Research Article

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Effect of Sudarshan Kriya Yoga (SKY) on daytime and situational sleep propensity in novice practitioners: a prospective cohort study

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Abstract

Objectives: Hectic, late-night lifestyle has reduced 90 min sleep in 20% adults resulting in insomnia and excessive daytime sleepiness (EDS). We assess the scope of Sudarshan Kriya Yoga (SKY), a 4-component, breathing process in reducing EDS, generally and situationally.

Methods: This is a prospective, controlled study involving randomized subjects without any sleep-wake cycle anomalies and prior experience in SKY. Subjects (n=52) performed 30 min of SKY for 6 days/week for 8 weeks, while controls (n=53) performed sitting activity and Suryanamaskar for 4-weeks each. Epworth Sleepiness Scale (ESS) was used to measure EDS at 0, 4, and 8 weeks.

Results: SKY group showed significant ESS score improvements between 0–4 weeks and 4–8 weeks of 1.22 (p=0.0001) and 1.66 (p=0.001) respectively. Controls however failed to improve with score differences of 0.02 (p=0.892) and 0.02 (p=0.8212) respectively. SKY group

showed significant ESS score improvement over controls at 4-weeks (difference=1.74; p=0.013) and 8-weeks (difference eight; p=0.0001). Improvement was most for obese people and those sitting in a halted car.

Conclusions: Improvement in subjects' nighttime sleep and daytime wakefulness in SKY practitioners can be attributed to polyvagal theory. Increased heart rate variability (HRV) alterations and sympathetic hyperarousal in chronic insomnia; and cholinergic and GABAergic dysregulation in anxiety disorders are countered by regulated vagal nerve stimulation post SKY. Our study establishes effectivity of SKY in reducing EDS (total and situational), provides a clinical correlation for prior polysomnographic evidence and paves way for larger trials directed towards SKY prescriptions for insomnia.

Keywords: insomnia; pranayama; sleep disorders; Sudarshan Kriya Yoga; yoga.

Introduction

The human body has adapted its sleep-wake (rest-activity) cycle diurnally i.e. with light and dark changes in the environment. This synchronization called the circadian rhythm ensures homeostasis between the milieu interior and milieu exterior and makes the human body energy and resource-efficient. Hence, any disturbance in this harmony can pose serious functional consequences.

In the past 30 years, increased late-night entertainment and hectic routines have reduced 18 min of an adult's nighttime sleep. Nearly 20% adults report impaired nighttime sleep and sleep 90 min lesser than adequate [1]. While 30% adults have reported 'some sleep issues over a year', 10% present with a clinical picture of chronic insomnia [2].

Excessive Daytime Sleepiness (EDS) is the most common repercussion and reflection of impaired nighttime sleep and is commonly seen in people with chronic insomnia, obstructive sleep apnea, narcolepsy, diabetes, and obesity [3]. Lack of standard definition of EDS and

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inability to identify the exact cause using standard investigating techniques have often underestimated the prevalence of EDS. Such cases are very common in the population and are termed as idiopathic hypersomnia [4].

Genetic studies suggest that circadian rhythm and health outcomes share common molecular and biochemical pathways. Hence sleep disturbances often are both the cause and effect of conditions like diabetes, obesity, chronic inflammatory processes, anxiety, and depression [1]. Nearly 10–15% of motor vehicle accidents are due to sleepiness and fatigue. Sleepiness amongst medical caregivers has been shown to be an important factor affecting medical decisions and causing medical errors [5]. Sleep disturbances have decreased school and work performance and impaired psychosocial functioning [3].

Current management of EDS is largely directed towards treatment of the underlying cause with continued pharmacotherapy for EDS with psychostimulants *viz.*, sympathomimetics (e.g. amphetamine, methylphenidate) and non-sympathomimetic drugs (e.g. caffeine, modafinil). However, these treatments are often responsible for rebound insomnia, daytime drowsiness, physical and psychological dependence, disturbed rapid eye movement (REM) sleep, cognitive function impairment leading to overall decreased quality of life. Existing data advocates only use of short-term pharmacological treatment whereas long term treatment has been shown to decrease effectiveness. As these interventions involve individualized attention by health care professional it becomes less cost-effective and less accessible [6, 7].

