Published Online: 2026 March 30 Research Article

Effects of a Yoga-Based Facial Massage Intervention on Reducing Eye Strain Among Young Adults with Prolonged Screen Time: A Randomized Pilot Trial

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Received: 28 January, 2026; **Revised:** 23 February, 2026; **Accepted:** 24 February, 2026

Abstract

Background: This study investigates the effects of specialised Thai Yoga facial massage (STYFM) on visual, musculoskeletal, cardiovascular, and autonomic functions in young adults with computer vision syndrome (CVS).

Methods: A randomized controlled trial was conducted with 30 participants with visual fatigue. Participants were randomly assigned to either an STYFM group (FMG, n = 15) or a control group (CTG, n = 15). The FMG received 10 - 15 minutes of STYFM, while the CTG rested with eyes closed for 15 minutes to control for time and removal of visual load. The primary outcome was visual fatigue assessed by the Computer Vision Syndrome Questionnaire (CVS-Q). Secondary outcomes included near point of convergence (NPC), amplitude of accommodation (AMP), visual acuity (VA), spherical equivalent refraction (SE), handgrip strength (HS), cervical range of motion (CROM), and cardiovascular/autonomic indicators (heart rate, heart rate variability [HRV], and peripheral oxygen saturation [SpO_2]). Outcomes were assessed at baseline and immediately post-intervention.

Results: The FMG demonstrated significant improvements in CVS-Q, NPC, AMP, VA ($P < 0.001$), HS ($P < 0.05$), CROM ($P < 0.001$), SpO_2, HRV, high-frequency power (HF), RMSSD, and PNN50 ($P < 0.05$). The CTG showed modest improvements in CVS-Q and NPC ($P < 0.05$), a decline in HS ($P < 0.05$), and increases in HRV, HR, RMSSD, and PNN50 ($P < 0.05$). Significant between-group differences were found in CVS-Q, NPC, AMP, VA, HS, CROM subcomponents ($P < 0.001$), SpO_2, and HR ($P < 0.05$).

Conclusions: STYFM, as a noninvasive and easily self-implementable yoga-based mind–body intervention, appears to reduce visual fatigue and improve musculoskeletal and autonomic-related indicators in young adults. Given yoga's role in stress regulation, STYFM may also help mitigate stress-related and extraocular symptoms associated with prolonged screen use, including headache. Larger, adequately powered trials are warranted. No intervention-related adverse events were reported.

Keywords: Asthenopia, Massage, Yoga, Young Adult, Visual Acuity, Randomized Controlled Trial

1. Background

Computer vision syndrome (CVS), also referred to as digital eye strain, has become an important public health concern with the widespread use of smartphones, tablets, and computers (1). It affects approximately 75% - 90% of computer users worldwide (2), presenting with ocular symptoms such as visual fatigue, blurred vision, dry eyes, photophobia, and conjunctival hyperemia, as well as extraocular symptoms including headache, neck, and shoulder discomfort (3, 4). These symptoms often persist beyond working hours and worsen with prolonged screen exposure (5, 6), severely impairing academic and occupational performance and increasing the risk of chronic ocular conditions such as dry eye disease (7).

How to Cite: Chen H, Ratanapakorn T, Sukonpatip M, Asawaphureekorn S, Wang X, et al. Effects of a Yoga-Based Facial Massage Intervention on Reducing Eye Strain Among Young Adults with Prolonged Screen Time: A Randomized Pilot Trial. Health Scope. 2026;15(2):e169874. doi: https://doi.org/10.5812/healthscope-169874

Moreover, large population-based eye cohort studies have demonstrated a substantial prevalence of refractive errors and their associations with demographic factors, underscoring the broad public health burden of visual disorders (8).

Current approaches to managing CVS and visual fatigue primarily focus on optimizing ergonomic conditions and promoting practices such as the 20-20-20 rule to reduce accommodative load (9). In addition to these behavioral strategies, optical corrections such as blue light-filtering lenses (10) and progressive lenses (11) aim to improve visual comfort by enhancing refractive support for near and intermediate tasks (12, 13). Moreover, pharmacological and nutritional interventions, such as oral antioxidants (4), omega-3 fatty acid supplementation (14), and artificial tears (15), have been explored for their potential to mitigate ocular surface inflammation and improve tear stability. Despite these benefits, most existing treatments are primarily symptomatic, failing to address deeper deficits in accommodation, convergence, musculoskeletal performance, and autonomic regulation. These limitations highlight the need for innovative, multifactorial, non-pharmacological strategies capable of targeting the complex pathophysiology underlying CVS and visual fatigue.

