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Comparative study on the effects of yoga on soft surface on sleep, strength, flexibility, and balance in senior university students with mild insomnia

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KEYWORDS
Pittsburgh Sleep Quality Index; Unstable surface; Exercise; Functional ability.

ABSTRACT
This study aimed to investigate the influence of yoga exercises performed on soft versus hard surfaces and to compare these effects with those of general exercise on sleep quality and isometric muscle strength, flexibility, and dynamic balance outcomes in senior university students with mild insomnia. An assessor-blind randomized controlled trial was conducted with 13 participants per group aged 18 years and older randomly assigned to practice yoga on a hard surface (YH), a soft surface (YS), or a control group that received a guidebook, in 45-minute sessions, three days a week, for four weeks. Sleep quality, the main outcome, improved markedly from baseline, most notably among those who practiced yoga on a soft surface, with a mean PSQI reduction of 7.11 points (95% CI: 3.81–10.41). In addition, muscle strength and flexibility also showed significant improvements. Thus, yoga, particularly on a soft surface, could effectively enhance sleep quality, muscle strength, and flexibility in senior university students facing sleep problems.

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Introduction

Senior university students reported experiencing sleep quality issues and excessive daytime sleepiness related to insomnia caused by academic workload, night shifts, and stress[1]. Previous research found that individuals who exhibited clinically significant insomnia at the assessment level, as defined by a Pittsburgh Sleep Quality Index (PSQI) score of ≥5, were associated with subthreshold (mild) insomnia[2,3]. Insufficient and poor-quality sleep due to insomnia is pervasive in contemporary society, serving as both a predictive indicator and a symptom of various health conditions[4]. Some studies reported that poor sleep quality was linked to impaired balance, primarily through its effects on the vestibular and visual systems[5]. A study among Chinese university students found a positive association between good sleep quality and muscle strength. Men with sleep durations of less than six hours exhibited poorer muscle strength than those with adequate sleep[6]. In addition, poor sleep quality was linked to sarcopenia, a condition characterized by loss of muscle mass and function, which could affect muscle flexibility and overall physical performance[7]. Furthermore, disrupted sleep patterns have been associated with notable declines in muscle strength, flexibility, and balance, consequently leading to a decrease in overall well-being[4]. Therefore, the exploration for an intervention helping to manage these problems is important.

Existing evidence reported benefit of mild-moderate aerobic exercise among young adults when performed approximately 30 minutes, three times a week[8,9]. Moreover, mind-body practices could reduce sleep onset latency, and increase total sleep time, flexibility[10-12], and resistance training enhanced sleep efficiency and reduced wake after sleep onset[13,14], potentially offering added benefits when combined with aerobic exercise. In addition, previous studies found that mind-body practices improved sleep quality by promoting relaxation, and reducing arousal, anxiety, and depression, which were often comorbid with insomnia[10]. These findings may suggest the combination of physical and mental exercises to augment sleep quality in people with insomnia.

Recent studies have reported the challenging effects of unstable surfaces after 3 to 8 weeks on various physical aspects, including proprioception, muscular co-contraction, and energy expenditure, in diverse populations, such as healthy young adults, older adults, and individuals with spinal cord injuries[15,16]. Yoga has been identified as a highly beneficial exercise for mental relaxation and flexibility[10,12,17,18]. However, yoga has not been determined as sufficient to improve strength and balance in young people under stress[19-21]. Thus, the researchers hypothesized that the combination of yoga exercise performed on a soft surface may attribute challenging effects on muscle strength, balance, flexibility, and mental wellbeing of stressed students. Therefore, this study compared the effects of practicing yoga on soft and hard surfaces on the sleep quality and isometric muscle strength, flexibility, and dynamic balance outcomes in senior university students with mild insomnia. The present findings may suggest that practicing yoga on a soft surface could improve sleep quality, muscle strength, flexibility, and dynamic balance in this group, potentially offering additional benefits compared with yoga on a hard surface, and supporting the value of integrating mind body practices with aerobic or resistance training on soft surface to enhance overall well-being in this population. Further research is needed to confirm causality, understand mechanisms, and determine optimal protocols.

Materials and methods

Participants

This assessor-blind randomized controlled study involved senior university students from Mae fah luang university, both males and females, had a normal body mass index (18.5-22.9 kg/m^2), were

aged 18 years and older, had a Pittsburgh Sleep Quality Index (PSQI) score of ≥ 5 points[22], and had not recently engaged in regular exercise. The study excluded individuals taking medications associated with heart disease and sleeping pills, or those with conditions affecting participation, such as unstable medical conditions, lower extremity joint inflammation with significant pain indicated by a visual analog scale of ≥ 5 points, or neurological deficits. The sample size calculation was performed in G*Power (version 3.1) to detect a standardized effect size three groups with d = 0.46 for the PSQI at week 4, using a baseline-adjusted analysis (ANCOVA) with 80% power, and α = 0.05. The findings indicated that 13 participants per group were needed for the study. All eligible participants were required to sign an informed consent form that was approved by the Human Research Ethics Committees of Human Research Ethics Committees of Mae Fah Luang University (EC 23098 - 25) prior to participation in the study, and their ID numbers were used as identifiers, all personal information was kept confidential.

