

Exploration of Muscle Activity Using Surface Electromyography While Performing Surya Namaskar

Abstract

Background: Limited information is available to understand the muscular demands of composite yogasanas such as Surya Namaskar, which is essential to guide prescription of Surya Namaskar in management of commonly prevalent musculoskeletal disorders such as back and knee pain. **Aim:** Therefore, muscle activation pattern in prime accessible muscles of the trunk and lower extremity, namely lower trapezius, latissimus dorsi, erector spinae, rectus abdominis, gluteus maximus, vastus lateralis, and gastrocnemius, was explored during the traditional 12-pose sequence of Surya Namaskar. **Methodology:** Muscle activity of 8 healthy trained yoga practitioners (5 females and 3 males) was recorded using wireless, eight-channel surface electromyography (sEMG) system at a sampling rate of 2000 Hz and bandwidth of 20–450 Hz. Data were processed using EMGworks analysis software, and root mean square values were normalized against muscle activity during maximal voluntary contraction (MVC). **Results:** The 12-pose sequence of Surya Namaskar activated muscles of the trunk, upper and lower extremities to a varying extent, in each pose. During sustenance, erector spinae demonstrated the highest muscle activation in Hastapadasana (64.7% MVC in Pose 3 and 64.3% MVC in Pose 11), lower trapezius during Hastapadasana (41.9% MVC in Pose 3 and 39.2% in Pose 11); latissimus dorsi during Bhujangasana (37.4% MVC), Ashtangasana (34.9% MVC), and Parvatasana (34.6% MVC in Pose 8.); gluteus maximus in Ashwa Sanchalanasana (38.5% MVC in Poses 9 and 4); and vastus lateralis in Ashwa Sanchalanasana (34.9% MVC). Rectus abdominis demonstrated low activation throughout Surya Namaskar, presenting the highest activation during Parvatasana (22.8% MVC). All recorded muscles demonstrated greater activation during transition compared to sustenance of pose. **Conclusion:** Surya Namaskar elicited high-to-moderate muscle activation of major postural muscles of the trunk and lower extremity during alternating flexion-extension movements of the spine, supporting its prescription in prevention and management of mechanical low back pain among vulnerable groups of people.

Keywords: Muscle activity, surface electromyography, Surya Namaskar

Introduction

Musculoskeletal disorders are a diverse group of complex regional syndromes leading to acute or chronic pain, impaired physical function, and disability. The prevalence of musculoskeletal disorders increases with age, obesity, and physical inactivity.^[1] The World Health Organization estimates that approximately 40% of people over 70 years suffer from osteoarthritis (OA) knee and 80% of individuals experience low back pain (LBP) pain during their lives.^[2] A prevalence study conducted by the Indian Council of Medical Research reported an overall prevalence of musculoskeletal disorders to be 7.08%–11.5%.^[1] High prevalence of OA and spinal pain is associated

with lifestyle factors, level of physical activity, occupation, and psychosocial factors.^[3] Muscle imbalance, improper posture, weakness of core trunk and lower extremity muscles and lack of flexibility are associated with excessive joint loading during routine activities of daily living. Rehabilitation programs include mobility exercises to increase the flexibility of soft tissues and training of muscles to increase strength and endurance. In addition, over the past decade, there is a rising awareness of positive health benefits of Yoga in treating musculoskeletal disorders.^[4-8]

Yogasanas move the spine and lower extremities through a wide range of motion and are used to achieve fitness and rehabilitation of neuromusculoskeletal disorders.^[9] Yogasanas use tonic muscle

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contraction, co-ordinated with breathing control and kinesthetic awareness, which economizes on energy compared to phasic muscle contraction, often observed in physical exercises. Co-ordinated, rhythmical activities during yogasanas result in correction of postural deviations, and muscle imbalance, increase in joint mobility and muscle strength, stimulation of postural control mechanisms, and expanded self-awareness without undue fatigue.^[10]