Specialised Thai yoga facial massage (STYFM) is an integrative intervention that combines diaphragmatic breathing with targeted facial stimulation techniques, resembling a low-intensity form of yoga practice. Yoga, as a mind-body approach, has been widely applied in stress regulation and autonomic modulation, both of which are implicated in the development and persistence of computer vision syndrome and its extraocular symptoms (16). Preliminary evidence indicates that STYFM, by stimulating the facial, cranial, and cervical regions, may alleviate symptoms such as visual fatigue, blurred vision, ocular irritation, and burning sensations (17). Further research has also shown that massage interventions (18), acupressure techniques (19), and facial massage therapies (20) can activate the parasympathetic nervous system, improve autonomic nervous system balance, and enhance ocular and lymphatic circulation, thereby alleviating symptoms of visual fatigue and ocular discomfort. Notably, facial massage has also been shown to improve dry eye symptoms (21), which are closely associated with visual fatigue (22), suggesting that the alleviation of dry eye may indirectly reduce visual discomfort. Moreover, facial massage has been reported to improve the cervical range of motion (CROM) (23), further relieving the visual symptoms associated with cervical tension. Additionally, recent studies indicate that facial massage, neck massage, and acupoint massage may promote the relaxation of the periorbital muscles and modulate neural function, facilitating improvements in accommodation and convergence functions (24). These findings suggest that targeted massage interventions could offer novel strategies for relieving visual fatigue and enhancing visual performance. Near point of convergence (NPC) testing is considered an important clinical method for evaluating the convergence function and visual fatigue symptoms associated with convergence insufficiency (25, 26). From a physiological perspective, the therapeutic effects of STYFM are thought to result from synergistic mechanisms, including the regulation of visual accommodation and convergence functions (27, 28), modulation of autonomic nervous system activity (29), activation of lymphatic circulation (20, 30), and enhancement of musculoskeletal performance (31). These converging pathways may potentially explain the improvements in multiple physiological domains reported in prior studies and support the rationale for further investigation.

Despite preliminary evidence suggesting the potential benefits of STYFM, existing studies have been limited by narrow outcome scopes and insufficient methodological rigor. To date, no systematic investigations have comprehensively evaluated the multidimensional effects of STYFM on visual, musculoskeletal, cardiovascular, and autonomic parameters in individuals with CVS. The absence of high-quality randomized controlled trials (RCTs) in this domain underscores a critical gap in the evidence base for its therapeutic utility.

2. Objectives

Therefore, this RCT aims to evaluate the efficacy of STYFM as a non-pharmacological intervention for CVS by assessing the visual parameters (CVS-Q, NPC, AMP, VA, SE), musculoskeletal outcomes (HS, CROM), and cardiovascular/autonomic indices (SpO_2, HR, HRV).

3. Methods

The study was approved by the Ethics Committee of Khon Kaen University, Thailand (approval number: HE672161) and registered in the Thai Clinical Trials Registry (TCTR) on 19/11/2024 (registration number: TCTR20241119007).

3.1. Participants

Participants were recruited through an announcement on the Khon Kaen University platform and comprised young adults aged 18 - 35 years. Visual fatigue was screened using the Computer Vision Syndrome Questionnaire (CVS-Q). Inclusion criteria were a CVS-Q score ≥ 6 and an NPC > 10 cm. Participants were screened for ocular disorders, autonomic dysfunction, cardiovascular diseases, and current medication use. Caffeine consumption and dietary intake were restricted for at least two hours prior to the trial. The study was conducted in accordance with the principles of the Declaration of Helsinki. Exclusion criteria were: (1) Ocular and/or systemic conditions that directly induce visual fatigue (e.g., cataracts, glaucoma, cranial nerve palsy); (2) history of refractive or ocular surgery; (3) moderate-to-severe refractive errors (SE > ± 3.00 D, astigmatism > ± 2.00 D, or anisometropia > ± 1.00 D); (4) pregnancy or lactation; (5) use of medications or supplements that may affect visual fatigue; and (6) engagement in alternative therapies for visual fatigue within the preceding six months.

3.2. Randomization and Allocation Concealment

An independent researcher who was not involved in recruitment, outcome assessment, or intervention delivery generated the random allocation sequence (1:1 ratio) using Randomization.com (Figure 1). No stratification was applied, and the allocation sequence was generated without restrictions (simple randomization). Allocation concealment was ensured using a password-protected allocation file that was accessible only to the independent researcher. After eligibility confirmation and completion of baseline assessments, the enrolling researcher contacted the independent researcher to obtain the group assignment. Participants were allocated either to the STYFM group (FMG), which received the intervention, or to the control group (CTG), which rested quietly with eyes closed for 15 minutes to control for time and removal of visual load.

3.3. Experimental Methodology and Measurements

Prior to the measurement process, participants were seated for 20 minutes in a climate-controlled environment (24°C) to ensure thermal acclimatization. Sequential baseline assessments included the CVS-Q, NPC, AMP, VA, diopter, HRV, SpO_2, CROM, and HS. Participants in the FMG received the STYFM intervention for 10 - 15 minutes (Figure 2), while those in the CTG rested quietly with eyes closed for 15 minutes. Post-intervention assessments were conducted in the following order: HRV, SpO_2, NPC, AMP, VA, diopter, CROM, HS, and CVS-Q.

3.4. Computer Vision Syndrome Questionnaire

The validated CVS-Q (ICC = 0.802, AUC = 0.826), developed by the University of Alicante (32) and translated in accordance with copyright regulations (33), was used. It comprised a self-assessment and a researcher-administered evaluation, followed by a summary of both. The questionnaire was completed prior to objective measurements. The CVS-Q consists of 16 items, with a total possible score of 64. Based on the score, the severity of visual fatigue is classified as follows: 0 - 5 points indicate no visual fatigue, 6 - 20 points indicate mild visual fatigue, 21 - 40 points indicate moderate visual fatigue, and a score greater than 41 points indicates severe visual fatigue.