Research protocols

The eligible participants underwent interviews regarding their demographics. Then, they were randomly assigned to one of the three groups: yoga on a hard surface (YH), yoga on a soft surface (YS), or a control group receiving a general exercise guidebook. On the next day, outcomes were measured at baseline and reassessed at four weeks. The program in each group was led by primary instructor with an additional instructor assisting who was one of the three researchers (Figure 1).

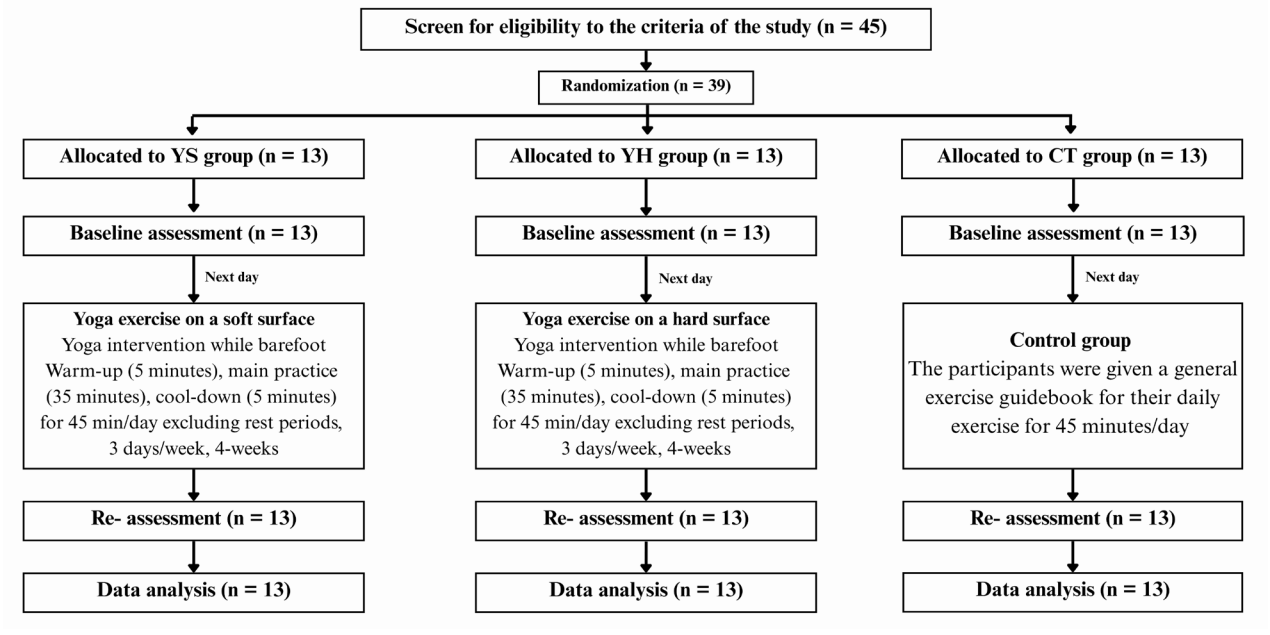

Figure 1 Participation flowchart.
Abbreviations: YS, Yoga exercise on a soft surface; YH, Yoga exercise on a hard surface; CT, Control group.

- Yoga exercise on a soft surface group (YS group): The participants performed yoga exercise program on a soft surface, which was developed from a compressed flexible 3-inch-thick sponge foam yoga mat with the dimensions of 1 meter in width and 2 meters in length (Figure 2)[15].

- Yoga exercise on a hard surface group (YH group): The participants practiced yoga exercise program on a flat, hard, smooth surface using a mat with the same poses as in the YS group.

- Control group (CT): The participants were given a general exercise guidebook for their daily exercise for 45 minutes/day[17].

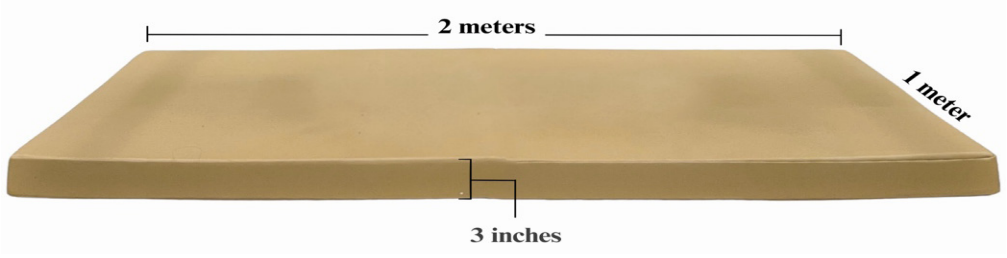

Figure 2 Characteristics of a soft surface used in this study

Yoga training programs

Yoga training sessions least 45 minutes (excluding rest periods) which were divided into 3 parts, including warm-up (5 minutes), main practice (35 minutes), and cool-down (5 minutes) (Figure 3). The yoga postures which were the main practice divided into two phases[17,21,23] with the following details:

Phase 1: Specific postures (asanas) comprising six poses: Prasarita Padottanasana Vinyasa, Parivrtta Trikonasana, Utkatasana, Garudasana, Vrikshasana, and Ushtrasana were performed five times/session over three sessions (Figure 3).

