controlled trials. The level of evidence was of fair quality with a high risk of bias. Following Suryanamaskar intervention, improvement in musculoskeletal function—muscle strength and endurance, and the flexibility of hip joint, wrist joint, hamstrings, and dorso-lumbar fascia were reported. Improvements in cardiorespiratory variables such as peak expiratory flow rate forced vital capacity, forced expiratory volume, vital capacity, and reduction in blood pressure and heart rate are reported in children. Improvements in cognition were also observed following Suryanamaskar's intervention. Suryanamaskar training confers health benefits and improves physical fitness components such as muscle strength, flexibility, cardiorespiratory endurance, and cognition. Suryanamaskar can emerge as a useful tool to increase physical fitness, deter physical inactivity, and promote healthy behavior (sanskar) in school-going children. High-quality longitudinal randomized control trials need to be undertaken to confirm the same.

Keywords: Health promotion, physical activity, physical fitness, physiological effects, Sun salutation, Suryanamaskar, yoga

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INTRODUCTION

The World Health Organization (WHO) estimates that over 170 million children, less than 18 years of age, in

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developing countries are physically inactive.^[1] WHO recommendations for daily physical activity for children aged 5–17 years include engaging in 60 min of moderate-to-vigorous activity. According to the Centers for Disease Control and Prevention, only 17%–39% of children in the United States are involved in organized physical activity for at least 60 min per day.^[1,2] Similar observations are reported from European and Asian countries.^[3–5]

In developing countries, like India, a decline in moderate-to-vigorous physical activity is observed among urban school children.^[1,6] Children engage in physical activity either during physical education classes during school hours or recreational playtime over weekends. Physical training in Indian educational institutes is restricted to less than 30–60 min of physical education activity period once or twice a week, which is inadequate and unstructured.

Further, it is well known that the practice of regular physical activity promotes fitness and enables a person to perform daily activities without fatigue. The modification of a sedentary lifestyle can contribute to an active and healthy life beyond childhood and adolescence.^[7,8] Industrialization has brought about changes in lifestyle with greater engagement of children in sedentary activities.^[6] Reduced physical fitness in children is associated with an elevated risk of presenting an increase in body mass index, elevated lipoproteins and cholesterol level, and developing obesity and insulin-resistance juvenile diabetes mellitus in school-aged children.^[2,9–11]

General recommendations for promoting physical activity in children include engagement in structured play, games, sports, planned exercise or physical education activity, and yoga.^[1,12,13] Yoga has been practiced for over 5000 years and is an ancient form of physical activity that encompasses breathing techniques, postures, strengthening exercises, and meditation. The practice of yoga originated in India and has slowly gained popularity all over the world.^[14]

Suryanamaskar is one of the ancient yogic practices, which means “to worship the Sun.” In Suryanamaskar, “*Surya*” denotes the Sun, and “*namaskar*” denotes salutation; therefore this yogic practice is discerned as “salutation to the Sun.”^[15]

Suryanamaskar is a set of six asanas or postures performed in a cyclic reversal, which include *Pranamasana* (prayer pose) as the first and 12th pose, *Hasta uttanasana* (raised arms pose) as the second and 11th pose, *Hastapadasana* (hand to foot) as the third and 10th pose, *Ashva sanchalanasana* (equestrian pose) as the fourth and ninth pose, *Parvatasana*

(mountain pose) as the fifth and eighth pose, *Ashtanga namaskar* (salutation with eight parts) as the sixth and ninth pose, and *Bhujangasana* (Cobra pose) as the seventh pose performed preferably in the morning facing the rising Sun^[16,17] [Figure 2].

The benefits of Suryanamaskar on the musculoskeletal, cardiovascular, neurological, gastrointestinal, and endocrinal systems have been studied predominantly in adults.^[18] Suryanamaskar confers great benefits on health, stamina, mental stability, physical strength, and mental calmness and is believed to revitalize cellular function.^[10]

Regular practice of Suryanamaskar has been reported to improve blood circulation, to maintain health, to increase strength, flexibility, and the general feeling of well-being in adults. Physiological benefits include increased blood circulation to the brain and spinal mobility due to the various 12 positions achieved in Suryanamaskar. It also helps improve the peristaltic movement of the gut and cardiac myocardial contractility.^[16]

Simultaneously, Suryanamaskar develops neuromuscular awareness (i.e., coordination and movement control), maintains healthy body weight, prevents chronic illnesses such as cancer, type 2 diabetes, and cardiovascular diseases, maintains good mental health, improves sleep, and lowers stress.^[14] However, the physiological effects of Suryanamaskar have not been reviewed in children.

