Balance Without Sight: A Surface Electromyography Study of Four Standing Yoga Postures Performed with and Without Visual Feedback

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ABSTRACT

Standing balance postures in yoga require continuous, moment-to-moment correction from the leg muscles and taking away vision is known to shift more of that correction onto the proprioceptive and vestibular systems. This study measured surface electromyography (EMG) from the gastrocnemius, soleus, vastus medialis, and vastus lateralis in 37 young adult male yoga practitioners while they held four standing balance asanas -- Natarajasana, Garudasana, Vrikshasana, and Virabhadrasana III -- first with the eyes open and then with the eyes closed. Root-mean-square (RMS) amplitude was compared across asanas and visual conditions using two-way repeated-measures ANOVA, with Greenhouse-Geisser correction when sphericity was violated. All four muscles trended higher without vision, and the pooled non-visual RMS ran 4.9 to 25.2 [mu]V above the visual condition in three of the four muscles. The interaction between asana and visual condition reached significance for the gastrocnemius, vastus medialis, and soleus (all $p < .05$). Vrikshasana produced by far the largest rise in gastrocnemius activity once the eyes closed (+59.7 [mu]V), while Virabhadrasana III produced the largest rise in soleus activity (+32.3 [mu]V). The two quadriceps muscles behaved differently in Natarajasana, where activity was actually higher with the eyes open, the only reversal found in the data set. These results indicate that the postural cost of closing the eyes is neither uniform across muscles nor constant across poses, and that the ankle muscles absorb more of that cost than the thigh muscles in most, though not all, of the asanas tested.

Keywords: *Yoga asanas, electromyography, postural control, sensory reweighting, balance, proprioception*

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DOI: https://doi.org/10.66509/IJPS.21.sp.2026.87-96

INTRODUCTION

Standing on one leg seems simple enough until you have to do it for more than a few seconds. The base of support is now the width of your foot, and your nervous system makes adjustments to your musculoskeletal system many times per second, using three different reference points: vision, the inner ear, and specialized receptors in muscles, tendons, and joints. Take one of those sources away and the body has to lean harder on the remaining two, a process usually called sensory reweighting. Calling it a simple on-off switch would be an understatement. Peterka modeled change of sway responses in reply to change in sensory input and the finding pointed that the nervous system keeps on adjusting amount of weight it gives to each sense continuously. Further work by Assländer and Peterka indicated that vision and proprioception are not reweighted together at the same time; each can shift individually and at its own pace. In other words, it can be said that closing the eyes is not simply a loss of information. It leads to a measurable and considerable change in the amount of hardwork the postural muscles have to do.

Yoga asanas form a natural place to notice this type of change, because many of the

standing poses are traditionally and deliberately difficult balancing tasks. A narrow base of support, sometimes even just using one foot, is held for many seconds at a time, and instructors have frequently asked students to close their eyes specifically to make a pose harder. Yet the majority of EMG research to date on yoga has been asking a narrower question of how active a given muscle is during a given pose, almost always with the eyes open. Ni et al. compared core-muscle activation across skill levels in several asanas and found pose-specific increases in external oblique activation even in experienced practitioners. Kelley et al. recorded the tibialis anterior, gastrocnemius, rectus femoris, and biceps femoris during tree pose, half-moon pose, and warrior III and found that warrior III produced the highest gastrocnemius and rectus femoris activity of the three. Lehecka et al., expanded on this line of research into the gluteus maximus and medius across five poses and found the highest gluteal demand in half-moon pose and warrior III, both single-leg poses which hold the trunk close to horizontal. Wang et al. and Yu et al. examined the biomechanics of standing poses, including tree pose, in older adults and found meaningful joint moments and postural sway even in a population with a smaller balance reserve to begin with. None of these studies, however, varied vision within the same pose to see what closing the eyes would do to a given muscle.

Outside the yoga literature, that question has been asked directly. Labanca et al. recorded EMG from thirteen lower-limb, hip, and back muscles during simple single-leg stance, eyes open and eyes closed, and found the same four muscle synergies in both conditions, but the ankle-dominant synergy grew stronger once the eyes closed while the hip-and-back synergy weakened. This suggests that the calf and shin muscles, not the hip or thigh, are the place where the postural bill for closing the eyes is paid, at least during plain single-leg stance without the added demands of an asana layered on top.