Few studies report muscle activity of yogasanas. Information on muscle activity provides insight on muscular demands of various asanas and guides prescription in musculoskeletal conditions to improve strength and endurance of specific groups of muscles such as the erector spinae, rectus abdominis, gluteus maximus, hamstrings, and scapular stabilizers.^[11-13] Benefits of standing yogasanas on muscle activity are reported in elderly individuals. It was observed that muscle activation was greater in unsupported asanas compared to supported asanas.^[6] Most standing asanas activated quadriceps femoris, gluteus medius, erector spinae, and rectus abdominis compared to walk activity.^[6] Similarly, increased activation of the tibialis anterior and gastrocnemius is observed during single-limb standing poses when compared to a rest pose (Mountain Pose).^[7,14] Variation in muscle activation patterns in standing poses is observed to be dependent on trunk and pelvic positions during yogasanas.^[15] Recently, a mathematical model using optical motion capture and surface electromyography (sEMG) has been developed to study muscle activation patterns during yogasana.^[16]

Most studies have focused on muscle activity in either standing or single weight-bearing postures. Composite postures such as Surya Namaskar remain underexplored. Surya Namaskar or “sun salutation” is an ancient form of yogasana, practiced as a sequence of 12-consecutive poses, performed with synchronized breathing.^[17] Various studies have explored the effects of Surya Namaskar on stress,^[18] physical fitness,^[9] pulmonary function,^[19] physiological function,^[20] reaction time, heart rate,^[21] and OA.^[22] One study reports muscle activity during Surya Namaskar in yoga practitioners with varying levels of skill.^[15] However, the poses were performed in a random sequence on two different days, and varying muscle activity was observed in all participants. Consequently, there is a need to investigate muscle activity during the 12-pose sequence of Surya Namaskar, performed sequentially with synchronized breathing and kinesthetic awareness. Therefore, the objective of the present study was to investigate muscle activation patterns in prime muscles of the trunk and lower extremity during the indigenous 12-pose sequence Surya Namaskar. It was hypothesized that variations in muscle activity would be observed during transition from one pose to the next and during sustenance of the pose.

Methodology

Following approval from the Ethical Committee for Research on Human Subjects, Mahatma Gandhi Mission

Institute of Health Sciences, Navi Mumbai, 8 healthy, trained yoga practitioners (5 females and 3 males) were recruited. All participants were certified yoga practitioners, practicing for 5–10 years without a known history of musculoskeletal, cardiovascular, respiratory, metabolic, and neurologic disorders. All participants signed written informed consent as per the Declaration of Helsinki guidelines. Participants performed the 12-pose sequence of Surya Namaskar during motion capture as described below.

The 12-pose sequence of Surya Namaskar was as follows: Pranamasana (Pose 1 – Salutation Pose), Hasta Uttanasana (Pose 2 – Raised Arms Pose), Hastapadasana (Pose 3 – Hand-to-Foot Pose), Ashwa Sanchalanasana (Pose 4 – Equestrian Pose), Parvatasana (Pose 5 – Mountain Pose), Ashtanga Namaskara (Pose 6 – Eight-Limbed Pose), Bhujangasana (Pose 7 – Cobra Pose), Parvatasana (Pose 8 – Mountain Pose), Ashwa Sanchalanasana (Pose 9 – Equestrian Pose), Hastapadasana (Pose 10 – Hand-to-Foot Pose), Hasta Uttanasana (Pose 11 – Raised Arms Pose), and Pranamasana (Pose 12 – Salutation Pose) [Figure 1]. Although the participants belonged to different schools and practiced slightly varying forms of Surya Namaskar, they were instructed to follow the above sequence to maintain consistency.

Two practice trials were performed prior to testing. Participants wore appropriate bodysuits to permit unobtrusive motion. They were instructed to attain and hold each pose for 1 sec.

Muscle activity was recorded using a wireless sEMG eight-channel system (Trigno Wireless EMG System; Delsys, Inc., Boston, MA, USA) with a sampling rate of 2,000 Hz, bandwidth of 20–450 Hz, common mode rejection ratio >80 dB, and noise <0.75 μ V.^[18] In our previous kinematic study, it was observed that all poses, with the exception of Poses 4 and 9, were bilaterally symmetrical. Hence, muscle activity was recorded on the right side which was the dominant side of the body. Muscle activity of Pose 4 was reported for the forward-placed leg and in Pose 9 of the backward-placed leg. sEMG inertial motion (IM) sensors consisted of two 1-cm long parallel bars, 1–2-mm wide, spaced 1 cm apart, and placed on the midline of the muscle belly between the myotendinous junction and the nearest innervations zone with the detection surface oriented perpendicular to the length of muscle fibers. Activity was recorded from 7 muscles, namely lower trapezius, latissimus dorsi in the upper quadrant as scapular stabilizers, erector spinae and rectus abdominis as core muscle and gluteus maximus, vastus lateralis, and gastrocnemius, as the antigravity muscles of the lower extremity.