Therefore, there is an urgent need to review the physiological effects of Suryanamaskar and the benefits conferred on various body systems by performing Suryanamaskar intervention in children. Thus, a systematic review was undertaken to inform existing evidence of physiological effects of Suryanamaskar for health promotion in children.

MATERIALS AND METHODS

The study was commenced following ethical approval from the Institution Ethical Review Committee. A systematic review was carried out to review existing knowledge regarding the physiological effects of Suryanamaskar in children to enable the prescription of Suryanamaskar as a healthy lifestyle measure. A review of the literature was performed using the Preferred Reporting Items for Systematic Review and Meta-Analyses guidelines. PubMed, Cochrane Library, Science Direct, and Google Scholar databases were searched using keywords “Suryanamaskar” AND “Children” AND “Physical fitness” OR “Yoga” OR “Sun salutation” [Figure 1].

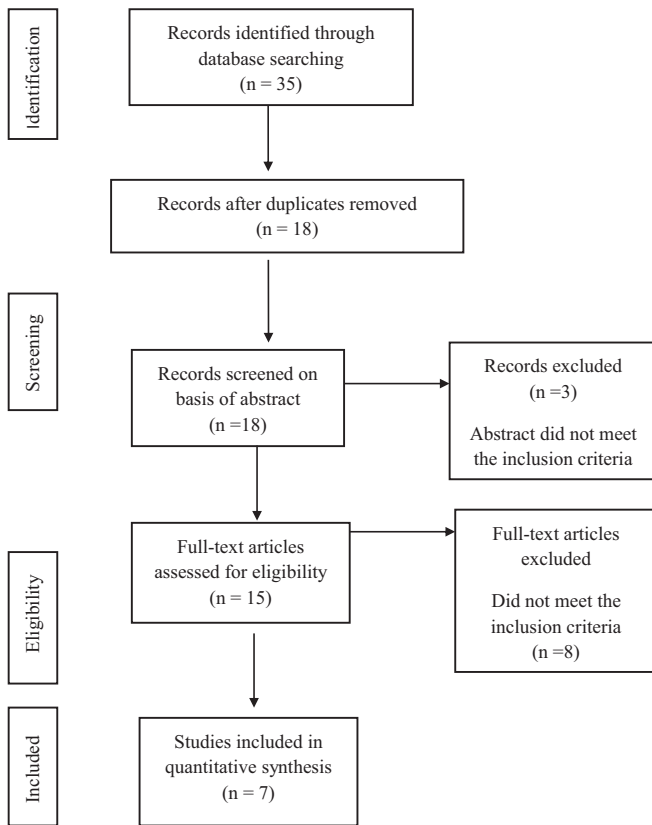


Figure 1: Flow diagram of the study selection process

Studies that included Suryanamaskar intervention in healthy children, in the age group of 9–15 years, published in the English language, in peer-reviewed journals were considered for inclusion. Studies with yoga interventions other than Suryanamaskar were not included. Studies included in the review were then screened in three stages: title screening, abstract screening, and screening for full-text articles. Titles that did not meet eligibility criteria were excluded. Further, abstracts of eligible studies were screened for content. The full texts of relevant articles were included in the review.