A direct look inside the same asanas that looks at how much extra work several leg muscles have to do once the sense of vision is removed is missing. It is also important to see whether that extra cost is the same from one pose to the next. Four asanas are studied here — Natarajasana, Garudasana, Vrikshasana, and Virabhadrasana III. All of these differ in the support base, angle of trunk, and position of limb. If sensory-reweighting theory holds, all of these should change how much any one muscle has to work extra or pick up the slack once the vision sense is disabled.

The study consisted of three questions. First, does the removal of vision result in higher EMG activity of the gastrocnemius, soleus, vastus medialis, and vastus lateralis muscles while practicing each of the four standing asanas? Second, does the asana itself result in muscle activity different within each visual condition independently? Third, does the magnitude of the visual effect depend on the asana (i.e., is there an asana × condition interaction)? According to the sensory-reweighting literature, RMS amplitudes are expected to be higher while participants have their eyes closed than open across all limbs; further, the ankle muscles are expected to demonstrate a greater increase than the thigh muscles, and the magnitude of increase is expected to vary across asana conditions.

METHOD

Participants

Thirty-seven male yoga participants between the ages of 18 to 25 years old were included in the study (M = 21.3). The years of reported yoga experience varied from 14 to 28 months (M = 21.6 months). Participants did not report any lower-limb injury, vestibular disorder, or uncorrected visual deficit in the six months leading to testing. All participants provided a written informed consent form.

Design and Procedure

Each participant performed four standing balance asanas — Natarajasana (dancer's pose), Garudasana (eagle pose), Vrikshasana (tree pose), and Virabhadrasana III (warrior III) — under two visual conditions, eyes open (visual) and eyes closed (non-visual), giving eight trials per participant. To control for order and fatigue effects, randomization of both the order of asanas and the order of visual conditions were done across participants.

EMG Recording

The following four muscles of the standing leg: gastrocnemius, soleus, vastus medialis, and vastus lateralis were observed and surface EMG was recorded from each. The skin was shaved, lightly abraded, and cleaned with alcohol and then the electrodes were placed over each muscle belly following the electrode-placement conventions that are used in other comparable EMG studies of yoga postures (Lehecka et al., 2021). To capture a stable window for recording, each asana was held for considerable time. To remove the transitioning into and out of the pose, first and last portions of each trial were trimmed before the analysis. Raw EMG was rectified and band-pass was filtered. For each trial, two amplitude measures were derived. One is root-mean-square (RMS) amplitude which is the primary outcome reported here. Other is peak amplitude which followed the same pattern as RMS with more trial-to-trial noise and is summarized only briefly. All EMG values are reported in microvolts (μV); because the study used raw amplitude rather than amplitude normalized to a maximum voluntary contraction, RMS values are best compared across the conditions and poses within this study rather than against %MVIC figures reported in other yoga EMG papers.

Statistical Analysis

For each of the four muscles, a two-way repeated measure of ANOVA (4 asanas × 2 visual conditions) was performed on RMS amplitude. Mauchly's test was used for the sphericity assumption; the Greenhouse-Geisser correction was applied to each effect of this test that violated sphericity. Within each visual condition, if the main effect of the asana was significant in its respective analyses, then we performed a one-way repeated-measures ANOVA (a simple-effects test) separately for that same condition and followed it up with paired t-tests of all six asana comparisons with Bonferroni's correction within muscle-by-condition family of comparisons. All effect sizes were reported with either partial eta-squared (ηp2) for ANOVA effects, or Cohen's dz for the paired comparisons. Normality of RMS amplitude was assessed with the Shapiro-Wilk test of every individual of the 32 muscles × asana × condition cells. Because more than half of these cells showed deviates from a normal distribution, a log-scaled version of the same analysis has been run as an additional sensitivity check alongside with the present results, and any effect that lost significance in the transformation to log scale is explicitly noted in the Results section. Finally, the alpha level for all primary analyses was set at .05; as a secondary, more conservative check, a Bonferroni-corrected alpha of .0125 (across the four muscles tested) was also employed.

