Association Mechanism and Exercise Intervention Study of Suboccipital Muscle Dysfunction with Visual Fatigue

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Abstract: With the widespread use of digital devices, visual fatigue has become a significant issue affecting the health and work efficiency of modern populations. This article describes the anatomical characteristics of the suboccipital muscle group and clarifies its neurophysiological basis as a "sensory organ" rather than merely a motor structure. Based on this understanding, we establish a pathological mechanism model: "forward head posture → sustained tension in the suboccipital muscles → altered muscle spindle sensitivity → impaired head-eye coordination → increased compensatory eye movements → reduced visual stability → visual fatigue." Visual stability relies on the integrated function of the visual, vestibular, and cervical proprioceptive systems. Disruption of proprioceptive input from the neck due to dysfunction of the suboccipital muscles is a key contributor to visual fatigue. Accordingly, we propose a comprehensive exercise intervention program including relaxation of the suboccipital muscles, training of deep neck flexors, head-eye coordination exercises, and balance training, offering practical guidance for clinical applications and future research in sports and health sciences.
Keywords:Suboccipital muscles; visual fatigue; forward head posture; neck-eye reflex; vestibulo-ocular reflex; exercise intervention

Introduction

The advent of the digital age has profoundly transformed human work and lifestyle. Prolonged use of visual terminal devices such as computers and smartphones has become a daily norm, leading to an increasingly severe and widespread problem of visual fatigue. Visual fatigue, also known as asthenopia, is primarily characterized by symptoms including dry eyes, blurred vision, periorbital pain, photophobia, and difficulty in concentrating. In severe cases, it may be accompanied by headache, neck and shoulder soreness, and general malaise. Epidemiological surveys have shown that visual fatigue has become a significant issue in the field of occupational health [1-3].

The maintenance of visual function does not depend solely on ocular structures, but rather requires the coordinated interaction of three major systems—visual, vestibular, and proprioceptive. Research in the field of sports science has demonstrated that physical exercise can improve visual function, enhancing dynamic visual acuity and gaze stability. The suboccipital muscles possess unique structural characteristics—a high density of muscle spindle distribution and direct fibrous connections to the dura mater (the so-called "myodural bridge"). These features suggest that the suboccipital muscles functionally resemble sensory organs more closely, with their afferent signals playing a critical regulatory role in head spatial orientation, eye movement control, and postural maintenance [4]. Dysfunction of the suboccipital muscles can impair cervical proprioceptive input, consequently leading to deterioration of visual function.

This paper elucidates the neurophysiological mechanisms by which the suboccipital muscles participate in visual control, constructs a theoretical model linking suboccipital muscle dysfunction to visual fatigue, and subsequently proposes targeted exercise intervention strategies.

1. Anatomical Characteristics of the Suboccipital Muscles

1.1 Fine Structure of the Four Suboccipital Muscles

The suboccipital muscles are located beneath the occipital bone, posterior to the atlas (C1) and axis (C2). They constitute the deepest layer of the posterior neck musculature, consisting of four pairs of short yet robust muscles: the rectus capitis posterior major, originating from the spinous process of the axis and inserting into the lateral aspect of the inferior nuchal line of the occipital bone, primarily functioning in head extension and ipsilateral rotation; the rectus capitis posterior minor, originating from the posterior arch of the atlas and inserting into the medial aspect of the inferior nuchal line, participating in head extension and fine regulation; the obliquus capitis superior, originating from the transverse process of the atlas and inserting into the lateral aspect of the inferior nuchal line, assisting in head lateral flexion and extension; and the obliquus capitis inferior, originating from the spinous process of the axis and inserting into the transverse process of the atlas, primarily responsible for head rotation.

Although small in size, these four muscles are of considerable functional importance. Deeply embedded within the deepest layer of the posterior cervical musculature and directly attached to the cranial base and upper cervical spine, they perform precise regulation of every degree of head tilt and rotation [5,6].