The placement of electrodes for each muscle was determined using anatomical landmarks.^[8] Electrode placement was determined by the sEMG for the noninvasive assessment of muscle protocol.^[23] Skin surface at each site

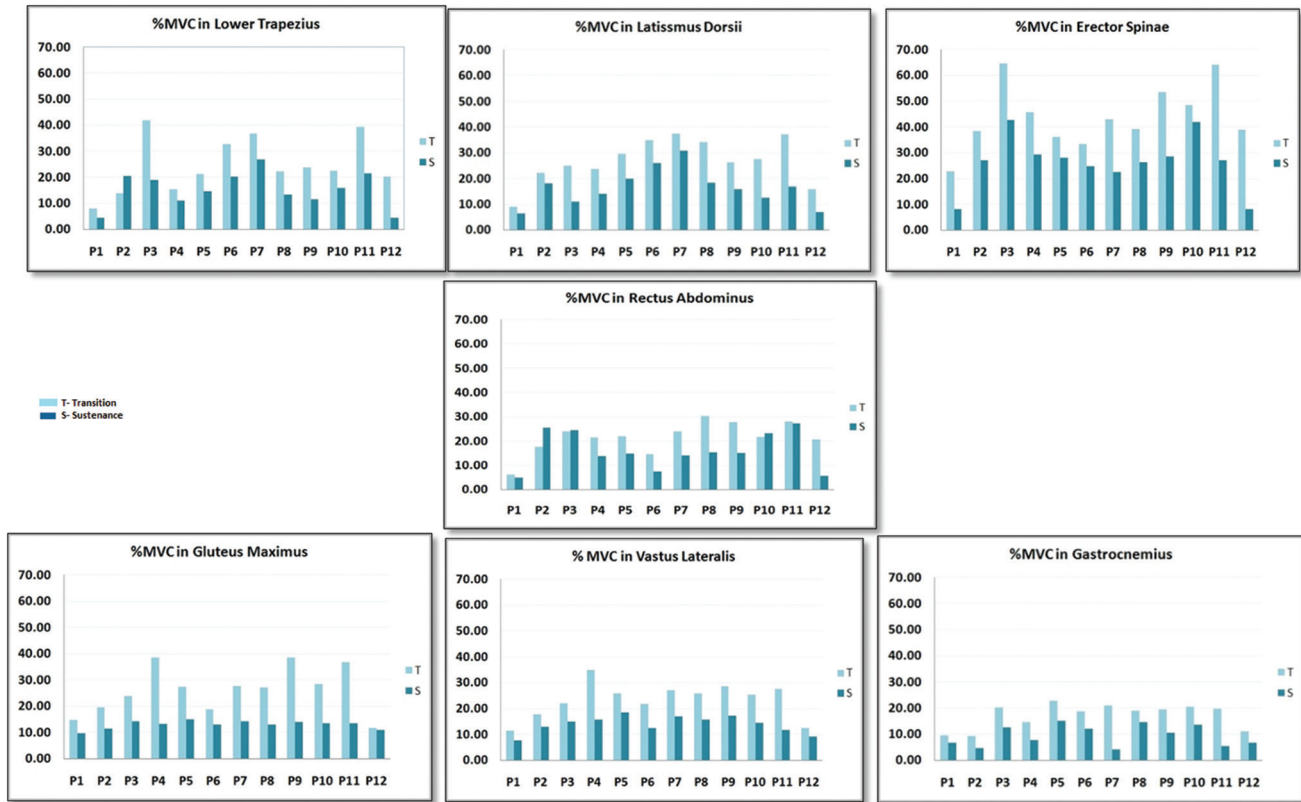


Figure 1: Comparative graph of trunk and lower extremity muscle activity as %MVC, during transition and sustenance of poses while performing 12-pose sequence of Suryanamaskar

was shaved; light repetitive peeling was done with a sticky tape and cleansed with alcohol to remove dead surface tissues and oil that might reduce conductivity. EMG data from each muscle were processed using EMGworks analysis software (Delsys Inc.). Root mean square (RMS) of the sEMG signal recorded from transition to sustenance of pose was used as a measure of average electrical muscle activity during each pose.