RESULTS

Descriptive Pattern

Across the four muscles, the non-visual condition produced a higher pooled mean RMS than the visual condition for three of the four muscles; gastrocnemius (81.1 ± 69.5 vs. 55.9 ± 43.1 μV), vastus medialis (78.8 ± 54.5 vs. 66.7 ± 71.6 μV), vastus lateralis (53.3 ± 36.9 vs. 45.0 ± 41.5 μV), and soleus (68.7 ± 31.4 vs. 51.3 ± 26.5 μV). The single largest cell in the entire data set was gastrocnemius activity in Vrikshasana with the eyes closed (135.0 ± 72.9 μV) which is almost double the activity in the same muscle using the same

asana, but with eyes open (75.4 ± 49.4 μV). The full analysis across the four muscles, two asanas, and two conditions can be found in Table 1.

Table 1. Mean (± SD) RMS Amplitude (μV) by Muscle, Asana, and Visual Condition (N = 37)

Muscle / Asana		Visual (M ± SD)	Non-visual (M ± SD)
Gastrocnemius	Natarajasana	78.9 ± 35.2	87.1 ± 73.0
	Garudasana	58.5 ± 28.7	72.9 ± 27.5
	Vrikshasana	75.4 ± 49.4	135.0 ± 72.9
	Virabhadrasana III	11.0 ± 6.9	29.5 ± 50.1
	Pooled	55.9 ± 43.1	81.1 ± 69.5
Vastus medialis	Natarajasana	103.0 ± 78.8	72.0 ± 63.0
	Garudasana	66.2 ± 40.9	91.6 ± 44.7
	Vrikshasana	19.6 ± 22.9	48.4 ± 40.5
	Virabhadrasana III	78.1 ± 93.6	103.1 ± 52.5
	Pooled	66.7 ± 71.6	78.8 ± 54.5
Vastus lateralis	Natarajasana	48.0 ± 51.2	37.8 ± 41.1
	Garudasana	49.6 ± 22.7	57.3 ± 24.9
	Vrikshasana	26.7 ± 34.0	51.1 ± 39.1
	Virabhadrasana III	55.6 ± 47.6	66.9 ± 35.4
	Pooled	45.0 ± 41.5	53.3 ± 36.9
Soleus	Natarajasana	58.3 ± 24.6	72.9 ± 26.2
	Garudasana	68.2 ± 21.7	77.5 ± 28.3
	Vrikshasana	54.3 ± 20.4	67.5 ± 32.1
	Virabhadrasana III	24.6 ± 17.1	56.9 ± 35.5
	Pooled	51.3 ± 26.5	68.7 ± 31.4

Note. "Pooled" rows average across the four asanas within each muscle and visual condition.

Main Effects

The two-way ANOVA revealed a significant asana main effect in all four muscles: gastrocnemius, $F(3, 108) = 41.98$, $p < .001$, $\eta p2 = .538$; vastus medialis, $F(3, 108) = 16.50$, $p < .001$, $\eta p2 = .314$; vastus lateralis, $F(3, 108) = 4.92$, $p = .003$, $\eta p2 = .120$; and soleus, $F(3, 108) = 19.27$, $p < .001$, $\eta p2 = .349$. Which asana a participant was maintaining had a substantial effect regardless of vision. The condition main effect (visual vs. non-visual, averaged across all four asanas) was significant in two of the four muscles: gastrocnemius, $F(1, 36) = 16.09$, $p < .001$, $\eta p2 = .309$, and soleus, $F(1, 36) = 37.49$, $p < .001$, $\eta p2 = .510$. Vastus medialis, $F(1, 36) = 2.76$, $p = .105$, $\eta p2 = .071$, and vastus lateralis, $F(1, 36) = 3.78$, $p = .060$, $\eta p2 = .095$, were not significant for condition alone — which is a surprising

result in a sense since both muscles displayed a significant interaction (to be described below) implying that the visual effect was present but dependent on the pose rather than constant. Table 2 contains the complete summary of main-effects and interactions.