1.2 High Density of Muscle Spindles: The Neural Basis of Proprioception

Anatomically, the most prominent feature of the suboccipital muscles is their exceptionally high density of muscle spindles. Muscle spindles are proprioceptors that sense muscle length and the rate of change in length, serving as essential neural end-organs for maintaining posture and motor control. The number of muscle spindles per gram of tissue in the suboccipital muscles far exceeds that of other skeletal muscles in the body, with a density comparable even to the extraocular muscles that govern fine eye movements [7].

This characteristic implies that the suboccipital muscles are not merely executors of movement, but also serve as "sensors" of head spatial position information. Muscle spindles continuously transmit feedback signals to the central nervous system regarding head posture, movement direction, and velocity—information that is indispensable for maintaining balance, coordinating eye movements, and stabilizing vision.

1.3 The Myodural Bridge: Direct Connection to the Central Nervous System

The suboccipital muscles possess a unique fibrous connection to the dura mater, a structure termed the "myodural bridge." Anatomical studies have confirmed that the rectus capitis posterior minor and rectus capitis posterior major are directly attached to the cervical spinal dura mater through connective tissue fibers, forming a physical pathway from muscle to the meningeal covering of the central nervous system [8].

The precise function and significance of the myodural bridge remain incompletely understood; however, some scholars have proposed that this structure may play a role in cerebrospinal fluid circulation regulation, dural tension maintenance, and mechanosensation at the craniocervical junction. This connection renders the suboccipital muscles the only skeletal muscles in the body directly linked to the meninges of the central nervous system, further supporting their functional designation as "sensory organs."

Based on these anatomical features—the abundant proprioceptive input provided by high-density muscle spindles, the direct neural connection established by the myodural bridge, and their regulatory role in fine head movements—the suboccipital muscles far exceed the traditional definition of muscles, more closely resembling a sophisticated "sensor array" embedded at the craniocervical junction, continuously transmitting critical information about head spatial orientation to the brain. The suboccipital muscles function much like the body's "built-in VR headset," with their functional status directly influencing our spatial perception and visual stability.

2. Mechanisms of Suboccipital Muscle Involvement in Visual Control

2.1 The Multisensory Integration Model of Visual Stability

Visual clarity and stability depend on the precision and constancy of retinal imaging. When the head moves, the eyes must generate accurate compensatory movements to maintain the stability of the external scene's projection on the retina. This process is not accomplished by a single system alone, but rather results from the synergistic integration of three major systems: visual, vestibular, and cervical proprioceptive.

The cervical proprioceptive system, particularly the afferent signals originating from the suboccipital muscles, plays a critical role in this integrative process. Cervical proprioceptive signals, along with visual and vestibular signals, converge and integrate within the central nervous system—especially in the vestibular nuclei and the cerebellum—ultimately generating coordinated head-eye movement commands [9].

2.2 Head-Eye Coordination

Head-eye coordination is central to visually guided behavior. In daily life, when we fixate on a target, we often initiate head movement first, followed by more precise eye movements to lock onto the target. During this process, proprioceptive feedback from the suboccipital muscles provides the brain with information about the velocity and direction of head movement, enabling the eyes to make anticipatory compensations, thereby shortening visual fixation time and improving fixation efficiency.

A functional anatomical connection exists between the suboccipital muscles and the extraocular muscles. Studies have observed that when the eyes move, the suboccipital muscles exhibit synchronous tension changes; conversely, tension in the suboccipital muscles can also affect the trajectory of eye movements. This close "eye-neck coupling" relationship positions the suboccipital muscles as a critical link in head-eye coordination [10].

2.3 Cervico-Ocular Reflex

The cervico-ocular reflex (COR) is a compensatory eye movement reflex elicited by cervical proprioceptive input. When the cervical muscles sense rotation of the trunk relative to the head, the COR triggers counter-rotation of the eyes to maintain gaze stability in space.

The COR is particularly active during low-frequency, large-amplitude head movements, and its gain—the ratio of eye movement amplitude to neck stimulation amplitude—reflects the efficiency with which cervical proprioception drives eye movements. A study of patients with chronic neck pain found that the COR gain (median 0.41) in neck pain patients was significantly higher than that in healthy controls (median 0.231), suggesting that abnormal cervical proprioception leads to an abnormal increase in COR gain. This elevation may represent a compensatory adjustment by the central nervous system to offset downregulation of VOR function; however, it also implies reduced precision of eye movements and increased risk of visual fatigue.