Muscle activity picked up by sEMG is known to be influenced by extrinsic and intrinsic factors influencing amplitude and frequency of signal. Extrinsic factors such as electrode structure and placement with respect to motor points in the muscle were controlled by reducing skin resistance and ensuring proper placement of electrodes to reduce noise. However, intrinsic factors such as number of active motor units, fiber-type composition of the muscle, fiber diameter, depth of muscle, and motor unit firing rate cannot be controlled. Hence, data were normalized using EMG activity from 10-s maximal voluntary contraction (MVC) of each muscle. During MVC test, participants were instructed to exert maximal effort and perform to the best of their ability. Data were normalized using RMS values during the middle 8 s of each 10-s MVC.^[13] Previously established test positions were used to record MVC of the erector spinae, lower trapezius, latissimus dorsi,^[24,25] rectus abdominis,^[26] gluteus maximus, vastus lateralis and gastrocnemius.^[27]

Results

The 12-pose sequence of Surya Namaskar activated muscles of the trunk, upper and lower extremities to a varying extent in each pose. The highest activity was recorded in the erector spinae, moderate activity in the lower trapezius, latissimus dorsi, gluteus maximus, vastus lateralis, and rectus abdominis, and the least activity was observed in gastrocnemius.

Erector spinae demonstrated the highest muscle activation in Hastapadasana (64.7% in Pose 3 and 64.3% in Pose 11); lower trapezius during Hastapadasana (41.9% in Pose 3 and 39.2% in Pose 11); latissimus dorsi during Bhujangasana (37.4% in Pose 7), Ashtangasana (34.9% in Pose 6), and Parvatasana (34.6% in Pose 8); and gluteus maximus in Ashwa Sanchalanasana (38.5% in Poses 9 and 4), whereas vastus lateralis was most active in Ashwa Sanchalanasana (34.9% in Pose 4). Rectus abdominis demonstrated low activation throughout Surya Namaskar with the highest activation during Parvatasana (22.8% in Pose 5). All muscles demonstrated greater activation during transition compared to sustenance of pose [Figure 2]. Muscle activation during each pose is described below:

- Pranamasana (Pose 1: Salutation Pose): It is an upright standing position with hands folded together in front of the body over the sternum in quiet stance with shoulder and elbow flexion, wrist extension, spine-hip-knee