Table 2. Two-Way Repeated-Measures ANOVA on RMS Amplitude by Muscle

Muscle	Effect	F (df1, df2)	p	ηp²
Gastrocnemius	Asana	41.98 (3, 108)	< .001	.538
	Condition	16.09 (1, 36)	< .001	.309
	Asana × Condition	5.04 (3, 108)	.003	.123
Vastus medialis	Asana	16.50 (3, 108)	< .001	.314
	Condition	2.76 (1, 36)	.105	.071
	Asana × Condition	3.99 (3, 108)	.010	.100
Vastus lateralis	Asana	4.92 (3, 108)	.003	.120
	Condition	3.78 (1, 36)	.060	.095
	Asana × Condition	2.73 (3, 108)	.048	.070
Soleus	Asana	19.27 (3, 108)	< .001	.349
	Condition	37.49 (1, 36)	< .001	.510
	Asana × Condition	2.89 (3, 108)	.039	.074

Note. p values for the Asana and Asana × Condition effects are Greenhouse-Geisser-corrected where Mauchly's test indicated a violation of sphericity.

Differences Among Asanas Within Each Condition

Because asana was such a powerful driver on its own, one-way repeated-measures ANOVAs were conducted separately within the visual and non-visual conditions for each muscle (Table 3). Each of these eight tests was significant besides the soleus in the non-visual condition, which was only marginally significant, F(3, 108) = 3.02, p = .033, p_GG = .035, ηp2 = .077, and did not survive the Bonferroni pairwise follow-up.The clearest pattern was seen in the gastrocnemius muscle. Vrikshasana produced more gastrocnemius activity than other asanas when eyes were closed. It read 47.96 μV more than Natarajasana (p_bonf = .037) and 62.17 μV more than Garudasana (p_bonf < .001). Virabhadrasana III produced the least gastrocnemius activity among the four poses (all p_bonf < .001). The ranking shifted when the eyes were kept open. Natarajasana produced the highest gastrocnemius activity. Virabhadrasana III still remained the lowest by a huge margin (67.98 μV below Natarajasana, p_bonf < .001).

The vasti told an entirely different story. Vrikshasana produced the lowest vastus medialis activity of the four poses in both eyes open as well as closed condition. It read 43.12 μV below Garudasana with the eyes closed (p_bonf < .001) and 58.53 μV below Virabhadrasana III with the eyes open (p_bonf = .004). It suggests that this particular pose demands comparatively little of the inner quadriceps regardless of open or closed eye, even while it demands a great deal of the calf.

When it came to soleus, the picture flipped depending on visual conditions. When the eyes were kept open, Virabhadrasana III produced far less soleus activity than the other poses (all p_bonf < .001). When the eyes were closed, the four poses were not statistically distinguishable from one another after correction. The omnibus test was marginally significant before correction.

Table 3. Simple Effects of Asana Within Each Visual Condition, by Muscle

Muscle	Condition	F (3, 108)	p	p_GG	ηp²
Gastrocnemius	Non-visual	22.83	< .001	< .001	.388
	Visual	29.46	< .001	< .001	.450
Vastus medialis	Non-visual	8.13	< .001	< .001	.184
	Visual	10.45	< .001	< .001	.225
Vastus lateralis	Non-visual	4.95	.003	.004	.121
	Visual	3.24	.025	.033	.082
Soleus	Non-visual	3.02	.033	.035	.077
	Visual	29.93	< .001	< .001	.454

Note. p_GG = Greenhouse-Geisser-corrected p value. Bonferroni-corrected pairwise comparisons are summarized in the text.

Interaction Between Asana and Vision

An asana × condition interaction was found to be significant for gastrocnemius, $F(3, 108) = 5.04$, $p = .003$, $p_GG = .005$, $\eta p^2 = .123$; vastus medialis, $F(3, 108) = 3.99$, $p = .010$, $p_GG = .019$, $\eta p^2 = .100$; and soleus, $F(3, 108) = 2.89$, $p = .039$, $p_GG = .039$, $\eta p^2 = .074$. A similar trend was observed for vastus lateralis, which did not reach the significance threshold for the Greenhouse-Geisser correction, $F(3, 108) = 2.73$, $p = .048$, $p_GG = .059$, $\eta p^2 = .070$.