2.4 Vestibulo-Ocular Reflex

The vestibulo-ocular reflex (VOR) is the core mechanism for maintaining visual stability. When the head rotates rapidly, the semicircular canals perceive angular acceleration and, through the VOR pathway, drive the eyes to move at an equal velocity in the opposite direction, keeping the fixation target stable on the retina. The gain of the VOR is approximately 1.0—that is, the velocity of eye movement equals that of head movement in the opposite direction.

There is a close interaction between cervical proprioceptive and vestibular signals. Research has shown that cervical muscle fatigue significantly reduces dynamic visual acuity (DVA), indicating that even when vestibular input to the VOR is normal, degraded quality of cervical proprioceptive input can impair VOR functional expression. Afferent signals from cervical muscle spindles and vestibular signals converge and integrate in the vestibular nuclei; abnormalities in either channel can affect the final oculomotor output [11].

2.5 Neural Pathways of Proprioceptive Input

Afferent signals from the suboccipital muscle spindles enter the spinal cord via the cervical dorsal roots (primarily the C1-C3 segments), synapse in the central cervical nucleus (CCN) of the spinal cord, and then ascend to the cerebellum and vestibular nuclei. The CCN serves as the gateway through which the cerebellum receives cervical proprioceptive information; its fibers project to the cerebellar cortex, participating in the integrative regulation of postural balance and body orientation.

Simultaneously, proprioceptive signals from the upper cervical spine also project directly to the superior colliculus, where they participate in visual spatial attention and the generation of oculomotor commands. This multi-pathway projection pattern indicates that proprioceptive input from the suboccipital muscles exerts multiple influences on oculomotor control.

2.6 The Integrative Role of the Cerebellum

The cerebellum is the core hub for the integration of signals from the three major systems—visual, vestibular, and proprioceptive. Cervical proprioceptive information, vestibular signals, and visual afferents converge in the cerebellar cortex; after processing by the deep cerebellar nuclei, coordinated commands for the VOR, COR, and spinal reflexes are output.

The cerebellum's regulation of the COR is particularly crucial. The COR is not a simple reflex arc, but rather a plastic reflex subject to continuous cerebellar modulation. When cervical proprioceptive input is abnormal, the cerebellum attempts to maintain visual stability by adjusting the gain balance between the VOR and COR. However, this compensation comes at a cost—imbalance in gain distribution means increased imprecision in eye movements, requiring the visual system to expend additional accommodative effort, ultimately leading to the accumulation of visual fatigue.

2.7 Integration: Visual Stability Depends on Three-System Synergy

In summary, visual stability is not a "solo performance" of the visual system, but rather the result of coordinated interaction among the visual, vestibular, and cervical proprioceptive systems. As the most important source of cervical proprioception, the functional status of the suboccipital muscles directly influences the gain level of the COR, the coordination between VOR and COR, and the quality of cerebellar integration of oculomotor commands [12].

This understanding carries significant clinical implications: any factor that leads to suboccipital muscle dysfunction—whether poor posture, muscle fatigue, or direct injury—may, through the above pathways, trigger a decline in visual function. The "root cause" of visual fatigue may not lie in the eyes, but at the back of the head—in the suboccipital muscles.

3. A Mechanistic Model of Visual Fatigue Induced by Suboccipital Muscle Dysfunction

3.1 The Burden of Prolonged Computer Use

The typical posture of contemporary office workers is characterized by forward head protrusion, cervical flexion, and elevated shoulders. This posture is anatomically termed "forward head posture" (FHP). In normal posture, the center of gravity of the head should be positioned directly above the spine, with the posterior cervical muscles maintaining only minimal tension to support the head (approximately 4.5–5 kg). However, when the head is tilted forward, the center of gravity shifts anteriorly, and the cervical extensor muscles must increase their contractile force exponentially to maintain head position.