Phase 2: Breathing exercises (Pranayama) comprising two poses: Anulom-vilom and Omkar Chanting (Figure 3).

The yoga program was led by primary instructor with an additional instructor assisting who was one of the three researchers. The participants performed the yoga exercise programs while barefoot for three days/week over four weeks with the intensity controlled by heart rate to maintain no more than approximately 75% of age-predicted maximum [24,25]. Each position was performed 10 times with 30–60 seconds of rest, and both phases were repeated at least twice. Supervision consisted of one primary instructor with an additional instructor assisting who was one of the three researchers. Adverse events were recorded, and intention-to-treat analyses were planned for missing adherence data. However, there were no missing data in the study.

Outcome measures

Participants' functional mobility was assessed using the PSQI, muscle strength, sit-and-reach, and timed up and go (TUG) tests in random order to balance test sequence across participants and minimize fatigue and learning effects. The randomization schedule was independent of data collection and not shared with assessors before testing. Three trained raters with excellent inter-rater reliability (intraclass correlation or ICC ranging from 0.90 to 0.99) conducted the outcomes assessments. The details of each assessment are as follows.

- Pittsburgh Sleep Quality Index: The PSQI (Thai version), a primary measure of the study, is a 19-item questionnaire with seven subscales scores, ranging from 0 to 3, to assess sleep efficiency, disturbances, duration, latency, quality, and daytime dysfunction [26]. The PSQI global score ranges from 0 to 21, with the higher scores indicating poorer sleep quality. Scores of 5 or more significantly denoted poor sleep[2,3,26].

- Isometric muscle strength testing: This study used the Takei 5002 (digital model) portable dynamometer to assess leg-back muscle strength (ICC > 0.99). Participants placed their feet on the

dynamometer and held their arms at the sides of their bodies, with the trunk positioned on their backs and slightly forward, avoid hip flexion/rotation. They were then instructed to pull the dynamometer bar with their hands at maximum speed, using only their legs and not their backs, until their knees were fully extended, hold no more than 3 seconds. Three trials were conducted, with a two-minute rest between each trial. Maximal muscle strength (in kilograms) was recorded for each trial[27].

- The sit-and-reach test: This validated method for assessing hamstring and low back flexibility was executed while participants seated with legs close together and feet against a support (ICC = 0.98)[28]. They were then instructed to lean forward as far as possible with straight arms, holding the position briefly, with the farthest reach recorded in centimeters in three trials and the highest value was reported[28].
- Timed Up and Go test: The TUG test, a high reliability measure (ICC = 0.76-0.99), was used to assess dynamic balance and mobility[29,30]. Participants were timed their ability of rising from a chair with armrests, walking around a traffic cone placed three meters ahead, and returning to a seated position on the chair quickly and securely in three trials, with the average time was reported[29,30].

An assessor monitored the participants to ensure safety and measurement accuracy, by either standing or walking nearby. If the participants experienced any condition or abnormal vital signs during the test or training, they could stop immediately.

All assessments were conducted by a blinded assessor at baseline and after four weeks (Figure 1). Additionally, to preserve blinding, a new test-record form was used for each assessment, and participants provided their ID number to the blinded assessor for data entry on the new form.

Statistical analyses

Data were analyzed using SPSS version 31. Descriptive statistics were used to explain the demographic data of the participants and the findings of the study. The dependent sample t-test was used to analyze the different findings between baseline and 4-week measurement of each outcome (within-group comparisons). The one-way analysis of covariance (ANCOVA) with the use of baseline data as covariate and the group as a fixed factor was used to compare 4-week data between the groups. The significance level was set at p-value < 0.05.