Each eligible article was reviewed for the objective of the study, age of the population included in the study, study design, outcome variables (physiological parameters, flexibility, vital capacity, musculoskeletal strength and endurance, and coordination), assessment tools, and primary observations. The internal validity of each article was independently assessed by using Physiotherapy Evidence Database (PEDro) score for randomized control trial (RCT) studies. The tool assesses the ability of each study to conclude the link between eligibility criteria and the physical parameters of the study. Flaws in the design and methodology of the study can increase the risk of bias and decrease the internal validity of the article. Two reviewers (AK and HB) scored each of the 11 items of the quality assessment tool as “YES” (✓) and “NO” (×). To compare

the risk of bias across studies, the answers weighted as “YES” were assigned a score of 1 and “NO” was assigned a score of 0. The total score for each study was used to classify the quality of the study and the risk of bias. Score < 4 was considered “poor,” 4–5 were considered “fair,” 6–8 were considered “good,” and 9–10 were considered “excellent.”^[19,20] In case of conflict between the assessors, a third reviewer (BA) assessed the methodological quality of the study [Tables 1 and 2].

RESULTS

Thirty-five studies were identified using the keywords. Seventeen titles were identified as duplicates and were excluded. Abstracts of 18 articles were screened. Three studies did not meet the eligibility criteria and were excluded from the review process. The full text of the remaining 15 articles was reviewed. Eight full-text articles were excluded as they did not meet the eligibility criteria. Seven RCTs meeting the inclusion criteria were included in this review.

Quality assessment interpretation

As per the PEDro scale, all studies were of fair quality with clearly defined eligibility criteria, objectives, inclusion–exclusion criteria, and variables. Participants were randomized to Suryanamaskar or a control condition. However, a high risk of bias was observed as none of the studies included blinding of participants or researchers. Individual characteristics of the study group, gender classification, duration of intervention, type of Suryanamaskar, and clinical variables studied are described in the further sections. The level of evidence based on Sackett is 2a (limited), at least one “fair” quality RCT (PEDro scale score = 4–5).

Characteristics of the study group

Most studies included school-going children in the age group 9–15 years. Both male and female children were included in three studies ($n = 221$), whereas four studies included only male children ($n = 126$). The gender distribution of the total number of samples was 53% boys and 47% girls. The duration of Suryanamaskar intervention ranged between 8 and 12 weeks.

Types of Suryanamaskar

The various studies included some variations in the types of Suryanamaskar studied. The forms used were slow Suryanamaskar, fast Suryanamaskar, Hatha Suryanamaskar, Vinyasa Sun salutation, mantra chanting with Suryanamaskar, and breathing control with Suryanamaskar.

In slow Suryanamaskar, participants performed all 12 poses slowly and rhythmically in which all 12 postures were held