Table 4 shows the direction and size of this interaction. It is the amount by which the mean RMS in each muscle and asana is raised (positive) or lowered (negative) by closing the eyes. Gastrocnemius activity in every asana was raised by closing the eyes, but in varying amounts. It rose by +8.1 μV in Natarajasana, +14.4 μV in Garudasana, +18.6 μV in Virabhadrasana III, and +59.7 μV in Vrikshasana. A related and similar pattern was followed by soleus. It rose most in Virabhadrasana III (+32.3 μV) and least in Garudasana (+9.3 μV). The vasti reversed direction in Natarajasana. Both vastus medialis (–31.0 μV) and vastus lateralis (–10.2 μV) were higher when the eyes were kept open than closed. It is the only asana in the entire data set where thigh-muscle activity increased during vision, rather than in its absence. In other asanas, both vasti followed the general rule and rose once the vision was disabled.

Table 4. Direction of the Asana × Condition Interaction (Non-Visual Minus Visual Mean RMS, μV)

Muscle	Natarajasana	Garudasana	Vrikshasana	Virabhadrasana III

Gastrocnemius	+8.1	+14.4	+59.7	+18.6
Vastus medialis	−31.0	+25.4	+28.8	+25.0
Vastus lateralis	−10.2	+7.7	+24.4	+11.3
Soleus	+14.6	+9.3	+13.2	+32.3

Note. Positive values indicate higher activity when the eyes are closed than when the eyes are open.

Robustness Checks

Normality was violated (Shapiro-Wilk $p < .05$) in 21 of the 32 muscle × asana × condition cell. It was majorly driven by a handful of strongly right-skewed cells. Gastrocnemius had a standard deviation (50.1 μV) which is larger than half its own mean (29.5 μV) during Virabhadrasana III with the eyes closed. A log-transformed version of the analysis was run as a check because repeated-measures ANOVA is reasonably tolerant of non-normality at this sample size. Main effect and interaction of every asana reported above reasonably held up on the log scale. Gastrocnemius condition main effect was the only exception. It was significant on the raw scale, $F(1, 36) = 16.09$, $p < .001$ but not so on the log scale, $p = .253$. This means that the particular effect is likely result of a small number of very high non-visual scores. It does not reflect a uniform shift across all 37 participants. The above observations must be read with this caveat.

When the stricter muscle-family-corrected alpha of .0125 was applied, it left every effect reported above significant except the soleus simple effect in the non-visual condition ($p = .033$). It had already failed to survive the standard Bonferroni correction when put through pairwise comparisons. It also drops out when the stricter threshold is applied.

DISCUSSION

The clearest and the most obvious finding here is also the simplest finding. It is clear that taking away vision lead to three of the four muscles working harder on an average across the four asanas that were tested. This finding resonates with the broader postural-control picture that is described by Horak and Macpherson (1996) and the sensory-reweighting models that were built by Peterka (2002) and later refined by Assländer and Peterka (2014). Removing one channel of sensory information makes the postural control system rely harder on what it is left with. It shows up here in the form of more electrical activity in the muscles that are doing the correcting. The contribution that this study makes is, mapping where exactly that extra load lands and also how disproportionately it is spread across the different poses.

Ankle Muscles Carried More of the Cost Than Thigh Muscles

Both ankle plantar flexors, gastrocnemius and soleus showed clear condition main effects (both $p < .001$). Both vasti, vastus medialis and vastus lateralis did not reach significance for condition on their own. This aligns closely with Labanca et al.'s (2021) finding that if the eyes are closed during simple single-leg stance, strengthens the ankle-dominant muscle synergy in comparison to the hip-and-back synergy. The present results take that finding one step further from plain single-leg stance to four considerably difficult and demanding balance positions. It suggest that even in such postures, the same basic rule holds. When vision is absent, then on an average, the ankle does more of the correcting work. This also fits well with basic anatomy of the muscles. The ankle rests closest to the base of the support. It is the first joint that is recruited when the body starts to sway or dwindle. It

naturally becomes the first responder once a major source of sway information disappears. The thigh muscles were pose-dependent rather than condition-dependent. Both vasti showed significant asana-condition interactions which means that their response to absence of vision depended entirely on which pose was being held at that time. That is a rather interesting result than a flat even overall main effect. It is because it suggests the vasti are not merely "quiet" when balancing with eyes closed. They are recruited selectively in particular asanas only when that particular pose demands it.