3.5. Near Point of Convergence and Amplitude of Accommodation

The NPC was measured using the pen tip method, gradually advancing the sight marker until binocular vision could no longer be maintained, and the corresponding distance was recorded. The near point of accommodation (NPA) was measured using an accommodation card and ruler, recording the distance to the sight marker. To enhance accuracy, the Royal Air Force Near Point Rule was applied for NPA measurement, requiring participants to focus on a target with one eye. The measurement was repeated three times, and the average of the recorded distances was used to represent the NPA, ensuring the reliability of the results (34). Subsequently, AMP was calculated using the formula AMP = 100/NPA (cm) to assess the eye's accommodative capacity.

3.6. Visual Acuity and Spherical Equivalent Refraction

The participants' VA was assessed using the Early Treatment Diabetic Retinopathy Study (ETDRS) visual acuity chart (maximum score: 100 points). Measurements were recorded from top to bottom after occluding one eye, with the highest score documented (35). The measurement assessed distance VA. For participants with astigmatism, data were recorded after correction using a pinhole astigmatism plate. The pinhole astigmatism plate effectively reduced the impact of astigmatism on VA and, compared to traditional trial lenses, offers a simpler and more accurate correction. Refraction was measured using the NIDEK ARK-F autorefractometer (Nidek, Japan), with

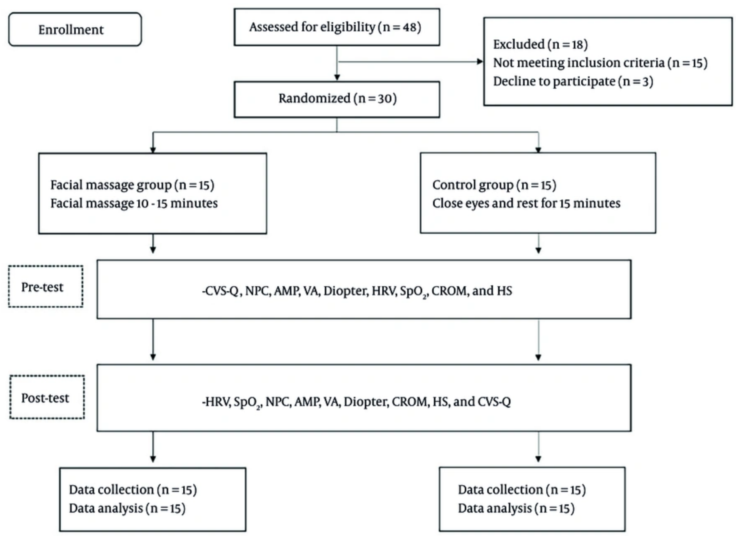

Figure 1. Participant recruitment flowchart

spherical equivalence calculated from the measured spherical and cylindrical values (36).

3.7. Heart Rate Variability and Peripheral Oxygen Saturation

Heart rate and HRV were recorded using the Polar H10 heart rate sensor (Polar Electro Oy, Kempele, Finland), a chest-strap device with validated accuracy and strong agreement with electrocardiogram-based recordings (37). SpO_2 was measured noninvasively at the fingertip using a clinically validated pulse oximeter, providing real-time monitoring of peripheral oxygen saturation. HRV analysis included time-domain indices, including the standard deviation of normal-to-normal RR intervals (SDNN), the root mean square of successive differences (RMSSD), and the percentage of successive normal-to-normal intervals differing by more than 50 ms (PNN50), as well as frequency-domain indices, including total power (TP), low-frequency power (LF), high-frequency power (HF), and the LF/HF ratio.

3.8. Cervical Range of Motion and Handgrip Strength

The CROM was measured using the Cervical Range of Motion Instrument (CROM; Performance Attainment Associates, United States) (38). Participants were seated during the assessment and performed the test three times, with the highest recorded value used for analysis. Grip strength was measured three times using the Takei Handgrip Dynamometer (GRIP-D; Takei, Japan), with the highest value documented (39).

3.9. Data Analysis

Descriptive statistics were used for participant characteristics. The Shapiro–Wilk test was used to test for the normality of continuous data. The paired *t*-test was used to test for within-group differences before and after the intervention. For between-group comparisons, ANCOVA was used to account for any baseline differences. Mauchly's test was employed to evaluate the assumption of sphericity, and repeated-measures ANCOVA was used to ascertain differences at the baseline and post-intervention. A post hoc analysis was conducted utilizing the Bonferroni correction. Since many indicators were tested, to control the false discovery rate (FDR) and reduce Type I errors, the Benjamini–Hochberg (BH) procedure was used to adjust P-values for multiple hypothesis testing with the FDR of 5%. All analyses were conducted using JASP version 0.19 (40). The BH procedure was performed using Julia version 1.11.3 (41) with the MultipleTesting package (42). For data processing, the vision-related parameters AMP, VA, and SE were averaged across both eyes, while the musculoskeletal-related parameters HS, CROM-Lateral, and CROM-Rotation were averaged separately for the left and right sides.