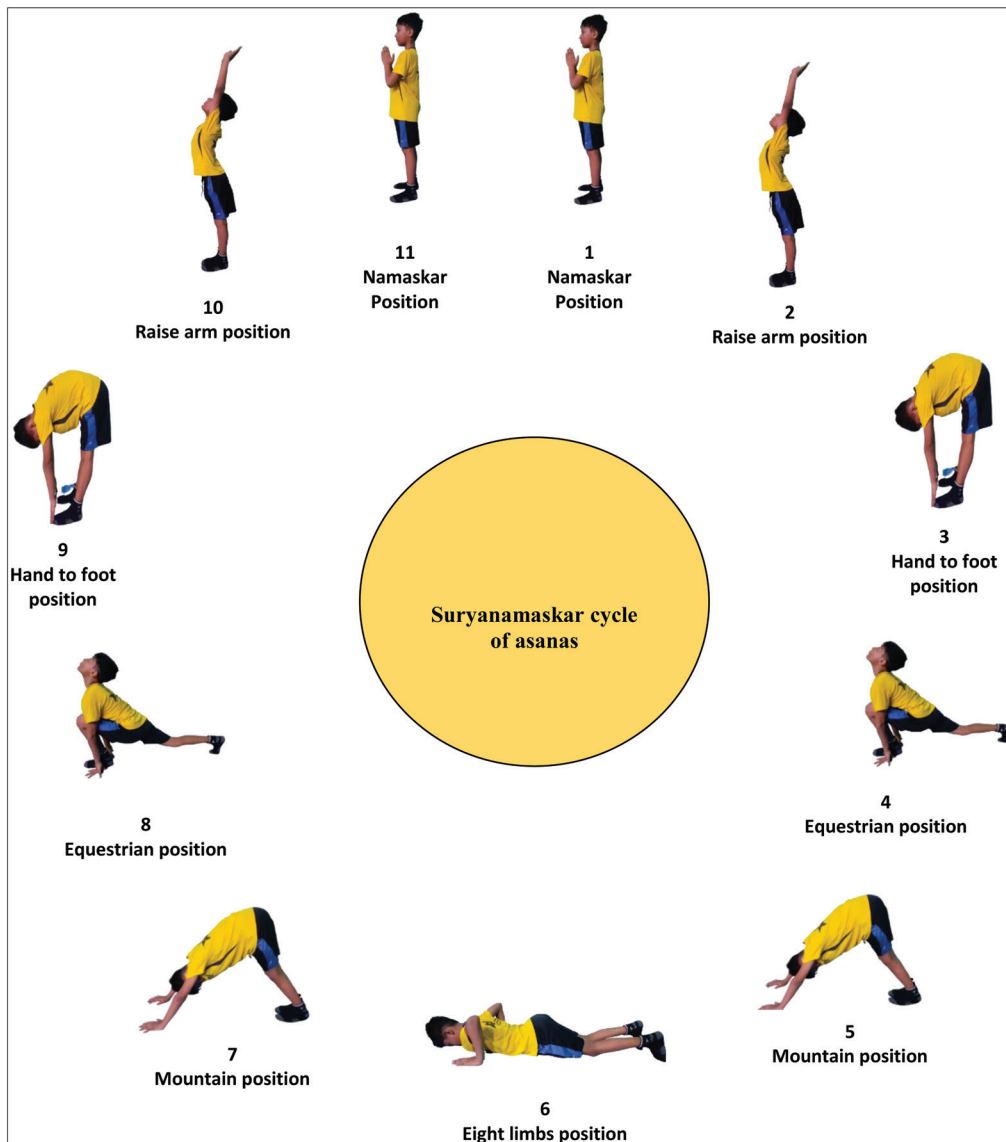


Figure 2: Suryanamaskar poses

Table 1: PEDro score quality assessment scale (PEDro scale)

	Bhavanani et al., 2011 ^[21]	Sharma and Acharya ^[22]	Sasi Kumar et al., 2011 ^[23]	Javadekar and Manjunath 2012 ^[24]	Pal 2014 ^[25]	Pal 2014 ^[25]	Pal 2014 ^[26]
Eligibility criteria	√	√	√	√	x	x	x
Randomized allocation	x	√	√	√	√	√	√
Concealed allocation	x	x	x	x	x	x	x
Comparable at baseline	√	√	√	√	√	√	√
Blinded subjects	x	x	x	x	x	x	x
Blinded therapist	x	x	x	x	x	x	x
Blinded assessors	x	x	x	x	x	x	x
Adequate follow-up	x	x	x	x	x	x	x
Intention to treat analysis	x	x	x	x	x	x	x
Between-group comparisons	√	√	x	√	√	√	√
Point estimate and variability	√	√	√	√	√	√	√
Total score	4/10	5/10	4/10	5/10	4/10	4/10	4/10
	Fair quality	Fair quality	Fair quality	Fair quality	Fair quality	Fair quality	Fair quality

for 30s. In fast Suryanamaskar, participants were instructed to perform all 12 postures rapidly without any holds. Vinyasa Sun salutation focused on dynamic connecting

posture that created a link between Suryanamaskar poses and breathing. These postures are performed at a quicker pace than other forms of Suryanamaskar. In one study,