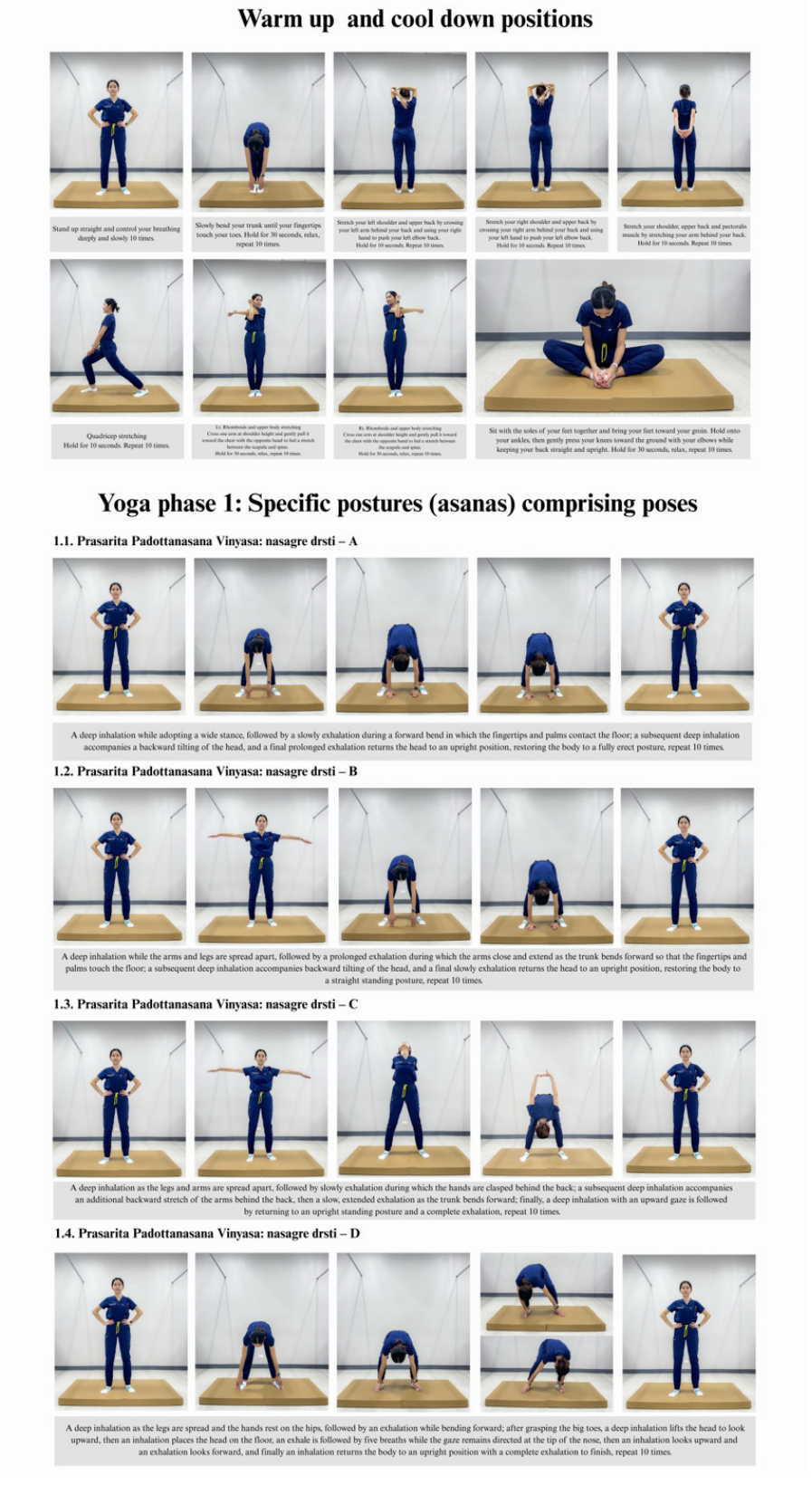

Figure 3 Detailed postures of yoga program

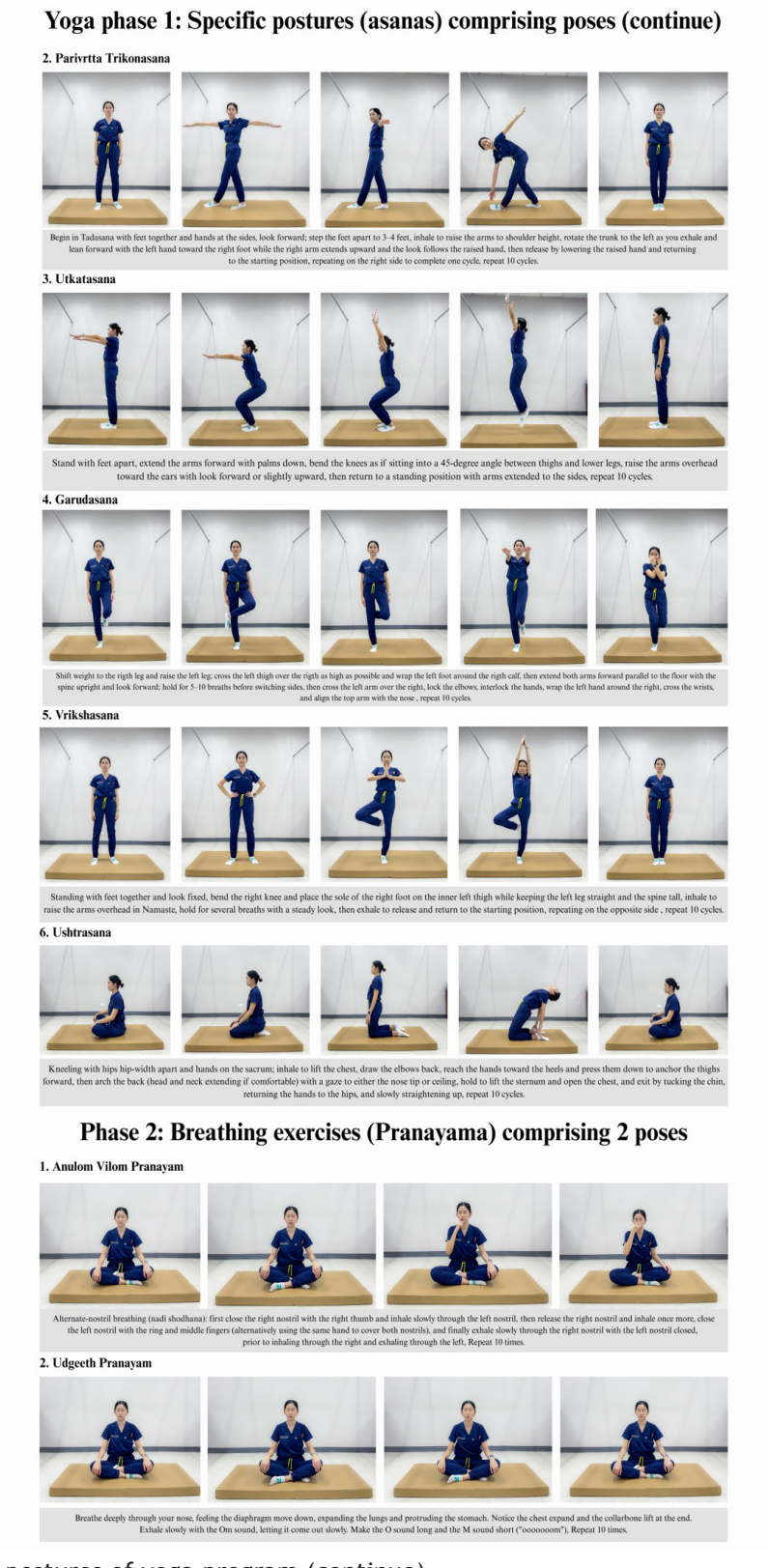

Figure 3 Detailed postures of yoga program (continue)

Results

Thirty-nine participants, with an average age of 21 years and normal body mass index, who did not perform regularly exercise, were included in the study. Most were female, and all participants reported sleep disturbances with the PSQI scores ≥ 5. Baseline demographics showed no significant differences between the groups (p-value > 0.05) (Table 1).

Table 1 Baseline demographics of the participants

Variables	Total (n=39)	CT (n=13)	YH (n=13)	YS (n= 13)	p-value[b]
Gender: male, n (%)	8 (20.51)	3 (23.08)	2 (15.38)	3 (23.08)	0.382
Age: year [a]	21.67 ± 1.00	21.03 ± 0.24	21.62 ± 0.65	21.92 ± 0.99	0.890
Body mass index: kg/m^2[a]	20.03 ± 2.20	20.80 ± 2.10	20.80 ± 2.70	21.22 ± 2.27	0.530
PSQI score [a]	11.32 ± 2.43	10.69 ± 1.70	11.67 ± 3.05	11.56 ± 3.24	0.140
PSQI score reduction ≥ 3 points from baseline, n (%)	22 (56.41)	3 (23.07)	7 (53.85)	12 (92.30)	0.012*
PSQI < 5 at 4-week, n (%)	13 (33.33)	2 (15.38)	4 (30.77)	7 (53.85)	0.042*
Frequency of exercise per week	1.74 ± 1.04	1.62±0.50	1.92±1.44	1.67±0.70	0.660

Note: [a] The data are presented using mean ± standard deviation, [b] p-values from one-way ANOVA. * The superscripts indicated significant differences with the p-value < 0.05.
Abbreviations: n, number; PSQI, Pittsburgh Sleep Quality Index; YH, Yoga exercise on a hard surface; YS, Yoga exercise on a soft surface; CT, Control group.

Quality of sleep outcomes

Sleep quality was determined using the PSQI. In the within-group analysis, participants in the YH and YS groups demonstrated highly significant improvement in PSQI scores, while participants in the control group did not show any improvement. The improvements were seen in all sub-score components for both yoga groups (p-value < 0.001, Table 2), with the YS group showing significantly better PSQI scores than the YH group. In contrast, the control group demonstrated significant changes only in the subjective quality and latency of sleep (p-value < 0.05, Table 2). Moreover, significant differences between the groups were observed in all sub-score components, except for sleep latency (Table 2).

In addition, at week 4, a greater proportion of participants in the YS group achieved a clinically meaningful improvement (≥ 3-point reduction in PSQI) compared with YH and CT (Table 1). The proportion with PSQI <5 at week 4 was higher in YS than in YH and CT (Table 1). These findings were interpreted against prespecified thresholds, defining a minimum clinically important difference of 3 points on the PSQI and PSQI < 5 as indicating good sleep.