Research has shown that the craniovertebral angle (CVA) is an objective indicator for assessing forward head posture. A CVA of less than 50 degrees indicates the presence of forward head posture, while patients with moderate to severe FHP may present with CVA values as low as 40.7° to 43.2°. This pattern is particularly prominent among long-term computer users.

3.2 Sustained Tension in the Suboccipital Muscles

Under forward head posture, the suboccipital muscles at the craniocervical junction bear the brunt of the load. In order to maintain a horizontal line of sight (to see the screen clearly), the suboccipital muscles must contract continuously to pull the backward-tilted head back to a horizontal position. This sustained low-intensity contraction keeps the suboccipital muscles in a state of chronic tension, leading to muscle fatigue, local ischemia, and accumulation of metabolic byproducts.

The tension in the suboccipital muscles is not only manifested as stiffness and soreness of the muscles themselves; more critically, their proprioceptive function is affected. Sustained muscle contraction alters the sensitivity of muscle spindles—the afferent discharge patterns of the spindles change, resulting in biased "head position signals" transmitted to higher centers.

3.3 Altered Muscle Spindle Sensitivity and Reduced Cervical Proprioception

The alteration of muscle spindle sensitivity is the core mechanism. When the suboccipital muscles are chronically maintained in a shortened or excessively stretched position, both the resting discharge frequency of muscle spindles and their response characteristics to length changes are modified. This alteration leads to distortion of cervical proprioceptive information received by the central nervous system—the brain's "perception" of the head's actual spatial position becomes biased.

Reduced proprioception can be assessed directly through the joint position error (JPE) test. Studies have shown that individuals with cervical proprioceptive deficits often exhibit JPE values greater than 4.5 degrees, indicating an inability to accurately perceive the head's position in space.

3.4 Decline in Head-Eye Coordination

Distortion of cervical proprioception is the direct cause of impaired head-eye coordination. When the brain cannot precisely obtain the head's position and movement parameters, the "feedforward control" of eye movements loses its reliable foundation. To maintain fixation, the oculomotor system must rely more heavily on "feedback control"—that is, correcting the eye after it has already deviated from the target.

The abnormal elevation of COR gain is a typical manifestation of this change. As previously noted, chronic neck pain patients exhibit significantly higher COR gain compared to healthy individuals. Elevated COR gain indicates that the eyes overreact to cervical input signals, and eye movements no longer precisely match the actual head movements, making visual target fixation more difficult.

3.5 Increased Compensatory Eye Movements

To compensate for the decline in head-eye coordination, the oculomotor system is forced to adopt compensatory strategies. This manifests as: decreased precision of smooth pursuit eye movements, requiring more "corrective saccades" to reacquire the target; reduced fixation stability, with increased micro-drift during fixation requiring more micro-saccades to maintain the target image on the fovea; and decreased saccade accuracy, with landing points deviating from the target and requiring secondary correction.

These increased compensatory eye movements signify a significant rise in the workload of the extraocular muscles. Prolonged oculomotor compensation leads to extraocular muscle fatigue, periorbital muscle tension, and abnormal tear secretion, ultimately manifesting as the classic "visual fatigue" symptoms—dry eyes, blurred vision, and ocular soreness.

3.6 The Development of Visual Fatigue

Visual fatigue is the ultimate outcome of the above cascade of events. In this model, the essence of visual fatigue is not merely "tired eyes," but rather an outward manifestation of dysfunction in the "eye-neck integration system." Its pathophysiological mechanisms can be summarized as follows: mechanical factors—suboccipital muscle tension can compress the traversing greater occipital nerve and vertebral artery, triggering headaches and cerebral hypoperfusion; reflex factors—cervical proprioceptive abnormalities, through the COR pathway, lead to imprecise eye movements and increased extraocular muscle load; and integrative factors—sensory conflicts among visual, vestibular, and proprioceptive inputs reduce central integration efficiency, requiring more cognitive resources for visual information processing, thereby exacerbating "brain fatigue."