4. Results

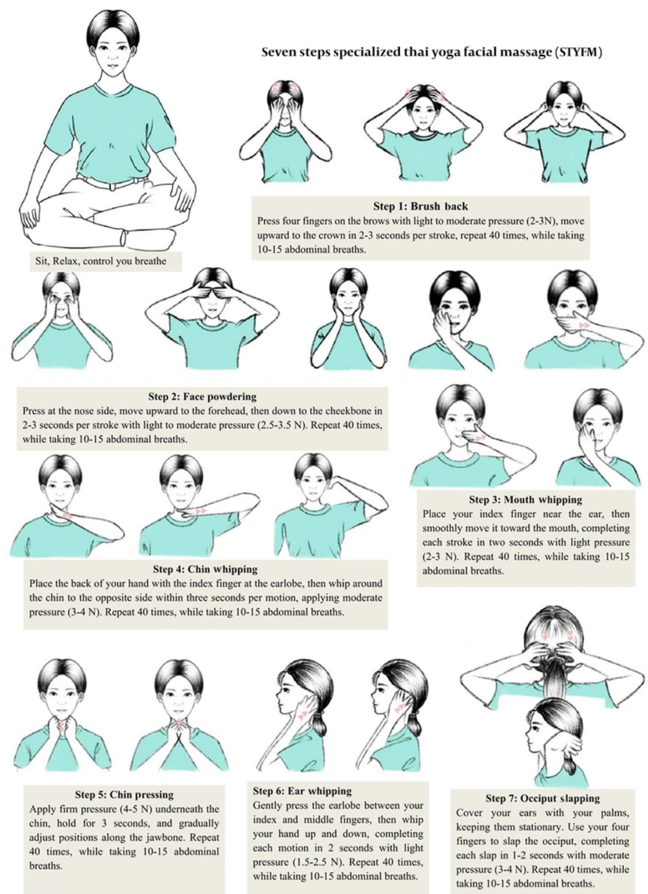

Figure 2. Steps of the STYFM

A total of 30 participants were analysed (FMG = 15, CTG = 15). The baseline characteristics, including age, sex distribution, vision-related parameters, musculoskeletal parameters, as well as cardiovascular and autonomic indices, were generally well balanced between the two groups. The mean age was 28.50 years, with females comprising 56.7% of the cohort. While the FMG demonstrated slightly lower baseline values in autonomic indices (such as HRV, SDNN, RMSSD, PNN50, TP, LF, and HF power), as well as marginally lower SpO_2 and HR, no statistically significant differences were observed in any baseline variable (all $P > 0.05$). Likewise, vision-related parameters (CVS-Q, NPC, AMP, VA, SE) and musculoskeletal parameters (HS and CROM subscales) were comparable between groups, indicating successful baseline matching (Table 1).

Within-group comparisons indicated that the FMG exhibited significant improvements across multiple domains. For vision-related parameters (Table 2), CVS-Q, NPC, AMP, and VA all showed significant improvements ($P < 0.001$), whereas SE remained unchanged. In the CTG, CVS-Q and NPC remained statistically significant after BH adjustment, but VA and SE showed no significant changes. Regarding musculoskeletal parameters (Table 3), the FMG showed significant increases in HS ($P < 0.05$) and all directions of CROM (extension, flexion, lateral bending, and rotation; $P < 0.001$), while the CTG exhibited a significant decline in HS ($P < 0.05$) with no changes in CROM. For cardiovascular and autonomic nervous system function-related parameters (Table 4), the FMG demonstrated significant improvements in SpO_2, HRV, HF, RMSSD, and PNN50 ($P < 0.05$), whereas TP, LF, LF/HF, and SDNN showed no significant changes. In the CTG, HRV, HR, RMSSD, and PNN50 remained significant, while SpO_2 and other indices did not change. Between-group comparisons confirmed that

Table 1. Baseline Characteristics [a, b]

Factors	FMG (n = 15)	CTG (n = 15)
Age (y)	29.87 (3.38)	27.13 (2.87)
Sex; No. (%)		
Female	9 (60.0)	8 (53.3)
Male	6 (40.0)	7 (46.7)
At baseline		
CVS-Q	27.87 (13.3)	30.73 (13.64)
NPC (cm)	14.36 (1.49)	14.59 (1.04)
AMP(D)	7.21 (0.98)	7.15 (0.62)
VA	80.93 (2.03)	80.33 (4.05)
SE(D)	-0.74 (0.73)	-0.92 (0.96)
HS (kg)	28.24 (9.53)	31.06 (11.18)
CROM-E(°)	61.87 (12.30)	60.4 (5.64)
CROM-F(°)	61.33 (9.90)	56.67 (10.29)
CROM-L(°)	43.03 (5.68)	45.70 (4.25)
CROM-R(°)	63.83 (8.55)	63.10 (9.41)
HRV	50.60 (7.06)	47.27 (5.44)
SDNN (ms)	49.40 (16.86)	38.39 (12.78)
RMSSD (ms)	29.60 (13.14)	22.72 (7.91)
PNN50 (%)	0.08 (0.07)	0.05 (0.07)
TP (ms^2)	1195.35 (1017.68)	751.01 (498.06)
LF (ms^2)	890.45 (917.06)	565.75 (393.43)
HF (ms^2)	304.84 (245.45)	185.31 (197.58)
LF/HF	4.17 (3.30)	4.41 (2.66)
SpO_2 (%)	96.93 (1.67)	98.00 (0.85)
HR (bpm)	78.87 (9.94)	86.87 (10.04)