Other non-pharmacological treatment modalities like cognitive behavioral therapy, relaxation training, stimulus control therapy, physical and breathing exercise, yoga have shown a beneficial role in improving nighttime sleep [6]. These beneficial effects have been attributed to decreased stress, depression and improved inflammatory profile [6, 8].

Sudarshan Kriya Yoga (SKY) is a rhythmic breathing process which uses four stages of integrated Pranayama (breathing) processes which can be self-administered at home by previously trained subjects.

Current understanding of SKY shows beneficial association in various neuropsychiatric conditions like stress, anxiety, depression, post-traumatic stress disorder, stress-related medical illnesses, substance abuse and also in bowel function, improving lipid profile, and diastolic hypertension [9, 10]. SKY has previously shown to reduce sleep latency and curb age-related decrease in slow wave sleep [11].

The research conducted on sleep disorders every year has raised dramatically owing to its independent as well

as multifactorial causal association with several non-communicable diseases such as cardiovascular disease, type-2 diabetes, obesity, and depression [1]. Hence, in view of the electrophysiological improvements in sleep architecture shown by SKY in a prior study, we seek to further assess its efficacy in improving wakefulness by assessing the daytime and situational sleep propensity using Epworth Sleepiness Scale (ESS).

Materials and methods

Design: This is a prospective, parallel, controlled, efficacy study conducted in healthy volunteers.

Subjects: Prior to the workshops, respective batches of healthy volunteers between 16 and 25 years-of-age were screened for enrolment in an 8-week study. Subjects who were unable to perform physical exercise or with history of known sleep-wake cycle abnormalities, neurological, pulmonary, psychiatric disorders, substance abuse, medications altering autonomic functions and uncorrected visual defects were excluded. Subjects unwilling for random allocation to control group were also excluded. Subjects had no previous experience with pranayama and were explained the study protocol and their informed consent was taken. Our research involved human subjects and was compiled in accordance to all regulations and policies and has been approved by the Surana Sethia Hospital and Research Centre Institutional Ethics Committee vide SSH/IEC No.1002–1003. Permission to use SKY technique was obtained from Sri Sri Institute for Advanced Research.

Study: Subjects were randomized into SKY and control group by using standard randomization square technique and were matched for age and sex.

SKY group was made to perform SKY (30 min/day and 6 days/week) for 0–8 weeks of which the first-week was administered and supervised by a professionally trained SKY teacher; and self-administered subsequently.

Sudarshan Kriya Yoga (SKY): It begins with Ujjayi Pranayama, Bhastrika Pranayama, and Om Chanting; and is followed by Sudarshan Kriya (SK). SK is a reproducible breathing process believed to energize the body by relaxing the mind. It involves rhythmic cyclical breathing performed with slow, medium and fast cycles of breathing followed by meditation [10]. So, the four components SKY are explained as follows:

- (1) Three-Stage Ujjayi Pranayama: It is a three-staged pranayama performed by sitting in Vajrasana (sitting with spine erect and legs folded underneath) and making three different positions of hands. For the first stage, hands are held at the waist; for the second stage, hands are at the chest level and for the third stage, hands are placed on the upper back with elbows pointing upwards. For this Pranayama, Ujjayi breathing is used. Ujjayi breathing is breathing with mild airway resistance achieved by slight contraction of laryngeal muscles and partial closure of glottis maintained throughout the respiratory cycle. Each breathing cycle consists of inspiration - breathholding - expiration - breathholding with a ratio of 4:4:6:2. Eight such respiratory cycles are done at all the three stages at rate of 2–4 cycles/min with a period of rest in between with normal breathing.

Figure 1: CONSORT diagram summarizing participation from all batches in the study. [Original].