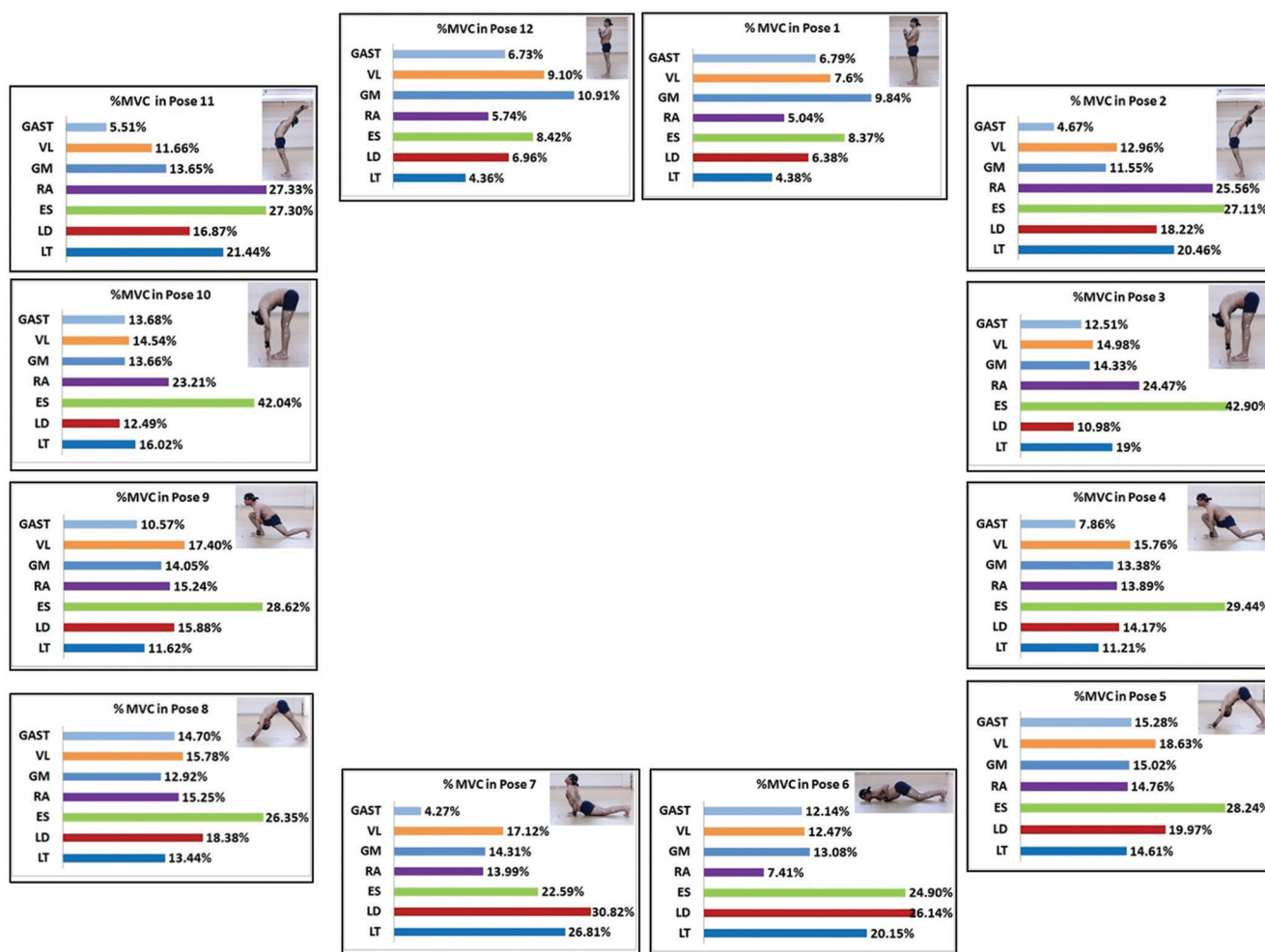


Figure 2: Muscle activity during sustenance of 12-pose sequence of Surya Namaskar. LT = Lower trapezius, LD = Latissimus dorsi, ES = Erector spinae, RA = Rectus abdominis, GM = Gluteus maxim, VL = Vastus lateralis, GAST = Gastrocnemius

extension, and ankle in neutral position. Transition from upright stand to Pose 1 demanded activation of erector spinae (22.8% MVC) while sustenance of this pose demanded low-level activity in all seven muscles. An increase in activation was defined as muscle activity $\geq 20\%$ MVC^[27,28]

- Uttanasana (Pose 2 – Raised Arms Pose): Transition from Pranamasana to Uttanasana (Pose 1–2), involved spinal extension with arms overhead. Increased activation was observed in the erector spinae, latissimus dorsi, and lower trapezius. Sustaining the pose demanded co-contraction of the erector spinae, rectus abdominis, and lower trapezius. Gastrocnemius demonstrated the least activity during this pose
- Hastapadasana (Pose 3 – Hand-to-Foot Pose): Transition from Pose 2–3 required spinal movement from 44.1° spine extension to 57.6° spine flexion, hip-knee flexion, and shoulders in flexion. The transition required a large forward and downward displacement of the center of mass (COM) (25 cm). The highest activity was recorded in the erector spinae and lower trapezius as

the spine moved from a position of extension to near full flexion. Stabilization of the spine while sustaining the pose was achieved by co-contraction of the erector spinae and rectus abdominis. Activation of the other muscles decreased as body weight was supported on the hands while sustaining this asana

- Ashwa Sanchalanasana (Pose 4 – Equestrian Pose): It is an asymmetrical pose with one lower extremity in flexion and other in extension. The forward limb demonstrated hip-knee flexion and ankle dorsiflexion while the backward limb demonstrated hip extension, minimal knee flexion, and ankle dorsiflexion. Body weight was borne on the upper extremities, knee of backward leg, and both feet. The transition required higher activation in the erector spinae, gluteus maximus, vastus lateralis, latissimus dorsi, and rectus abdominis of the flexed leg. However, once the pose was sustained, increased activation was observed only in the erector spinae
- Parvatasana (Pose 5 – Mountain Pose): Transition from Pose 4–5 demanded flexion of spine and hip bilaterally;

knee remained in neutral and ankle demonstrated peak dorsiflexion. Body weight was borne on flexed shoulder, elbow and wrist and feet, forming an inverted “V.” Moderate activation was observed in all 7 muscles with the highest activity in erector spinae. Sustaining the pose demanded higher activity in erector spinae