[a] Values are expressed as mean (SD) unless otherwise indicated.
[b] No significant baseline differences between groups were found (all $P > 0.05$)

CVS-Q, NPC, AMP, VA, HS, and all CROM directions differed significantly ($P < 0.001$), while SpO_2 and HR also showed significant between-group differences ($P < 0.05$). No significant between-group differences were observed for SE, TP, LF, HF, LF/HF, SDNN, RMSSD, or PNN50.

5. Discussion

This study demonstrates the short-term effectiveness of the STYFM intervention in alleviating visual fatigue, enhancing musculoskeletal function, and modulating autonomic nervous system activity. Participants in the FMG, who received STYFM, exhibited significant reductions in visual fatigue, as measured by the CVS-Q, and significant improvements in NPC, AMP, and VA, whereas SE remained unchanged. While both the CTG (CVS-Q, NPC, VA) and FMG (CVS-Q, NPC, AMP, VA) showed statistically significant post-intervention changes in vision-related parameters, only the improvement in CVS-Q reached the threshold for clinical significance. Notably, the reduction in CVS-Q score in the FMG was nearly twice that observed in the CTG, with a between-group difference of 7.8 points, further supporting the clinical relevance of the intervention. In addition, FMG participants demonstrated significant improvements in CROM (extension, flexion, lateral bending, and rotation) and a slight increase in HS, indicating a beneficial effect on musculoskeletal function. Moreover, the FMG showed significant enhancements in SpO_2, HRV, HF, RMSSD, and PNN50, suggesting improved autonomic regulation characterized by increased parasympathetic activity and oxygen saturation. However, given the small sample size and the relatively homogeneous population of young adults, these findings should be interpreted with caution and regarded as preliminary.

Specialised Thai Yoga facial massage effectively alleviated visual fatigue and improved ocular motor and accommodative function in individuals with high VDT exposure. Compared with the CTG, FMG participants showed meaningful reductions in CVS-Q scores and improvements in NPC, AMP, and VA, while SE remained unchanged, consistent with previous findings that refractive status requires longer intervention (43, 44). These improvements may involve multiple

Table 2. Vision-Related Parameters

Outcomes and Groups	Before (n = 15); Mean (SD)	After (n = 15); Mean (SD)	Within-Group Difference (After - Before); Mean (95% CI)	Original P-Value [a]	Adjusted P-Value [b]	Between-Group Difference (FMG - CTG); Mean (95% CI)	Original P-Value [c]	Adjusted P-Value [d]
CVS-Q						-7.79 (-10.87, -4.71)	< 0.001 [e]	< 0.001 [e]
FMG	27.87 (13.3)	13.6 (7.46)	-14.27 (9.88, 18.65)	< 0.001 [e]	< 0.001 [e]			
CTG	30.73 (13.64)	23.27 (11.72)	-7.47 (5.35, 9.58)	< 0.001 [e]	< 0.001 [e]			
NPC (cm)						-0.40 (-0.54, -0.26)	< 0.001 [e]	< 0.001 [e]
FMG	14.36 (1.49)	13.79 (1.41)	-0.57 (0.45, 0.68)	< 0.001 [e]	< 0.001 [e]			
CTG	14.59 (1.04)	14.41 (1.06)	-0.18 (0.09, 0.27)	< 0.001 [e]	0.007 [f]			
AMP (D)						0.53 (0.38, 0.68)	< 0.001 [e]	< 0.001 [e]
FMG	7.21 (0.98)	7.74 (1.06)	0.53 (-0.69, -0.38)	< 0.001 [e]	< 0.001 [e]			
CTG	7.15 (0.62)	7.16 (0.62)	0.01 (-0.02, 0.01)	0.484	0.605			
VA						3.57 (2.84, 4.30)	< 0.001 [e]	< 0.001 [e]
FMG	80.93 (2.03)	85.03 (2.07)	4.10 (-4.71, -3.49)	< 0.001 [e]	< 0.001 [e]			
CTG	80.33 (4.05)	80.83 (4.50)	0.50 (-0.94, -0.06)	0.030 [f]	0.075			
SE (D)						0.05 (-0.16, 0.26)	0.627	0.784
FMG	-0.74 (0.73)	-0.73 (0.81)	0.01 (-0.17, -0.15)	0.869	0.869			
CTG	-0.92 (0.96)	-0.95 (0.92)	-0.03 (-0.11, 0.17)	0.644	0.715			

Abbreviations: SD, standard deviation; 95% CI, confidence interval.