- (2) Bhastrika Pranayama: For one round of Bhastrika or Bellows breath pranayama, air is rapidly inhaled and forcefully exhaled for 20 breath cycles. Three such rounds are done sitting in Vajrasana with rest in between with normal breathing. During inspiration arms go straight up, hands open, and during expiration arms come down and hands close.
- (3) Om Chanting: 'Om' chanting was done three times.
- (4) Sudarshan Kriya (SK): The principal component of SKY consists of rhythmic synchronized breathing. It has three types of breathing rhythms, slow, medium and fast. It is followed by 5 min rest in supine position.

Controls were assured training in SKY after the conclusion of the study. During 0–4 weeks, they were instructed to do any sitting activity for 30 min. Subsequently, between 5 and 8 weeks, they were trained to perform three cycles/day of Suryanamaskar (SN) at gaps of 10 min (6 days/week).

Suryanamaskar (SN) is a 12-step yogic physical exercise wherein the subject assumes 12 different postures in sequential succession.

ESS is a subject-rated questionnaire used to determine subjective daytime and situational sleepiness. Respondents answer eight questions pertaining to their chance of dozing off or falling asleep in 8 day-to-day activities viz., sitting and reading, watching television, sitting inactively in public place, continuously sitting in a car as a passenger for an hour, talking to someone while sitting, resting by lying down in the afternoon, quietly sitting after lunch without alcohol and while a car is stopped for a few minutes in traffic [12, 13].

Each question was scored on a scale of 0–3 where zero indicates no chance of dozing and three indicates the highest chance of dozing

off, with a total ranging between 0 and 24. Score is interpreted as 0–5 lower normal daytime sleepiness; 6–10 higher normal daytime sleepiness; 11–12 mild EDS; 13–15 moderate EDS; 16–24 severe EDS. Data was obtained from subjects using questionnaire sheets before the first session and immediately after the sessions at 4 and 8 weeks. The individual daytime sleep propensity data were tabulated in MsExcel and ESS scores, both total and situational were computed. Data was analyzed using Stata/MP 15 software for Windows and subjected to paired t-test and two-sample t-test with equal variances.

Results

Out of the 180 subjects approached in all batches, only 105 actually participated (Figure 1) They were randomized into two groups viz., study (SKY) group (n=52) and control group (n=53). Sample size (n=105) was calculated using Cohen's formula with population proportion of 0.5, Cronbach's alpha of 0.05 and 5% margin of error. Detailed baseline history, anthropometry, and vitals were documented.

The randomly assigned subjects in SKY group had an average age of 19.68 years (SD=2.444), males 48%, height 165.23 cm (SD=4.65), weight 62.5 kg (SD=3.83) were compared to control group with an average age of 19.92

Table 1: Demographic Data of SKY and Control Groups (Standard Deviation values in brackets).

Variables	SKY Group (n=52)	Control Group (n=53)	Std. Deviation	Std. Error	p-Value
Age (years)	19.68 (2.45)	19.92 (5.22)	0.08	0.5	0.6301
Gender					
Male	25	27			
Female	28	25			
Body weight (kg)	62.5 (3.83)	64.1 (3.26)	3.6	0.701	0.0231
Height (cm)	165.2 (4.65)	165.9 (3.87)	4.04	0.83	0.43
Body Mass index (kg/m ²)	23.06 (2.13)	23.25 (2.47)	2.3	0.45	0.6741

Table 2: Comparison of ESS Scores in SKY and Control Groups (Standard Deviation values in brackets).

ESS scores	SKY Group	Control Group	Std. Deviation	Std. Error	p-Value
Week 0	9.2 (3.68)	9.68 (3.83)	0.15	0.75	0.5241
Week 4	7.98 (2.95)	9.7 (3.80)	1.72	0.68	0.0131
Week 8	6.32 (2.40)	9.68 (3.63)	1.22	0.62	0.0001

years (SD=2.52), males 53%, height 165.89 cm (SD=3.87), weight 64.1 kg (SD=3.26) (Table 1)

Comparison within SKY Group: SKY group showed consistently significant improvement in ESS score between 0 and 4 weeks of 1.22 (SD=1.919) ($p=0.0001$) and between 4 and 8 weeks of 1.66 (SD=1.813) ($p=0.001$) (Table 2)