Table 2: Study selection process

Authors	Study type and sample size	Population	Intervention	Primary outcome	Outcome measures
1. Bhavanani et al., 2011 ^[21]	Interventional study n = 42 Two groups with 21 children in each group	School children, 12–16 years of age	Group 1–Fast Suryanamaskar was performed in such a way that all 12 postures were completed in 2 min, and to complete 15 rounds of Suryanamaskar, took 30–40 min	Slow Suryanamaskar reduced diastolic pressure, whereas fast Suryanamaskar increased systolic pressure	Isometric handgrip, respiratory pressure such as MIP, and MEP measured by mercury manometer Pulmonary function test, PEFR, FVC, and FEV were measured by computerized spirometer Cardiovascular parameter–blood pressure (BP)–was measured using semi-automatic BP monitor
	Group 1 performed fast Suryanamaskar Group 2 performed slow Suryanamaskar		Group 2–Slow Suryanamaskar was performed such that each of the 12 postures was held for 30 s. Each round was completed in 6 min, five rounds were performed in 30–40 min. Duration of intervention is 6 months	Both types increased isometric handgrip strength and endurance, increased MIP, and peak flow rate	
2. Javadekar and Manjunath 2012 ^[24]	Interventional study n = 64 32 in each group	School children, 12–14 years	The experimental group underwent Suryanamaskar practice	Suryanamaskar group showed a 16.7% improvement	DLST visual scanning, mental flexibility, sustained attention, psychomotor speed of information processing
			The control group underwent routine physical exercises for 30 days	The physical exercise group showed 13.2% improvement in DLST. No difference was observed between the two activities	
3. Sasi Kumar et al., 2011 ^[23]	Interventional study n = 115	School children, 10–14 years of age	Suryanamaskar was performed for 45 days Cardiorespiratory parameters–BP, heart rate, RR, FVC, and PEFR–were measured pre- and postintervention	An increase in FVC and PEFR was observed Reduction in heart rate, diastolic pressure, and RR was reported after the practice of Suryanamaskar	FVC was measured by a spirometer, PEFR by using mini-Wright peak flow meter, BP using a sphygmomanometer, and RR by manual method
4. Pal 2014 ^[25]	Interventional study n = 30 15 in each group The experimental group performed a Vinyasa Sun salutation The control group was given no intervention	School children, 14–16 years	The experimental group performed Vinyasa training for 45 min in the morning, 3 days a week for 8 weeks	Participants who followed Vinyasa Sun salutation training improved their hip joint flexibility higher than participants in the control group	Hip joint flexibility was measured using goniometry
5. Pal 2014 ^[26]	Interventional study n = 30 15 in each group The experimental group performed Vinyasa Sun salutation The control group was given no training protocol	14–16 years student	The experimental group performed Vinyasa training for 45 min in the morning 5 days a week for 8 weeks The control group continued routine daily activities	An increase in vital capacity (VC) was observed following Vinyasa training	VC was measured by a dry spirometer and recorded in liters
6. Pal 2014 ^[2]	Interventional study n = 30 15 in each group	School children, 14–16 years	The experimental group performed Vinyasa training for 45 min in the morning, 3 times a week for 8 weeks. The control group continued a basic daily routine	A significant difference was seen in the experimental group who followed Vinyasa Sun salutation poses, which improved wrist joint flexibility among school-going children	Flexibility for the wrist joint was measured using a goniometer in degrees

Table 2: Continued

Authors	Study type and sample size	Population	Intervention	Primary outcome	Outcome measures
7. Sharma and Acharya ^[22]	The experimental group performed Vinyasa Sun salutation The control group was given no training protocol School children, 13–15 years of age	Group 1 performed Suryanamaskar with mantra chanting Group 2 performed Suryanamaskar with a fixed breathing pattern Group 3 performed general Suryanamaskar	No difference was observed on the DLST between the mantras and breathing group and breathing and control group following the intervention	DLST involves visual scanning, mental flexibility, sustained attention, psychomotor speed of information processing	

FVC = forced vital capacity

one group of children performed mantra chanting and another group performed breathing control with 12 Suryanamaskar poses.^[9,25,27] Hatha Suryanamaskar consisted of 12 spinal poses performed with emphasis on breathing patterns and was the commonest form practiced. Poses included were *Pranamasana*, *Hasta uttanasana*, *Hastapadasana*, *Ashwa sanchalanasana*, *Parvatasana*, *Ashtanga namaskar*, and *Bhujangasana* performed in a cyclic manner.^[16,17]

Effect of Suryanamaskar on physiological variables

Cardiorespiratory variables

Three studies observed a significant improvement in the cardiorespiratory variables post-Suryanamaskar intervention. Significant improvement was observed in systolic blood pressure and diastolic blood pressure with Suryanamaskar training. Resting cardiovascular variables such as heart rate and diastolic blood pressure decreased significantly following Suryanamaskar training for 6 months.^[23,25,26]