The Vrikshasana Surprise

The single steepest change in the entire study was produced by Vrikshasana. Gastrocnemius RMS rose from 75.4 μV to 135.0 μV (almost doubled) once the eyes were closed. This is a jump that overshadowed the effect of vision in any other muscle-asana combination. This is a remarkably major effect for a pose that is often taught to beginners as one of the softer standing balance postures. A probable elucidation is base of support. In case of Vrikshasana, the standing foot is flat and leveled whereas the raised foot rests against the inner thigh or calf. This narrows the base to the width of one foot and there is no counterbalancing trunk lean that is provided in case of Virabhadrasana III or Garudasana. With no forward lean with which to spread the correction out over the hip and trunk, the calf may be left to compensate almost entirely once vision is removed — in line with Kelley et al.'s (2019) finding that Vrikshasana already involves reasonably substantial gastrocnemius demands even with the eyes open, and with Yu et al.'s (2012) and Wang et al.'s (2013) reports of non-trivial ankle-joint demands in the same pose among older adults, who have comparatively even less reserve to draw upon for their balance than do younger people.

Why Virabhadrasana III Behaved Differently

Warrior III was associated with the lowest gastrocnemius activity of the four poses tested in both visual conditions, contradicting previous EMG studies that highlighted this asana as one of the most demanding standing postures for the muscle group in question: Kelley et al. (2019); Lehecka et al. (2021) both reported it to be a high-activation pose for the muscles they targeted (gastrocnemius and rectus femoris in the former, gluteus maximus and medius in the latter). The probable explanation for this is that each pose distributes its demand to a different muscle group. When holding Warrior III pose, the trunk and free leg are held roughly parallel to the floor. This puts a heavy load on the hip and glutes to keep the trunk from dropping down. There is comparatively little load on the calf of the standing leg which stays almost vertical under the center of mass of the body. If the gastrocnemius is quiet in this pose, it may simply reflect that the muscular demand required by warrior III is carried elsewhere. This study could not see this pattern directly because the gluteal and hip muscles were not observed and recorded. But the pattern fits neatly with what Lehecka et al. (2021) reported for the same pose. A related story is told by soleus. It showed the single largest increase in activity of any muscle-asana pair once the eyes were closed in warrior III (+32.3 μV). It suggests that although the calf muscle is quiet overall in this pose, it becomes so much more important once eyes are closed and the standing leg has to balance a horizontal trunk without any visual feedback to rely on.

The Natarajasana Reversal

In Natarajasana (dancer's pose), the general rule fell flat entirely. Both vastus medialis and vastus lateralis were more active with the eyes open when compared to closed eye pose. This forms the only reversal in the entire data set and the reversal appeared in both

quadriceps muscles at once. This means that it is worth taking seriously and not to be dismissed as usual noise. There is substantial backward trunk lean that is combined with hip extension of the raised leg in Natarajasana. This is fundamentally different from the balance required in Vrikshasana which is vertical and narrow base. When the eyes are open, it is possible that the participants used visual feedback which helped them actively deepen the backbend and monitor limb position. This in turn recruited the quadriceps to control knee extension of the standing leg as the pose was pushed further. When the eyes were closed, the participants may have held a shallower and conservative version of the same shape because of caution. This would in turn lower quadriceps demand even as ankle demand itself increased for balance. This explanation is based on plausibility rather than proof. It points to pose depth and not merely the presence or absence of vision as something that future work in this area can and should track directly. This can perhaps be done through joint-angle measurement alongside EMG.