Comparison within Control Group: Control group on the other hand didn't show significant difference in ESS score between 0 and 4 weeks (difference: 0.02, SD=1.039, $p=0.892$) and between 4 and 8 weeks (difference: 0.02, SD=0.622) ($p=0.8212$) (Table 2)

Comparison between SKY Group and Control Group: The baseline difference of ESS score between the groups was not significant at 0 weeks with a difference of 0.48 ($p=0.5241$). At 4 weeks, SKY group showed significant improvement in ESS score over control group of 1.72 ($p=0.013$); while at 8 weeks, SKY group continued to show significant improvement with ESS difference of 8 ($p=0.0001$) (Table 2)

Situational Sleep Propensities: Situational sub-scores of ESS showed the highest improvement in a car halted for a few minutes in traffic (52.94%) followed by sleepiness while sitting quietly after lunch without alcohol (38.68%). There was variable improvement in the other situations with the least improvement in sleepiness while watching television (13.07%) [12, 13] (Figure 2)

Obesity/Overweight and ESS: After completion of the study, the 17 overweight subjects (with BMI ≥ 25 kg/m²) showed statistically significant improvement of 3.41 which was greater than the 35 subjects with BMI lower than 25 kg/m² who improved by 2.52 ($p=0.0023$) (Figure 3).

Figure 2: Situational Sleep Propensity Scores at Week 0 and Week 8 (Percentages denote ESS Situational Scores between Week 0 and Week 8) [Original] (Index: Likelihood of falling asleep or dozing off while on an increasing scale of 0–3 as per ESS: Q1: Sitting and Reading, Q2: Watching Television, Q3: Sitting inactive in a Public Place (e.g. a theatre or a meeting place), Q4: As a passenger in a car for an hour without a break, Q5: Lying down to rest in the afternoon when circumstances permit, Q6: Sitting and talking to someone, Q7: Sitting quietly after a lunch without alcohol and Q8: In a car, while stopped for a few minutes in the traffic).

Figure 3: Comparative assessment of ESS Score change between Week 0 and Week eight wrt BMI in SKY Group [Original].

Discussion

This study demonstrated that Sudarshan Kriya Yoga (SKY) therapy for 8 weeks had a significant reduction of daytime and situational sleep propensity in previous non-practitioners of yoga. Improvement was more pronounced in overweight individuals and while waiting in a static car. These results confirm that the promising effects of SKY on sleep architecture demonstrated earlier translate into reduced EDS and make a case for research directed towards actual therapeutic recommendations.

Subjects who already practiced these yoga processes were excluded in order to obtain baseline ESS scores. Subjects whose response to SKY may be affected due to inability to perform physical and respiratory exercises, read ESS questionnaire or those with sleep-wake cycle anomalies like dyssomnias (hypersomnia, insomnia) or parasomnias (arousal disorder, sleep-wake transition disorders), psychotropic medication and neurological conditions were excluded from the study. However, subjects with previously undetected or subclinical sleep disturbances were included.

Subjects selected were between 16 and 25 years, automatically reducing age-specific variations in EDS. Subjects were matched for gender to exclude gender-specific variation in EDS like females reporting fatigue as sleepiness or sleepiness due to premenstrual syndrome [14]. Women tend to report insomnia higher than similar age men during the reproductive years as evidenced by higher ESS scores. This has been inconclusively linked to premenstrual syndrome, fluctuating progesterone levels and higher fatigability in luteal phase [14]. Randomization for age-sex was done to avoid errors observed by previous workers [15].

Current pharmacological management of sleep disturbances using benzodiazepines and nonbenzodiazepines is not only expensive but produces side effects like psychomotor imbalance, rebound insomnia, and altered REM sleep [7]. Low cost, ease of administration, near-universal applicability, better bio-safety profile compared to medications, and previously demonstrated positive effect on sleep architecture prompted us to choose SKY as a yoga-pranayama technique to reduce EDS [11, 16]. Sulekha et al. compared sleep architecture using polysomnography in Vipassana and SKY practitioners which is the only SKY-Sleep study yet. It showed that SKY reduced sleep latency but didn't improve REM sleep duration and quality, both very equivocal sleep-related outcomes [11]. We used ESS to assess if improved sleep actually improved daytime and situational sleep propensity in an attempt to alleviate any ambiguity.