Studies reported a significant improvement in peak expiratory flow rate (PEFR), forced vital capacity (FVC), and a decrease in respiratory rate (RR) after Suryanamaskar practice.^[23,25,26] PEFR and FVC were measured using spirometer.^[28] Change in lung volumes was observed following both slow and fast Suryanamaskar. Similarly, pulmonary functions such as PEFR, FVC, and forced expiratory volume (FEV) increased following both fast Suryanamaskar and slow Suryanamaskar. Additionally, an

increase in respiratory muscle strength evaluated using maximum inspiratory pressure (MIP) and maximum expiratory pressure (MEP) was observed following the Suryanamaskar intervention. A greater increase in MIP was reported following fast Suryanamaskar compared with slow Suryanamaskar, whereas a greater increase in MEP was observed in the slow Suryanamaskar group compared with the fast Suryanamaskar group. These values were measured using a mercury manometer.^[25]

Muscle strength and endurance

Studies have reported an improvement in muscle strength and endurance following Suryanamaskar. Isometric handgrip strength endurance and time for 33% of isometric handgrip, i.e., handgrip endurance, improved in children performing fast and slow Suryanamaskar, with a greater increase in the fast Suryanamaskar group. Handgrip strength was measured with the dominant hand gripping the inflated cuff of mercury and sustaining the gripped cuff measured the handgrip endurance.^[13,15,29]

Flexibility

A significant improvement in the flexibility of children is reported following Suryanamaskar intervention.^[2] The flexibility of hip and wrist joints was observed to increase after 8 weeks of Vinyasa Suryanamaskar training. Flexibility was assessed by recording joint range of motion using a standard goniometer.^[2]

Cognition

Two studies report a significant improvement in the cognition and reaction time in children after Suryanamaskar intervention.^[23,30] Significant difference in the performance of the digit letter substitution test (DLST) was reported between children performing Suryanamaskar with mantra chanting for 6 weeks compared with the control group children who did not perform any intervention.^[24,28]

DISCUSSION

This systematic review was undertaken to identify the physiological effects of Suryanamaskar and the benefits to include this style of yogic practice (Suryanamaskar) in routine physical activity for health promotion in children. Based on a literature review inclusive of seven studies, the benefits of Suryanamaskar on physical fitness and mental health are discussed further.

Most of the reviewed studies included school-going children in the age group 9–15 years. Children younger than 9 years were not included in any of the reviewed studies. All interventions were carried out during school hours, indicating that the inclusion of Suryanamaskar into the physical education curriculum is a feasible option for the health promotion of children within the school environment. Children of both genders were included in the studies reflecting on the application of common physiological benefits to both genders.

First, an improvement in the cardiorespiratory function is reported after Suryanamaskar training.^[25-27] Resting cardiovascular variables such as heart rate decrease with increased training of Suryanamaskar. Systolic blood pressure was observed to increase, and diastolic blood pressure decreased significantly with increased Suryanamaskar training. Suryanamaskar is a dynamic aerobic activity that activates large muscles of the trunk and lower extremity, thus placing a volume overload on the heart. The dynamic muscle contractions help increase venous return and cardiac output during exercise. Long-duration training leads to the conditioning of the skeletal muscles with enhanced mitochondrial oxygen extraction and aerobic enzymatic activity, thus reducing the O₂ demand following training.^[21,25]

A significant improvement is reported in PEFR, FVC along with a reduction in RR.^[31] Also respiratory pressures such as MIP and MEP show a significant improvement that increases the endurance and strength of respiratory and expiratory muscles. In pulmonary functions, FVC and FEV increased significantly.^[29] VO₂max value was

also hypothesized to have a significant improvement after practicing Suryanamaskar with physical activity exercise.^[1] Suryanamaskar asana such as *Hasta uttanasana*, *Bhujangasana*, and *Ashtangasana* stretch the respiratory and intercostal muscles, thus facilitating respiratory muscle contraction. This concept can be related to the Frank Starlings law, which suggests that greater stretch of the muscle leads to forceful muscular contraction.^[32] Similarly, compression of the abdominal contents with a consequent diaphragm stretch during *Ashwa sanchalanasana* can increase tidal breathing and subsequently the vital capacity following long-duration training. Further, breathing coordination with exhalation during trunk flexion and inspiration during trunk extension along with mantra chanting improve total lung capacity as it improves the strength of respiratory muscles, which leads to adequate inflation and deflation of the lungs as the respiratory muscles work to their maximal extent.^[17,33]