[a] P-values for within-group differences (paired t-test) before adjustment

[b] Benjamini–Hochberg adjusted p-values for within-group differences

[c] P-values for between-group differences (ANCOVA using baseline as covariate) before adjustment

[d] Benjamini–Hochberg adjusted p-values for between-group differences.

[e] $P < 0.01$.

[f] $P < 0.05$.

mechanisms. Prolonged visual tasks can lead to the accumulation of metabolic byproducts, oxidative stress, and disrupted redox homeostasis, thereby impairing retinal function (45, 46). In this context, massage therapy is thought to alleviate visual fatigue by enhancing ocular blood flow, improving retinal oxygenation, and reducing intraocular pressure (30, 47). Animal studies have also shown that ocular massage can transiently lower intraocular pressure and increase blood flow to the eye and optic nerve (48), suggesting that improved microcirculation may play a key role in relieving visual fatigue. By integrating targeted facial massage techniques, STYFM may not only relax the ciliary and periocular muscles and improve local circulation, but also promote accommodative function recovery (49, 50). Additionally, facial massage may facilitate lymphatic drainage around the ocular and cervical regions, potentially reducing periorbital congestion and inflammation (20, 47). Overall, these mechanisms are consistent with Fisher's hypothesis, which proposes that enhancing ocular blood flow and muscle relaxation can support the restoration of reversible accommodative deficits (27, 28). In this study, FMG showed improvements in AMP, NPC, and VA, whereas CTG exhibited only NPC improvement, indicating that brief eye closure alone is insufficient to substantially restore accommodative function and visual acuity. However, these proposed mechanisms should be considered hypothetical, as this study did not directly assess ocular blood flow, lymphatic circulation, or related physiological indicators.

The STYFM intervention demonstrated significant effects on indicators related to musculoskeletal function, with FMG participants showing marked improvements in the CROM across all directions and handgrip strength (HS). Prolonged use of visual display terminals is commonly associated with forward head posture and cervical muscular imbalance, primarily due to weakness of the deep cervical flexors and compensatory overactivation of superficial muscles such as the sternocleidomastoid and anterior scalene (51-55). The observed improvements in CROM and HS in the FMG suggest that STYFM may alleviate visual fatigue-related cervical musculoskeletal dysfunction through myofascial relaxation, restoration of muscle function, enhanced neuromuscular transmission, improved peripheral circulation, and reduced muscle stiffness (31, 56-59). In addition, parasympathetic activation induced by STYFM may further facilitate muscle recovery by reducing physiological stress. In contrast, the CTG

Table 3. Musculoskeletal-Related Parameters

Outcomes and Groups	Before (n = 15); Mean (SD)	After (n = 15); Mean (SD)	Within-Group Difference (After – Before); Mean (95% CI)	Original P-Values [a]	Adjusted P-Value [b]	Between-Group Difference (FMG – CTG); Mean (95% CI)	Original P-Value [c]	Adjusted P-Value [d]
HS (kg)						2.89 (1.64, 4.14)	< 0.001 [e]	< 0.001 [e]
FMG	28.24 (9.53)	29.77 (10.73)	1.29 (-2.17, -0.41)	0.007 [e]	0.011 [f]			
CTG	31.06 (11.18)	29.49 (11.28)	-1.57 (0.61, 2.53)	0.004 [e]	0.016 [f]			
CROM-E (°)						4.19 (2.34, 6.04)	< 0.001 [e]	< 0.001 [e]
FMG	61.87 (12.30)	66.27 (13.38)	4.40 (-6.27, -2.53)	< 0.001 [e]	< 0.001 [e]			
CTG	60.4 (5.64)	60.53 (5.98)	0.13 (-0.64, 0.37)	0.582	0.684			
CROM-F (°)						4.73 (3.08, 6.38)	< 0.001 [e]	< 0.001 [e]
FMG	61.33 (9.90)	65.47 (9.00)	4.13 (-5.86, -2.41)	< 0.001 [e]	< 0.001 [e]			
CTG	56.67 (10.29)	56.47 (9.94)	-0.20 (-0.23, 0.63)	0.334	0.446			
CROM-L (°)						4.39 (3.37, 5.41)	< 0.001 [e]	< 0.001 [e]
FMG	43.03 (5.68)	47.30 (5.25)	4.27 (-5.08, -3.45)	< 0.001 [e]	< 0.001 [e]			
CTG	45.70 (4.25)	45.33 (4.17)	-0.37 (-0.32, 1.06)	0.274	0.391			
CROM-R (°)						4.67 (3.35, 6.00)	< 0.001 [e]	< 0.001 [e]
FMG	63.83 (8.55)	68.43 (8.28)	4.60 (-5.87, -3.33)	< 0.001 [e]	< 0.001 [e]			
CTG	63.10 (9.41)	63.03 (9.78)	-0.07 (-0.41, 0.55)	0.769	0.769			

Abbreviations: SD, standard deviation; 95% CI, confidence interval; CROM, cervical range of motion; CROM-E, extension; CROM-F, flexion; CROM-L, lateral; CROM-R, rotation.

[a] P-values for within-group differences (paired *t*-test) before adjustment.

[b] Benjamini–Hochberg adjusted P-values for within-group differences.