ESS was selected as a tool for the detection of EDS due to superior prognostic value, reliability of reporting by lay subject or observer and high internal consistency aiding in group-wise comparisons. It confers two major advantages over Pittsburgh Sleep Quality Index (PSQI) viz., less cumbersome and can comment on situational sleep [14]. It is more sensitive than the Stanford Sleepiness Scale (SSS) [17].

Controls were made to perform two activities for four weeks each to verify the sleep neutrality of each. For the first four weeks, subjects were made to sit in clusters but at two feet distance from their peers in a well-illuminated and well-ventilated room. They sat erect, their feet touched the ground and were allowed to chat intermittently. In the next four weeks, they performed mild exercise in form of slow cycles of SN. Controls showed no significant differences in ESS score changes after stationary activity (0–4 weeks) and

SN (5–8 weeks); thus, concluding that neither maneuvers impact daytime sleep propensity and both serve as suitable controls.

The improvement in ESS scores in SKY group can be attributed to improvements in either the subject's nighttime sleep or daytime alertness or both. Several studies link components of SKY to factors that directly or indirectly favor a balanced sleep-wake cycle [18, 9, 19].

To understand the rationale behind the remarkable improvements in the SKY Group's ESS scores and sleep profile we need to understand the role of neuroendocrine influences in balancing sleep.

Jereth et al. present an interesting perspective on the influences of autonomic nervous system (ANS) on sleep onset latency, duration, and quality [20]. Their dysevolution theory proposes that the chronic sympathetic hyperactivation and/or parasympathetic hypoactivation disrupts sleep [20–22]. Monitoring heart rate variability (HRV) and respiratory sinus arrhythmia (RSA) is the current standard for studying the role and impact of ANS on sleep architecture. Increased alterations in HRV before sleeping and during stage-2 of non-rapid eye movement (NREM) sleep indicate sympathetic hyperarousal as a pathomechanism of chronic insomnia and general hyperarousal disorder [23].

Brown et al. design a heuristic model by combining several studies utilizing slow breathing to favorably increase the vagal tone (polyvagal theory) as the basis of the beneficial effects of SKY [19]. Ujjayi breathing just like Zen breathing practiced by the Rinzi sect involves slow, resistive and deep abdominal breathing. Resistive breathing against contracted laryngeal muscles and partially closed glottis stimulates upper respiratory somatosensory receptors that project upon the parabrachial nucleus (PBN) through the vagal afferents. This further increases lower frequency component of HRV and RSA [19, 24]. Practitioners of SK commonly experience drowsiness during or at the end of the hyperventilation (rapid cyclical breathing) followed by an "edge of sleep" state because resultant hypocapnia suppresses mesencephalic reticular activating system, thereby depriving thalamus of any non-vagal inputs [19].

Such predominantly vagal and sympathetically quiescent activity post SKY ensures better nighttime sleep and improved daytime wakefulness [22].

Short term stress has certain benefits due to autonomic arousal like heightened alertness and improved immunologic defenses [25]. However, prolonged and/or heightened stress levels produce a sustained autonomic tone that causes anxiety, mental blockage and dysfunctional lifestyle that impair cognition and ultimately disturb sleep. Thus, an autonomic response that was otherwise beneficial

turned debilitating due to persistent sympathoneural hypertonicity and dysregulation, a state which has been referred to as 'tired but wired' [26]. Practice of SKY showed relief of post-traumatic stress disorder symptoms when practiced in survivors of disasters and natural calamities [27]. Replacement of sympathetic tone by increased vagal activity reduces autonomic hypertonicity which plays an important role in reduction of stress-related insomnia [9, 19]. SK caused reduction in stress hormone (ACTH and cortisol) levels in a study involving detoxification of alcoholics which might indirectly suggest favorable actions on physiological and emotional stress [28]. Gene expression profiling has shown SK practitioners to have increased antioxidant levels further reducing oxidative stress [29].