Isometric muscle strength, flexibility, and dynamic balance outcomes

All participants completed the program safely. After four weeks, significant improvements were observed in isometric muscle strength and flexibility in both yoga groups (YS and YH) (p-value < 0.01, Table 3). Dynamic balance did not show a significant improvement in either yoga group. Between-group comparisons revealed that the YS group showed greater gains in isometric muscle strength and in the sit-and-reach flexibility test than both the YH and control groups (p-value < 0.01, Table 4). No significant differences were found between YH and control for these outcomes.

Table 2 Pittsburgh Sleep Quality Index and sub-scores in each group (n = 13 per group)

Variables	Group	Baseline	4-week assessments	Mean change from baseline data (Baseline - 4-week assessments)[a]	*p-value*[b]
PSQI score	CT	10.69 ± 1.70 (8.54, 11.84)	7.46 ± 2.69 (5.64, 9.29)	2.23 ± 3.06 $^{YS***, YH***}$ (0.38, 4.08)	0.055
	YH	11.67 ± 3.05 (9.46, 13.87)	6.33 ± 2.67 (3.40, 8.26)	5.33 ± 3.28 ^{CT***} (4.25, 8.42)	0.001***
	YS	11.56 ± 3.24 (8.50, 14.61)	3.44 ± 3.53 (1.11, 7.78)	7.11 ± 4.28 $^{CT***, YH***}$ (3.81, 10.41)	0.001***
Subjective sleep quality	CT	1.85 ± 0.37 (1.59, 2.10)	1.38 ± 0.50 (1.04, 1.73)	0.46 ± 0.52 ^{YS***} (0.15, 0.76)	0.008**
	YH	1.83 ± 0.38 (1.55, 2.11)	0.95 ± 0.62 (0.98, 1.80)	0.83 ± 0.67 ^{YS**} (0.66, 1.51)	0.001***
	YS	1.89 ± 0.33 (1.57, 2.20)	0.34 ± 0.52 (-0.09, 0.98)	1.44 ± 0.53 $^{CT***, YH**}$ (1.04, 1.85)	0.001***
Sleep latency	CT	1.92 ± 0.64 (1.49, 2.36)	1.31 ± 0.85 (0.73, 1.89)	0.61 ± 0.87 (0.09, 1.14)	0.025*
	YH	2.33 ± 1.07 (1.56, 3.11)	1.25 ± 0.86 (0.62, 1.88)	1.08 ± 1.24 (0.18, 2.95)	0.012*
	YS	2.56 ± 0.72 (1.87, 3.24)	0.89 ± 0.78 (0.15, 1.63)	1.67 ± 1.00 (0.89, 2.44)	0.001***
Sleep duration	CT	2.45 ± 0.80 (1.30, 2.79)	1.69 ± 0.75 (1.18, 2.20)	0.15 ± 1.06 ^{YS***} (-0.49, 0.79)	0.613
	YH	2.33 ± 0.49 (1.98, 2.69)	1.08 ± 0.90 (0.43, 1.73)	1.25 ± 0.96 ^{YS**} (0.64, 1.86)	0.005**
	YS	2.22 ± 0.66 (1.16, 2.85)	0.58 ± 0.97 (-0.19, 1.89)	1.44 ± 1.13 $^{CT***, YH**}$ (0.58, 2.31)	0.001***
Sleep efficiency	CT	1.26 ± 0.87 (1.03, 2.20)	1.38 ± 0.76 (-0.24, 1.10)	-0.23 ± 0.73 $^{YH*, YS**}$ (-0.21, 0.67)	0.273
	YH	1.17 ± 1.19 (0.31, 2.03)	0.62 ± 0.79 (-0.26, 1.12)	0.55 ± 0.96 $^{CT*, YS**}$ (-0.22, 1.78)	0.111
	YS	1.11 ± 1.45 (-0.26, 2.48)	0.33 ± 1.00 (-0.61, 1.28)	0.77 ± 0.85 $^{CT**, YH**}$ (0.14, 1.36)	0.021*

Note: The data were presented using mean ± SD (95% confidence intervals). Superscripts CT, YH, YS, and denote the groups that differed significantly from the indicated groups, as determined by the Bonferroni post-hoc comparisons: ^{CT} = Control group, ^{YH} = Yoga exercise on hard surface, and ^{YS} = Yoga exercise on soft surface, [a] The one-way analysis of covariance (ANCOVA) was used to compare 4-week data between the groups. [b] A paired-samples t-test was used to compare baseline and 4-week outcomes within each group. * The superscripts indicated significant differences with the $^{*}p$-value < 0.05, ** p-value < 0.01, $^{***}p$-value < 0.001.

Abbreviations: n, number; PSQI= Pittsburgh Sleep Quality Index; YH, Yoga exercise on a hard surface; YS, Yoga exercise on a soft surface; CT, Control group.

