

Yoga in Motion: The Science and Technology Behind Postural Stability

KID: 20250323 | Mr S Uday Kumar



Based on the study “Biomechanical Analysis of Yogasana for Prevention and Rehabilitation: An Active LED-Based Marker Motion Capture System Approach”

Part 1 – The Science of Stillness: Classical Roots of Yogic Posture

“स्थिरसुखमासनम्” (Yoga Sūtra 2.46) – Āsana is a posture that is steady and comfortable. With this simple aphorism, Sage Patañjali defined what modern science now calls postural stability—the ability to hold alignment with minimal effort.

In the Bhagavad Gītā, Śrī Kṛṣṇa calls yoga “समत्वं योग उच्यते” (2.48) – equanimity. In 6.13, he instructs:

“समं कायशिरोग्रीवं धारयन्नचलंस्थिरः । संप्रेक्ष्य नासिकाग्रं स्वं दिशश्चानवलोकयन्॥”

(Samaṁ kāya-śīro-grīvaṁ dhārayann acalaṁ sthiraḥ...) — maintaining axial alignment of the spine, neck, and head while fixing the gaze at the nose tip (nāsāgra dr̥ṣṭi).

This ancient description mirrors what neuroscience identifies as visual anchoring – reducing unwanted eye movements to calm the nervous system.

The Gheraṇḍa Saṁhitā (1.9) states: “षट्कर्मणा शोधनं च आसनेन भवेद् दृढम्।” Through purification comes stability; through āsana, firmness. These verses reveal that early yoga texts viewed posture not as mere physical training but as a precise science of alignment, balancing gravity, breath, and consciousness. Modern biomechanics now interprets this stability through neuro-musculoskeletal coordination—a dynamic equilibrium of brain, nerves, and muscles that keeps the body upright and steady.

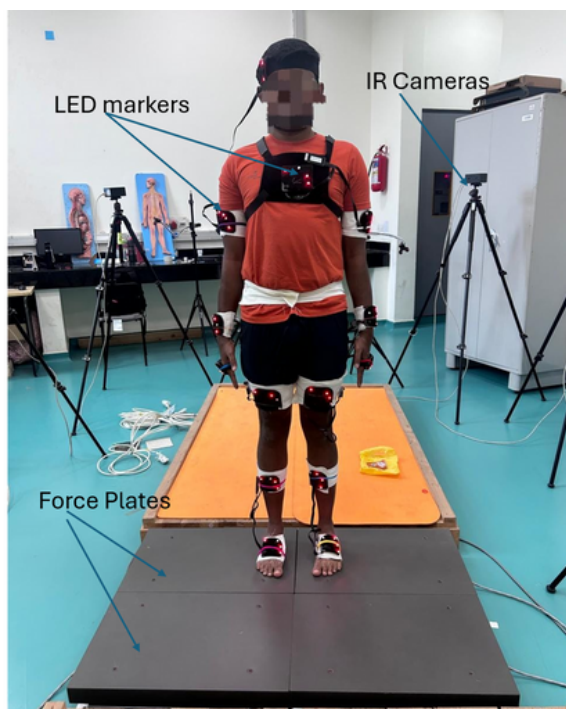


Fig 1. Capturing alignment in Tādāsana using LED-based motion tracking

When practiced mindfully, asanas such as Tādāsana (Mountain Pose) align natural spinal curves so that the center of gravity rests directly above the base of support. Weakness or imbalance disrupts this harmony, demanding more muscular effort and leading to fatigue.

By contrast, yogic training optimizes this equilibrium—strengthening core muscles, improving proprioception, and conserving energy.

Part 2 – Modeling Motion: Biomechanics of Yogāsana through Modern Technology

To explore how āsanās create stability, researchers are applying advanced active LED-based motion capture (MoCap) systems. Each marker on the body emits infrared light, allowing cameras to record its precise 3-D position up to 1000 times per second. This high-resolution data is processed in OpenSim software using Inverse Kinematics (to calculate joint angles) and Inverse Dynamics (to estimate joint moments and reaction forces).

Synchronized EMG data further reveals muscle activation patterns—turning classical postures into quantifiable movement models.