[c] P-values for between-group differences (ANCOVA using baseline as covariate) before adjustment.

[d] Benjamini–Hochberg adjusted p-values for between-group differences.

[e] $P < 0.01$.

[f] $P < 0.05$.

exhibited a transient decline in HS post-intervention, which may reflect a short-term lack of muscle activation or a state of complete relaxation.

In the present study, significant improvements were observed in HRV and SpO_2. In the FMG, HRV, PNN50, RMSSD, SpO_2, and HF components all increased significantly ($P < 0.05$). In contrast, in the CTG, although HRV indicators such as RMSSD and PNN50 also improved, SpO_2 decreased, and HF showed no significant change. The elevation of the HF component reflects enhanced vagal tone and is closely associated with the respiratory cycle, suggesting that the abdominal breathing incorporated in STYFM may contribute to physical and mental relaxation (60). HRV is a well-recognized biomarker for cognitive performance sensitive to fatigue (61), while improvements in PNN50 and RMSSD highlight STYFM's potential to reduce physiological stress. Furthermore, pupil size, regulated by autonomic balance, typically enlarges under sympathetic dominance during visual fatigue, leading to blurred vision (62, 63). Although HRV-related indices did not differ significantly between groups, the FMG showed greater increases in SpO_2 and decreases in HR compared to the CTG, suggesting superior cardiovascular efficiency following STYFM. These findings are consistent with previous studies, which have shown a strong association between improvements in blood oxygen saturation and the alleviation of visual fatigue symptoms (64). Interestingly, the CTG exhibited a decline in post-intervention SpO_2 and only a minimal reduction in visual fatigue, whereas the FMG demonstrated substantial enhancements in both parameters. These results further reinforce the efficacy of STYFM in improving peripheral circulation, optimizing oxygen delivery, and mitigating fatigue-related symptoms.

In summary, STYFM, through facial massage combined with abdominal breathing, can simultaneously improve visual accommodative function, musculoskeletal health, autonomic regulation, and cardiovascular efficiency, thereby alleviating visual fatigue.

Study Limitations and Future Directions This study adopted a rigorous randomized controlled design and used the BH procedure to control for multiple comparisons. It systematically evaluated the effects of STYFM on visual, musculoskeletal, cardiovascular, and autonomic nervous system functions, thereby enhancing the credibility and internal validity of the findings. However, some limitations remain, including a

Table 4. Cardiovascular and Autonomic Nervous System Function-Related Parameters

Outcomes and Groups	Before (n = 15); Mean (SD)	After (n = 15); Mean (SD)	Within-Group Difference (After – Before); Mean (95% CI)	Original P-Values [a]	Adjusted P-Value [b]	Between-Group Difference (FMG – CTG); Mean (95% CI)	Original P-Value [c]	Adjusted P-Value [d]
SpO_2 (%)						1.65 (0.55, 2.74)	0.005 [e]	0.009 [e]
FMG	96.93 (1.67)	98.47 (0.92)	1.53 (-2.47, -0.60)	0.003 [e]	0.006 [e]			
CTG	98.00 (0.85)	97.13 (1.73)	-0.87 (0.01,1.73)	0.048 [f]	0.104			
HRV						-0.44 (-3.92, 3.05)	0.798	0.887
FMG	50.60 (7.06)	55.00 (9.22)	4.40 (-6.31, -2.50)	< 0.001 [e]	< 0.001 [e]			
CTG	47.27 (5.44)	52.33 (4.78)	5.07 (-7.96, -2.17)	0.002 [f]	0.014 [f]			
HR (bpm)						4.24 (0.96, 7.52)	0.013 [f]	0.024 [f]
FMG	78.87 (9.94)	78.60 (9.32)	-0.27 (-3.03, 3.57)	0.055	0.073			
CTG	86.87 (10.04)	81.67 (7.39)	-5.20 (2.02, 8.38)	0.003 [e]	0.025 [f]			
TP (ms^2)						459 (-1027.47, 1947.14)	0.532	0.709
FMG	1195.35 (1017.68)	1974.11 (2408.58)	778.77 (-1657.32, 99.79)	0.078	0.098			
CTG	751.01 (498.06)	1514.16 (1451.83)	763.15 (-1557.53, 31.22)	0.058	0.106			
LF (ms^2)						-434.48 (-1307.42, 438.46)	0.316	0.489
FMG	890.45 (917.06)	1383.59 (2059.33)	493.15 (-1213.10, 226.80)	0.164	0.193			
CTG	565.75 (393.43)	1227.23 (1238.58)	661.47 (-1329.81, 6.86)	0.052	0.104			
HF (ms^2)						139.62 (-65.55, 344.79)	0.174	0.29
FMG	304.84 (245.45)	526.44 (376.49)	221.60 (-370.58, -72.62)	0.007 [e]	0.011 [f]			
CTG	185.31 (197.58)	286.93 (248.72)	101.62 (-242.35, 39.11)	0.144	0.221			
LF/HF						0.89 (-5.91, 7.69)	0.790	0.929
FMG	4.17 (3.30)	5.29 (13.33)	1.23 (-7.91, 5.65)	0.727	0.765			
CTG	4.41 (2.66)	4.69 (2.60)	0.28 (-1.98, 1.42)	0.727	0.766			
SDNN (mms)						1.04 (-13.25, 15.33)	0.882	0.929
FMG	49.40 (16.86)	55.25 (23.82)	5.84 (-16.88, 5.20)	0.275	0.306			
CTG	38.39 (12.78)	46.77 (15.80)	8.38 (-17.35, 0.59)	0.065	0.108			
RMSSD (mms)						-0.37 (-1.30, 9.56)	0.94	0.94
FMG	29.60 (13.14)	42.14 (27.52)	12.54 (-22.02, -3.06)	0.013 [f]	0.019 [f]			
CTG	22.72 (7.91)	31.50 (9.51)	8.78 (-14.25, -3.32)	0.004 [f]	0.016 [f]			
PNN50 (%)						0.02 (-0.03, 0.08)	0.410	0.586
FMG	0.08 (0.07)	0.17 (0.12)	0.09 (-0.12, -0.05)	< 0.001 [e]	< 0.001 [e]			
CTG	0.05 (0.07)	0.11 (0.08)	0.06 (-0.11, -0.02)	0.011 [f]	0.031 [f]			