Anxiety in moderation is a protective mechanism against potential danger. However, anxiety in excess and/or in response to false triggers causes dysfunctional arousal and sleep-wake abnormalities [30]. Insomnia and anxiety are linked pathologically by dysregulation of cholinergic and GABAergic (GABA: Gamma Amino Butyric A.) neurotransmitters and disruption of the corticolimbic circuit [31]. Agte et al. demonstrated reduction in anxiety scores while studying behavioral outcome measures in SK practitioners [32]. SKY has shown a balancing effect on the acetylcholine milieu in the brain by regulating vagal nerve stimulation [19]. Raised prolactin levels were linked to improvement in anxiety and depression in a study comparing SKY with imipramine and electroconvulsive therapy as therapeutic options [33].

While getting defeated in a battle and when escape is not possible animals develop certain innovative defense mechanisms. They perform ujjayi-like forced-resistive breathing that stimulates vagal afferents to nucleus tractus solitarius which further project onto hypothalamic vigilance center via parabrachial nucleus increasing vigilance and attentiveness [19]. It's possible that such augmented alertness can improve subjects' daytime wakefulness.

The highest reduction in situational daytime sleepiness as observed in our study was seen when sitting in a halted car in traffic could indicate beneficial effect in terms of alertness and wakefulness during commute thereby showing the potential to decrease road traffic accidents [14].

Sulekha and Thennarasu's findings were in professionals with long training duration and cannot correlate for general population. Additionally, our study shows benefits in younger population in spite of lack of polysomnographic improvement in this demographic as reported before [11]. Improvement in 'perception' of sleep-wake quality, in young population after relatively short training observed by us is not only an upgrade over

existing knowledge but also a strong motivator for further research in SKY and sleep.

A limitation of our study is that it relies extensively on ESS as a tool for measuring the efficacy of SKY. While ESS is an easy to use questionnaire, its combination with PSQI and polysomnography would give better understanding of the mechanisms of beneficial effects of SKY. A self-administered questionnaire is less likely to be completed than a physician-administered one, although this is much less of a case in online self-administered format [34]. The complex nature of SKY owing to multiple and mixed breathing patterns involved makes it difficult to administer and more so to standardize and document for every subject [19]. Smaller sample size and shorter duration of the study are common to most SKY research including this one, hence future researchers should focus more on long term efficacy of SKY while also inquiring the physiologic alterations that account for these benefits.

Of most advocated SKY practices, 5–10 min of slow Ujjayi breathing with eyes closed and a slight focus on partially contracted laryngeal muscles but without any breath counting or breath holding have been postulated to be most effective in improvement of sleep-wake patterns and reduction of insomnia. Our study almost conclusively upholds this understanding. As SKY has shown beneficial effects on stress, anxiety, and depression in other studies too, it can prove beneficial in insomnia due to these underlying psychiatric conditions [16].

Conclusions

We conclusively establish the usefulness of SKY in reduction of EDS confirming that the beneficial effects on sleep architecture observed by our predecessor translates into reduced daytime sleep; while eliminating ambiguity created by their equivocal findings [11]. We recommend large size, longer duration studies to develop exercise prescriptions and practicing guidelines to establish SKY as an inexpensive and preventive tool against sleep disorders.

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Author contributions: KSC, HBR conceived the idea; KSC, SSC, HBR, RRT drafted the protocol, conducted the study, collected and analyzed data; HBR trained subjects in Sudarshan Kriya Yoga and Suryanamaskar; VK Approved the protocol, analyzed data; KSC, SSC, HBR, VK, RRT wrote manuscript, approve the final version and guarantee response to queries.

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Informed consent: Informed consent was obtained from all individuals included in this study.

Ethical approval: Our research involved human subjects was compiled in accordance to all regulations and policies and has been approved by the Surana Sethia Hospital and Research Centre Institutional Ethics Committee vide SSH/IEC No.1002–1003.

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