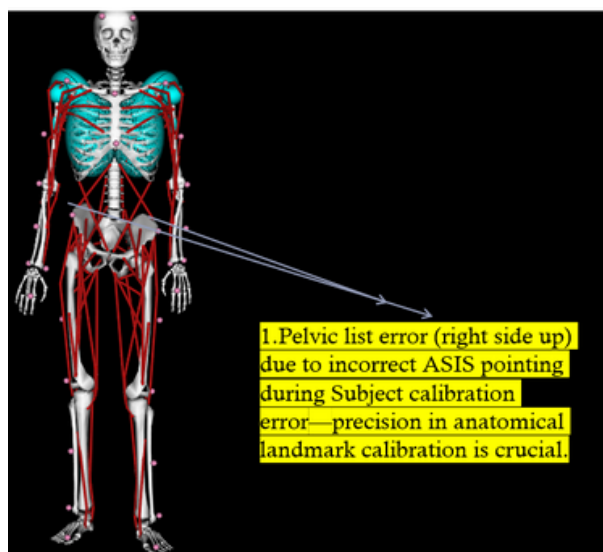


Fig 2. Inverse Kinematics in OpenSim helps visualize pelvic and spinal alignment during Tādāsana.

Common challenges such as marker displacement or calibration errors can distort data, especially if anatomical landmarks like the ASIS (anterior superior iliac spine) are imprecisely located. Soft-tissue movement may also shift markers, causing false pelvic tilt or range-of-motion (ROM) readings. Hence, precise placement and repeated calibration are crucial for reliable biomechanical modeling.

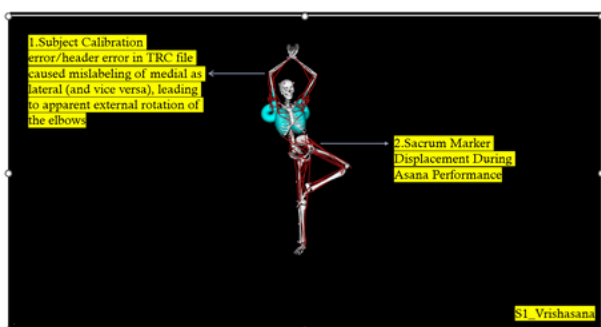


Fig 3. Marker Displacement Error: soft-tissue shifts causing apparent pelvic deviation

Kinematic Insights from a Pilot Study on Tādāsana

Subject	Training Level	Total ROM (°)	Observation
S1	Trained	7.41	Minimal joint movement → High stability and symmetry
S2	Semi-trained	19.94	Greater hip/knee motion → Moderate imbalance
S3	Untrained	15.30	Larger adjustments → Less control and uneven posture

Trained practitioners displayed the least overall movement, reflecting refined neuromuscular control and improved postural symmetry. As training level decreased, joint fluctuations increased—indicating compensatory movements and less stable alignment.

A secondary analysis of bilateral asymmetry showed that experienced subjects exhibited near-equal right–left motion (difference < 1°), while semi-trained practitioners showed up to 0.5° difference, and untrained ones nearly 0.7°.

Such micro-imbalances, though small, can translate into fatigue or joint strain over time. These findings demonstrate how yoga training gradually conditions the body for mechanical efficiency, echoing ancient ideals of “effortless steadiness.”

Future Scope

Integrating MoCap with electromyography (EMG) and force-plate data will deepen understanding of how muscles, joints, and gravity interact during āsanas. Refined marker placement, advanced musculoskeletal modeling in OpenSim, and larger participant cohorts will enable causal mechanical models of yogic stability. Such frameworks could help clinicians personalize post-operative or rehabilitative yoga prescriptions based on age, weight, and comorbidities—bridging traditional insight and medical application.

Heritage Science and Technology thus stands at a unique juncture: preserving ancient wisdom while defining it through data. In the end, whether seen through the lens of Sanskrit philosophy or biomechanical simulation, yoga remains a living bridge where stillness meets science.

References & Further Reading

1. Carini F. et al. Posture and Posturology: Anatomical and Physiological Profiles. Acta Biomed, 2017.
2. Kim D.-H. et al. Influences of Posterior-Located Center of Gravity on Lumbar Extension Strength. J Back Musculoskeletal Rehabil, 2014.
3. Takakusaki K. Functional Neuroanatomy for Posture and Gait Control. J Mov Disord, 2017.
4. Wang M.Y. et al. Biomechanical Demands of Standing Yoga Poses in Seniors. BMC Complement Med, 2013.
5. Yang J. Analysis of Motion Capture Technology Research and Typical Applications. Appl. Comput. Eng, 2024.

Mr S Uday Kumar

Research Scholar

Dept of Heritage Science and Technology