- Ashtangasana (Pose 6 – Eight-Limbed Pose): Pose 6 involved eight points of contact with the ground demanding spinal extension, hip-knee flexion, ankle dorsiflexion, shoulder extension, and elbow flexion. Body weight was borne on eight points of contact, namely both sides of the pelvis, hands, knees, and feet. Maximum activation was noted in the lower trapezius, latissimus dorsi, and erector spinae and vastus lateralis. The co-contraction of the lower trapezius and latissimus dorsi ensures scapular stabilization while the spinal extension was maintained by contraction of the erector spinae. Sustaining the asana required higher activation in the lower trapezius, latissimus dorsi, and erector spinae
- Bhujangasana (Pose 7 – Cobra Pose): Pose 7 demanded extension of the spine and hip, knee flexion, ankle dorsiflexion, and slight flexion of the shoulder and elbow, while the wrist was dorsiflexed. Upper body weight was supported on hands, whereas lower body weight was supported on the ground. The transition demanded activation of antigravity extensor muscles, namely erector spinae, lower trapezius, and latissimus dorsi. The asana was sustained by activity in all three muscles.

Although asanas 8, 9, 10, 11, and 12 are mirror images of asanas 5, 4, 3, 2, and 1, respectively, wherein kinematics of the poses are similar, muscle activation was marginally different due to reversal of transitions. However, sustenance of Poses 8, 9, 10, 11, and 12 demanded similar muscle activity as that of Poses 5, 4, 3, 2, and 1, respectively.

Discussion

The present study reports rigorous evaluation of muscle activity of 12-pose Surya Namaskar sequence in seven muscles of the upper extremity, trunk, and lower extremity. Although Surya Namaskar would activate many more muscles of the body, these seven muscles were selected as prime movers of the spine, scapula, and lower extremity.

The 12-pose sequence of Surya Namaskar activated muscles of the trunk, upper and lower extremities to a varying extent in each pose. It was observed that the pattern of muscle recruitment during the entire 12-pose sequence was similar in all the yoga experts tested who practiced yogasana for a minimum of 5 years. It is known that regular practice of any posture results in consistent performance.^[6]

During entire sequence of Surya Namaskar, substantial muscle activation was observed in the erector spinae; moderate activation in the lower trapezius, latissimus dorsi, gluteus maximus, vastus lateralis, and rectus abdominis;

and least activation in the gastrocnemius. Salem *et al* (2013) have also reported high muscle activity of gluteus medius, hamstrings, vastus lateralis, and gastrocnemius while performing standing asana compared to walking at a self-selected speed.^[6]

Transition from one pose to another required isotonic muscle contraction compared to sustenance of pose, which can be considered as an isometric contraction. Each muscle was activated to varying extent during the poses. Lower trapezius was activated maximally (72%) during transition from Ashtangasana (Pose 6) to Bhujangasana (Pose 7). Similarly, latissimus dorsi demonstrated greater muscle activation (82.3%) during transition from Ashtangasana (Pose 6) to Bhujangasana (Pose 7), erector spinae (86%) during transition from Ashwa Sanchalanasana (Pose 9) to Hastapadasana (Pose 10), rectus abdominis (143%) during transition to Uttanasana (Pose 11), gluteus maximus (91%) during transition to Pranamasana (Pose 12), vastus lateralis (73.2%) during transition to Pranamasana (Pose 12), and gastrocnemius (78%) during transition to Parvatasana (Pose 8). Thus, it can be summarized that various asanas place varying muscular demands which can be used to target specific muscle activation patterns desirable for therapy. Neuromuscular control required to maintain balance and large displacement of COM is reflected in increased activation of all 7 muscles through the 12 poses of Surya Namaskar.

In our previous study, it was observed that Surya Namaskar moved joints of the spine and lower extremity across high range of motion in alternating flexion-extension movements.^[17] Although it is argued that spine extension exercises may increase loads on apophyseal joints of the lumbar spine, it is speculated that these loads may be off-set by alternate flexion-extension movements in Surya Namaskar, performed in a slow, rhythmic pace. It would also prove to be a beneficial exercise, which can be adopted for gentle stretching of the erector spinae muscle and posterior soft-tissue structures of the hip observed in swayback posture, which is known to cause increased stress on the lumbosacral junction.