LIMITATIONS

Several limitations should be noted. The sample included only young adult male practitioners with relatively limited experience (14–28 months), and these findings should not be extrapolated to female practitioners, older adults, complete beginners, or highly experienced yogis, who demonstrate different EMG patterns in prior yoga research (e.g., the sex and experience effects detailed in Lehecka et al., 2021). RMS amplitude was reported in raw microvolts rather than expressed as a percentage of a maximum voluntary contraction, which is standard in some of the comparison literature (i.e., expressed there as %MVIC) but not others; this allows the within-study comparisons shown here to be reliable while limiting the ability to directly compare those numbers to studies that utilized a %MVIC normalization. Over half of the cells in the tables departed from a normal distribution, and while the log-transformed sensitivity analysis supported nearly all findings, the gastrocnemius condition main effect did not survive that check and should be treated cautiously. Finally, only four lower-limb muscles were recorded, and the interpretation offered above for Virabhadrasana III, in particular, rests on an inference about the demands on hip and gluteal musculature, which this work did not directly measure.

CONCLUSION

Closing the eyes did not add a uniform tax to these four standing yoga asanas. It added a large one to the calf in Vrikshasana, a smaller but still real one to the calf in Virabhadrasana III, and, in Natarajasana, it actually lowered thigh-muscle activity rather than raising it. The bulk of the average vision effect across the sample was carried by two ankle muscles, the gastrocnemius and soleus. This aligns cleanly with a model in which once the visual input is removed, the ankle takes over most of the postural correcting. There was involvement of the thigh muscles, but their response depended largely on which asana or pose was being held. It was most clearly observed in the reversed pattern that was seen in Natarajasana. These results are suggestive of the fact that the challenge to balance added by closing the eyes in a standing yoga sequence is pose-specific rather than fixed. Instructors, clinicians, and researchers who are designing closed-eyes balance progressions should not treat different standing asanas as interchangeable variations on the same basic task. They should treat the different poses as putting different demands on the lower limb.

REFERENCES

Assländer, L., & Peterka, R. J. (2014). Sensory reweighting dynamics in human postural control. Journal of

Neurophysiology, 111(9), 1852–1864. https://doi.org/10.1152/jn.00669.2013

Horak, F. B., & Macpherson, J. M. (1996). Postural orientation and equilibrium. In L. B. Rowell & J. T. Shepherd (Eds.), Handbook of physiology: Section 12. Exercise: Regulation and integration of multiple systems (pp. 255–292). American Physiological Society.

Kelley, K. K., Giannico, K., Lesnett, G., & Romano, A. (2019). A comparison of EMG output of four lower extremity muscles during selected yoga postures. Journal of Bodywork and Movement Therapies, 23(2), 329–333. https://doi.org/10.1016/j.jbmt.2019.01.016

Labanca, L., Ghislieri, M., Knaflitz, M., Barone, G., Bragonzoni, L., Agostini, V., & Benedetti, M. G. (2021). Muscle synergies for the control of single-limb stance with and without visual information in young individuals. BMC Sports Science, Medicine and Rehabilitation, 13, Article 163. https://doi.org/10.1186/s13102-021-00392-z

Lehecka, B. J., Stoffregen, S., May, A., Thomas, J., Mettling, A., Hoover, J., Hafenstine, R., & Hakansson, N. A. (2021). Gluteal muscle activation during common yoga poses. International Journal of Sports Physical Therapy, 16(3), 662–670. https://doi.org/10.26603/001c.22499

Peterka, R. J. (2002). Sensory integration for human balance control. Journal of Neurophysiology, 88(3), 1097–1118. https://doi.org/10.1152/jn.2002.88.3.1097

Wang, M. Y., Yu, S. S., Hashish, R., Samarawickrame, S. D., Kazadi, L., Greendale, G. A., & Salem, G. J. (2013). The biomechanical demands of standing yoga poses in seniors: The Yoga Empowers Seniors Study (YESS). BMC Complementary and Alternative Medicine, 13, Article 8. https://doi.org/10.1186/1472-6882-13-8

Yu, S. S., Wang, M. Y., Samarawickrame, S., Hashish, R., Kazadi, L., Greendale, G. A., & Salem, G. J. (2012). The physical demands of the tree (Vriksasana) and one-leg balance (Utthita Hasta Padangusthasana) poses performed by seniors: A biomechanical examination. Evidence-Based Complementary and Alternative Medicine, 2012, Article 971896. https://doi.org/10.1155/2012/971896