Abbreviations: SD, standard deviation; 95% CI, confidence interval; HR, heart rate; TP, total power; LF, low frequency; HF, high frequency; SDNN, standard deviation of normal-to-normal RR intervals; RMSSD, root mean square of successive differences; PNN50, percentage of successive RR intervals differing by more than 50 ms.

[a] P-values for within-group differences (paired *t*-test) before adjustment.

[b] Benjamini–Hochberg adjusted P-values for within-group differences.

[c] P-values for between-group differences (ANCOVA using baseline as covariate) before adjustment.

[d] Benjamini–Hochberg adjusted p-values for between-group differences.

[e] $P < 0.01$.

[f] $P < 0.05$

small sample size, short intervention duration, a relatively homogeneous participant group, and the lack of an active control group. Specifically, the absence of a placebo-controlled or sham massage control may have introduced expectation effects, potentially influencing participants' subjective and physiological responses. Future studies should consider incorporating placebo-controlled or sham massage designs to better isolate the specific effects of the intervention. Cycloplegic refraction and axial length measurements were not performed, nor direct assessments of the autonomic nervous function, limiting in-depth exploration of the intervention's mechanisms. Overall, future studies should expand the sample size and diversity, extend the observation period, introduce appropriate active control groups, include more subjective and objective indicators, and utilize advanced monitoring techniques such as EEG and eye-tracking to more comprehensively elucidate the mechanisms and clinical value of STYFM.

Conclusion STYFM, as a noninvasive and easily self-implementable yoga-based intervention, appears to alleviate visual fatigue in young adults and improve musculoskeletal function as well as autonomic-related indicators. Given the established role of yoga in stress regulation and autonomic balance, both of which are closely related to the multidimensional manifestations of computer vision syndrome, STYFM could contribute to mitigating stress and autonomic dysregulation associated with prolonged screen use, including extraocular symptoms such as headache. Therefore, larger-scale studies with long-term follow-up are warranted to further validate its efficacy. No intervention-related adverse events were reported.

Acknowledgements

The authors extend their sincere gratitude to the Graduate School of Khon Kaen University for providing research facilities and staff support. They would also like to thank the Department of Ophthalmology, Faculty of Medicine, Khon Kaen University, for their assistance with equipment for assessment. Finally, the authors express their appreciation to all participants for their cooperation and contributions to this study.

Footnotes

AI Use Disclosure: The authors declare that no generative AI tools were used in the creation of this article.

Authors' Contribution: H.C., conceptualization, data management, funding acquisition, investigation, methodology, and writing of the original manuscript; W.E., experimental design, resources, supervision, funding support, and writing—review and editing; T.R., experimental design, resources, supervision, and writing—review and editing; S.A., methodology and writing—review and editing; W.T., data processing, formal analysis, and visualization; M.S., data collection and experimental measurements; X.W., project administration, funding support, and supervision; B.W., data collection. All authors read and approved the final manuscript.

Clinical Trial Registration Code: TCTR20241119007 (https://www.thaiclinicaltrials.org/show/TCTR20241119007).

Conflict of Interests Statement: The authors assert the absence of any conflict of interest.

Data Availability: The data supporting the findings of this study are available in the Thai Clinical Trials Registry at the following URL: https://www.thaiclinicaltrials.org/show/TCTR20241119007

Ethical Approval: This study was approved under the ethical approval code HE672161 by the Ethics Committee of Khon Kaen University, Thailand (https://echr.kku.ac.th/index.php?r=site%2Findex).

Funding/Support: This study was supported by the Fundamental Fund of Khon Kaen University and the National Science, Research, and Innovation Fund (NSRF) under grant number SD-65-015. It was also partially supported by the National Key Research and Development Program of China, specifically the project entitled "Empirical Study on Key Technologies of AI-Assisted Intervention for Individualized Sports Health Behavior" (project number 2020YFC2007205).

Informed Consent: Written informed consent was obtained from all participants.

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