It is already reported that even low muscle activity equivalent to 10%–25% of MVC is effective in stabilizing the low back during activities of daily living.^[28,29] Surya Namaskar elicited muscle activity to a maximum of 64.7% of MVC during sustenance and as high as 86% of MVC during transition. Therefore it is expected that Surya Namaskar, performed at slow, rhythmic pace with kinesthetic awareness and synchronized with breathing control is best suited to activate erector spinae muscle which is largely composed of aerobic, slow-fatiguing muscle fibers.

Second, the contribution of core muscles such as erector spinae and rectus abdominis coupled with latissimus dorsi

and lower trapezius is known to enhance spinal stability.^[30] Current evidence suggests that weakness of erector spinae, multifidus, abdominals, latissimus dorsi, and lower trapezius predisposes to risk of back pain and dysfunction of the upper quadrant.^[12,30] During Surya Namaskar, low-to-moderate activation of rectus abdominis was observed throughout all poses. The abdominal muscles generate force and change in length throughout the range of motion of the lumbar spine, acting like a cylinder around the spine to distribute compressive forces.^[31] Our findings demonstrate that large transitions requiring rising up from floor from Bhujangasana (Pose 7 – Cobra Pose) to Parvatasana (Pose 8) demanded large excursion of COM (23.5 cm) of the body with consequent concentric contraction of the rectus abdominis for stabilization of the pelvis.^[31]

Third, latissimus dorsi acts as an important trunk stabilizer to produce a moderate amount of force over a large range of length, with maximum activation during flexion/extension of the trunk. Simultaneously, eccentric contraction of the lower trapezius stabilizes scapula against the thorax while weight-bearing on the upper extremities in Ashtangasana (Pose 6) and Bhujangasana (Pose 7). The co-contraction of all four trunk muscles was observed through the 12 poses of Surya Namaskar which is therapeutically beneficial to treat muscle weakness among people presenting with low back pain and trunk and shoulder girdle muscle weakness.^[11]

Additionally, along with spinal stability, strength and stability of lower extremity are important determinants of performance of functional activities of daily living. Antigravity muscles, namely the gluteus maximus: a pelvic stabilizer and hip extensor, quadriceps muscles: a knee extensor, and gastrocnemius: an ankle plantar flexor, work together to enhance the stability of the lower extremity. It is noticed that Surya Namaskar can also effectively activate these three prime antigravity muscles of lower extremity kinetic chain to improve muscle strength and endurance among people with lower extremity disorders such as OA of the knee.^[32]

In summary, Surya Namaskar is known to produce movement across majority of joints of the upper extremity, spine, and lower extremity and therefore is a potential therapeutic tool for improving mobility across all major joints of the body. Large transitions of body segments during Surya Namaskar resulted in large excursion of COM in vertical and anteroposterior directions, thereby activating postural control mechanisms and muscle activity necessary to maintain the stability of the body in all 12 asanas (poses).^[17] Precise knowledge of muscle activity during 12 asanas can be used to target specific muscle weakness encountered in clinical practice while treating musculoskeletal disorders.^[29]

In addition, it may be used to improve the activity profile of elderly individuals who present with low muscle strength

and endurance. Varying activation of muscles during transition and sustenance of poses can be used to obtain the desired therapeutic effect in terms of strength training and motor control. Slow transitions may be prescribed for elderly people with low muscle strength. Overall, Surya Namaskar can be included in prophylactic programs for health promotion and in rehabilitation of musculoskeletal conditions such as low back pain, neck pain, and shoulder dysfunction.

Conclusion

The 12-pose sequence of Surya Namaskar elicited substantial activation of muscles of the trunk, upper and lower extremities to a varying extent in each pose. The highest muscle activation was observed during poses involving large transitions of spinal flexion and extension, namely Hastapadasana (Pose 3), Uttanasana (Pose 2), Bhujangasana (Pose 7), and Ashtangasana (Pose 6). Erector spinae was maximally activated, followed by latissimus dorsi and lower trapezius. Erector spinae worked as a core stabilizer during these asanas; however, latissimus dorsi and lower trapezius were recruited synergistically to achieve postural control during slow controlled movements resulting in gentle transitions during the asanas. Higher muscle activation was observed during transition from one pose to another compared to sustenance of pose.

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Conflicts of interest

There are no conflicts of interest.

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