3.7 Model Summary

Synthesizing the above analysis, the mechanistic model of visual fatigue induced by suboccipital muscle dysfunction can be summarized as follows:

Prolonged computer/mobile phone use → Forward head posture (reduced craniovertebral angle) → Sustained tension and shortening of suboccipital muscles → Altered muscle spindle sensitivity (distorted proprioceptive afferents) → Reduced cervical proprioception (increased joint position error) → Abnormal COR elevation / Impaired head-eye coordination → Increased compensatory eye movements (reduced fixation stability, decreased saccade accuracy) → Increased extraocular muscle workload → Visual fatigue

This model extends the "source" of visual fatigue from the eyes to the suboccipital muscles of the neck, revealing the causal chain linking posture, proprioception, and oculomotor control. This model provides a novel target for visual fatigue prevention and intervention—rather than merely "treating the eyes," it calls for simultaneous "treatment of the neck."

4. Exercise Intervention Protocol

4.1 Principles of Intervention Design

Based on the mechanistic model described above, exercise interventions for visual fatigue caused by suboccipital muscle dysfunction should follow three principles. First, release tension—alleviate excessive tension in the suboccipital muscles and restore their normal proprioceptive function. Second, correct posture—rectify forward head posture to reduce the load on the suboccipital muscles at its source. Third, rebuild function—through head-eye coordination and balance training, re-establish the synergistic integration of the visual, vestibular, and proprioceptive systems.

The intervention protocol outlined below is synthesized from existing research and clinical experience, and may be adjusted according to the specific conditions of the target population.

4.2 Training Module 1: Suboccipital Muscle

Relaxation

Purpose: To alleviate excessive tension in the suboccipital muscles, restore normal muscle spindle sensitivity, and improve the quality of cervical proprioceptive input.

Method 1: Massage ball pressure release

In a supine position with knees bent, place a massage ball (or tennis ball) at the lower edge of the occipital bone along the hairline, corresponding to the surface projection of the suboccipital muscles. Use the weight of the head to allow the ball to press gently into the target area. Combine this with slow "nodding" and slight head-shaking movements to allow the ball to roll and release the suboccipital muscles. Perform for 1–2 minutes on each side.

Method 2: Manual release

In a seated or supine position, place both thumbs in the depressions on either side of the lower edge of the occipital bone (the region of the Fengchi acupoint). Perform gentle circular kneading, with pressure sufficient to produce a sense of soreness and distension but not sharp pain. Perform for 1–2 minutes per session, 2–3 sets daily.

Method 3: Active stretching

In a seated position, interlace the fingers and place both hands behind the head. Gently pull the head forward and downward (bringing the chin toward the collarbone), feeling the stretch in the posterior neck. Hold for 15–30 seconds, repeat 3–5 times. Note that movements should be slow and gentle.

Precautions: Avoid excessive force during relaxation training, and be especially careful not to press directly on the cervical spinous processes. If dizziness occurs during initial attempts, pause and rest.

4.3 Training Module 2: Deep Cervical Flexor Training

Purpose: To strengthen the deep cervical flexors (primarily the longus capitis and longus colli), restore the physiological cervical lordosis, correct forward head posture, and fundamentally reduce the compensatory load on the suboccipital muscles.

Method 1: Chin tuck

In a seated or supine position with the head level, perform a "double-chin" movement—move the chin horizontally backward, bringing the back of the head closer to the rear, and feel the contraction of the deep anterior cervical muscles. Hold for 3–5 seconds, then relax. Perform 10–15 repetitions per set, 3 sets daily.

Advanced version: Perform while standing against a wall, with the back and waist against the wall, the back of the head as close to the wall as possible, and the eyes looking forward.

Method 2: Supine cervical flexor isometric contraction

In a supine position with knees bent, tuck the chin slightly so that the back of the cervical spine is flat against the surface. In this position, press the head gently into the surface (without actually lifting it off), maintaining isometric contraction of the cervical flexors. Hold for 5–10 seconds, then relax. Perform 10 repetitions per set, 2–3 sets daily.

Precautions: The key movement is "chin retraction" rather than "head lowering"—the distinction is important. Lowering the head would further tension the posterior cervical muscles, which is counterproductive.

4.4 Training Module 3: Head-Eye Coordination Training

Purpose: Through active head-eye coordinated movements, improve COR gain regulation and enhance the precision of head-eye coordination.