Table 3 Isometric muscle strength, flexibility, and dynamic balance outcomes of the participants in each group (n= 13 per group)

Variables	Group	Baseline	4-week assessments	Mean change from baseline data (4-week assessments - Baseline) [a]	*p*-value [b]
Isometric Muscle Strength Testing (kg)	CT	65.34 ± 28.72 (45.90, 84.79)	61.03 ± 31.63 (49.61, 92.44)	-5.67 ± 7.12 ^{YS**} (-9.98, -1.38)	0.086
	YH	62.34 ± 23.56 (45.34, 89.36)	69.75 ± 29.48 (49.47, 92.03)	7.40 ± 9.69 ^{YS*} (-1.25, 14.56)	0.014*
	YS	63.72 ± 21.38 (43.58, 83.86)	75.06 ± 25.57 (50.97, 99.14)	11.33 ± 7.36 ^{YH*} (-2.00, 17.67)	0.012*
Sit-and-reach test (cm)	CT	5.84 ± 12.26 (-7.09, 16.52)	3.22 ± 4.28 (-9.89, 16.44)	-1.44 ± 4.66 ^{YS**} (-4.25, -1.37)	0.288
	YH	6.88 ± 10.04 (-0.38, 14.13)	8.59 ± 8.46 (2.49, 14.70)	1.72 ± 2.07 ^{YS*} (0.40, 3.03)	0.015*
	YS	6.02 ± 7.70 (-3.23, 11.28)	10.82 ± 6.66 (1.55, 14.09)	4.80 ± 2.72 ^{YH*} (1.71, 5.89)	0.003**
Timed up and go test (s)	CT	6.16 ± 0.62 (5.74, 6.58)	5.55 ± 0.39 (5.29, 5.82)	-0.60 ± 0.47 (-0.32 to 0.89)	0.819
	YH	6.14 ±0.86 (5.52, 6.77)	6.55 ± 4.16 (3.55, 9.55)	0.41 ± 4.32 (-3.15 to -2.34)	0.784
	YS	6.67 ± 1.17 (5.56, 7.77)	5.52 ± 0.67 (4.88, 6.15)	-1.15 ± 0.98 (-2.15 to -0.15)	0.510

Note: The data were presented using mean ± SD (95% confidence intervals). Superscripts CT, YH, YS, and denote the groups that differed significantly from the indicated groups, as determined by the Bonferroni post-hoc comparisons: ^{CT} = Control group, ^{YH} = Yoga exercise on hard surface, and ^{YS} = Yoga exercise on soft surface, [a] The one-way analysis of covariance (ANCOVA) was used to compare 4-week data between the groups. [b] A paired-samples t-test was used to compare baseline and 4-week outcomes within each group. * The superscripts indicated significant differences with the $^{*}p$-value < 0.05, $^{**}p$-value < 0.01, $^{***}p$-value < 0.001.

Abbreviation: The data were presented using kg, kilograms; cm, centimeters; s, second; n, number; YS, Yoga exercise on soft surface; YH, Yoga exercise on hard surface; CT, Control group.

Table 4 Difference between groups regarding the mean scores of isometric muscle strength, flexibility, and dynamic balance outcomes in each group (n= 13 per group)

Dependent Variable	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	95% Confidence Interval		*p*-value
					Lower Bound	Upper Bound	
Isometric Muscle Strength Testing (kg)	CT	YH	-5.65	4.96	-15.76	4.45	0.263
		YS	-6.72	2.58	-12.05	6.61	0.006**
	YH	YS	4.93	1.04	-9.35	13.21	0.043*
Sit-and-reach test (cm)	CT	YH	2.08	1.51	-1.01	5.18	0.179
		YS	-5.24	1.49	-8.28	-2.20	0.001***
	YH	YS	-3.16	1.38	-5.96	-0.35	0.029*
Timed up and go test (s)	CT	YH	0.54	1.16	-1.83	2.90	0.645
		YS	-1.01	1.07	-3.20	1.17	0.351
	YH	YS	-1.55	1.18	-3.96	0.85	0.197

Note: * The superscripts indicated significant differences with the **p*-value < 0.05, ***p*-value < 0.01, ****p*-value < 0.001.

Abbreviation: The data were presented using kg, kilograms; cm, centimeters; s, second; n= number; YS, Yoga exercise on soft surface; YH, Yoga exercise on hard surface; CT, Control group.

Discussion

The participants in our study showed significant improvements before and after participation in YH and YS on sleep quality (all sub-scores of PSQI; *p*-value < 0.001, Table 2), flexibility, and muscle strength outcomes (Table 3), particularly in the YS group (*p*-value < 0.001, Table 2, 3). Compared with the control group, the 4-week outcomes for both yoga groups differed significantly (*p*-value < 0.001, Table 4) in muscle flexibility and strength. No significant differences were observed in sleep latency and balance ability (TUG; *p*-value > 0.05, Table 2, 3, 4).