Second, muscle strength and endurance were reported to improve following Suryanamaskar intervention in children. Performing the 12 asanas included in Suryanamaskar demands isotonic muscle activation, whereas the maintenance of the postures requires isometric contraction during the steady state of different postures in Suryanamaskar as shown in Figure 2. Suryanamaskar is a well-sequenced composite asana designed in such a way that soft tissues such as the fascia muscles are stretched and joints undergo a varying degree of flexion and extension movements. While performing asanas such as *Hasta uttanasana*, *Hasta padasana*, *Ashwa sanchalanasana*, *Ashtangasana*, *Parvatasana*, and *Bhujangasana*, major muscle activity is observed in erector spinae, latissimus dorsi, lower trapezius, gastrocnemius gluteus maximus, vastus lateralis, and rectus abdominis. The activation of these postural muscles improves the posture of the body.^[16,31] The regular performance of Sun salutation training thus strengthens the muscles of the lower extremity and trunk and improves muscle strength and general body endurance.^[1,3,30]

Further, in comparison between fast and slow Suryanamaskar, studies indicate a greater increase in muscle strength following fast Suryanamaskar.^[25] During physical activity, motor units are recruited in order of size during voluntary contraction concerning the increase in force and effort. During fast Suryanamaskar, the high-intensity exercise leads to increased recruitment of large motor units that produce greater muscle contraction and confers greater gains in muscle strength.^[32]

Third, Suryanamaskar involves 12 asanas that demand alternate flexion and extension postures of the spine and extremities. These alternate postures improve

the stretchability of muscles of the lower limb, back, thorax, gluteal group of muscle, and length of the fascial structures such as the dorso-lumbar fascia.^[10] Asanas such as the *Hasta padasana* stretches the hamstring and calve muscles while bringing about a complete flexion of the spine and hips, whereas *Bhujangasana* brings about the complete extension of the spine and hips.^[10,17] It has also been shown to increase the flexibility of the hip joint, knee joint, ankle joint, and wrist joint.^[2,25,29] Studies indicate that Suryanamaskar moves the joints of the spine and lower extremity through a large range of motion, which can result in the overall improvement in body flexibility observed following the regular practice of Suryanamaskar.^[34]

Lastly, cognition was observed to be improved significantly following Suryanamaskar training, in the parameters such as DLST. Mantra chanting during the practice of Suryanamaskar improves sustained attention, visual scanning, mental flexibility, sustained attention, and psychomotor speed of information processing, leading to enhanced performance on DLST.^[25,28,35]

This review summarizes the benefits offered by Suryanamaskar in children in the age group of 9–15 years on health-related physical fitness domains such as muscular strength and endurance, flexibility, cardiovascular and respiratory endurance cognition, and reaction time.^[35] Existing studies were methodological of fair quality. Thus, better quality RCTs with a low level of bias need to be undertaken to establish the role of Yoga and Suryanamaskar as a lifestyle practice and health promotion strategy in school-going children.

The current review identified a lacuna in information regarding the benefits of Suryanamaskar on performance measures such as balance, speed, and agility. Further research is required in this area to study the comprehensive health benefits of Suryanamaskar in children. Most studies have been undertaken to include healthy children; therefore, the benefits of Suryanamaskar can be explored in children with attention disorders and children with developmental disorders.

CONCLUSION

Based on the current review, it can be concluded that Suryanamaskar training improves muscle strength and endurance, flexibility, cardiorespiratory function, cognition, and reaction time in children. The inclusion of Suryanamaskar into the regular physical education curriculum at school emerges as a feasible plan to

increase physical fitness, deter physical inactivity, and promote healthy behavior (sanskar) in school-going children.

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Conflicts of interest

There are no conflicts of interest.

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