The yoga practice performed in this study involved stretching to stimulate blood vessels and coordinated body movements and breathing to induce relaxation[29,31], leading to improve quality and reduced latency of sleep and fewer sleep disorders, as indicated by various studies in other populations[18,19,31,32]. Participants in the intervention groups of previous research typically showed shorter average sleep duration yet better habitual sleep efficiency compared to the control groups. The synchronized body movements and breathing techniques employed in yoga practices can help alleviate functional disability and anxiety[33]. Studies have consistently shown that sleep quality in various group is improved by yoga[10,19,21,23]. For instance, a 6-month program involving postures, relaxation, breathing, and philosophy enhanced sleep latency, duration, and morning refreshment[31]. Yoga was also shown to improve overall sleep quality among elderly nursing home residents. Moreover, previous studies also demonstrated that gentle yoga postures and controlled breathing decreased sympathetic activity, thereby promoting parasympathetic dominance and reducing stress responses in healthy individuals and those with psychosomatic conditions[34]. Although it focused on young students with study-related sleep issues without other health problems, this research showed that practicing yoga significantly improved sleep quality, even in individuals without additional health concerns. Therefore, both groups that practiced yoga exercises experienced significantly improved sleep (*p*-value < 0.001, Table 2).

These changes may have increased the metabolic rate and energy expenditure through harder yoga exercise on soft surfaces, potentially enhancing sleep quality[35]. Furthermore, exercising on a soft surface promoted muscle co-contraction and proprioceptive input due to the unstable nature of the surface, which led to muscle fatigue and soreness, influencing sleep onset and quality[36]. The condition could have resulted in unstable positions during yoga exercise, increasing energy expenditure leading to the intensity beyond the intended moderate level of the soft surface yoga intervention. Consistent with previous studies reporting that high-intensity exercise is often associated with psychological stress, which may predispose individuals to insomnia and impair sleep performance. Thus, this study demonstrated that soft-surface yoga can be performed at a moderate intensity and is appropriate for improving sleep[25]. The significant enhancements in isometric muscle strength, flexibility, and dynamic balance outcomes seen following participation in the YS training are linked to the utilization of a soft surface. Research indicates that exercising on an unstable sand surface decreases muscle mechanical work, leading to increased muscle co-contraction and greater challenges for leg and back muscle strength compared to exercising on a hard surface[37].

Thus, the participants showed significantly dramatic improvement in the isometric muscle strength testing (6% on the soft surface, 3% on the hard surface; Table 3), which is commonly used to reflect functional leg and back strength [27], in comparison with those who trained on a firm surface. Although statistically significant, the changes observed in the yoga group that practiced on a hard surface were not clinically meaningful. Previous research suggests that isometric outcomes in healthy students require a 5% minimal clinically important difference to be significant[27]. Similarly, prior research has demonstrated that walking on sand increases electromyographic activation, leading to a 13% average improvement in lower extremity motor strength among participants, while those walking on a solid surface did not show any enhancements[37,38].

Furthermore, yoga poses not only improved muscle strength but also served as a joint and muscle stretching regimen emphasizing controlled breathing and posture, especially on soft surfaces. The study results indicate significant gains in flexibility (4.8 cm, *p*-value < 0.001) after four weeks. Previous research also indicated that yoga improved flexibility in women, with increases of 3.5-10 cm after 8-16 weeks[39,40].

Hence, the practice of rigorous yoga on a soft surface led to significant improvements in sleep quality, flexibility, and strength measures within four weeks (Table 2, 3). However, reliance on subjective measures such as the PSQI limited accuracy; thus, future research should incorporate objective assessments for more precise sleep quality evaluation.

Conclusion

The effect 4-weeks of yoga, especially on a soft or unstable surface, may enhance sleep quality and increased isometric strength and flexibility with no between-group difference in dynamic balance in stress with poor sleep students. However, longer-term follow-up with larger samples and more advanced assessments is needed to confirm durability and clarify the underlying mechanisms.

Take home messages

This finding suggests that stressed students with mild insomnia may benefit from 4-weeks of yoga on either a hard or soft (unstable) surface, as both improve sleep quality, flexibility, and muscle strength, with soft-surface yoga yielding superior and more pronounced improvements than hard surface yoga.

Conflicts of interest

The author declares no conflict of interest.

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Author contributions

Donlaya Promkeaw: Conceptualization, Methodology, Data collection, Formal analysis, Writing – Original draft, Review and Editing.

Dirk Möller: Formal analysis, Writing – Original draft and Review

Karitta Soontronwibool: Conceptualization, Methodology, Data collection, Formal analysis.

Panjaporn Bauedok: Conceptualization, Methodology, Data collection, Formal analysis.

Phattranit Praphajareneying: Conceptualization, Methodology, Data collection, Formal analysis.

Theerasak Boonwang: Conceptualization, Methodology, Data collection, Formal analysis, Writing – Original draft, Review and Editing.

Data availability

Author elects to not share data

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