Method 1: Head turning with fixed gaze

In a seated position, select a fixed target at eye level (such as a point on the wall). Maintain gaze fixation on the target while slowly turning the head left and right to maximum amplitude (approximately 45 degrees), keeping the eyes focused on the target throughout. Perform 10 repetitions to each side, 2–3 sets daily.

Method 2: Head rotation combined with saccadic eye movements

In a seated position with the head kept still, perform rapid horizontal saccadic eye movements from side to side to the limits of the visual field, 10 times in each direction. Then switch to the vertical direction. Keep the head stationary, activating the coupling with the suboccipital muscles solely through eye movements.

Method 3: Head-eye same-direction tracking

In a seated position, hold a pen approximately 30 cm in front of the eyes. Slowly move the pen to the left while simultaneously turning the head to the left, keeping the eyes tracking the pen tip. Perform 10 times to each side, 2 sets daily.

Precautions: Head turning should be slow and at a constant speed to avoid causing dizziness. Beginners may start with reduced turning amplitude and gradually increase.

4.5 Training Module 4: Balance Training

Purpose: Through training on unstable support surfaces, activate the integrative pathways of the visual, vestibular, and proprioceptive systems, enhance the cooperative function of the three systems, and indirectly improve visual stability.

Method 1: Single-leg stance with eye tracking

Stand on one leg (initially with hand support against a wall or chair for stability) and maintain balance. Hold an object (such as a pen or finger) in front of the eyes and slowly move it horizontally while tracking the target with the eyes. Hold for 30–60 seconds, then switch to the other side. Perform 2–3 sets daily.

Advanced version: Single-leg stance with eyes closed (ensure a safe environment)—with reduced visual input, the demand for vestibular and proprioceptive integration increases.

Method 2: Standing on an unstable surface

Stand on a cushion or balance pad with feet shoulder-width apart, attempting to maintain body balance. Simultaneously perform head-eye coordination exercises (such as head turning with fixed gaze) to further increase the challenge to sensory integration.

Precautions: Ensure a safe environment during balance training to avoid falls. Elderly individuals or those with balance disorders should have a spotter present for protection.

4.6 Summary of the Training Protocol

The comprehensive intervention protocol recommended in this paper is presented in Table 1.

Table 1 the Intervention Protocol

Training Content	Frequency	Duration per Session	Recommended Time
Suboccipital muscle relaxation	1–2 times daily	5–10 minutes	Work breaks
Deep cervical flexor training	2–3 sets daily	3–5 minutes per set	Morning / Work breaks
Head-eye coordination training	2 sets daily	5 minutes per set	Lunch break / Evening
Balance training	1 set daily	5 minutes per set	Evening

5. Limitations and Recommendations

5.1 Limitations of Existing Research

Although anatomical, neurophysiological, and clinical observations have provided substantial theoretical support for the association between the suboccipital muscles and visual fatigue, the existing evidence still has the following limitations. First, insufficient causal validation: most studies are cross-sectional in design or based on mechanistic inferences, and there is a lack of randomized controlled trials (RCTs) that directly verify the causal chain from "suboccipital muscle intervention → visual function improvement." Second, lack of standardized assessment tools: assessment tools for visual fatigue (such as the ASQ-17 questionnaire) vary across different studies, and evaluation methods for cervical proprioception (such as the JPE test) have not yet been unified. Third, unclear dose–response relationship of intervention protocols: the optimal frequency, intensity, and duration of exercise interventions remain unknown, and long-term follow-up data on the maintenance of intervention effects are also lacking.

5.2 Recommendations for Future Research

Based on the above limitations, it is recommended that future research be conducted in the following four directions.

Direction 1: Randomized controlled trials to validate causal mechanisms

Design rigorous RCTs that enroll participants with forward head posture and visual fatigue symptoms, randomly assigning them to an intervention group (suboccipital muscle relaxation + cervical flexor training + head-eye coordination training) and a control group (conventional eye relaxation or no intervention). Compare the two groups in terms of visual fatigue scores (ASQ-17), cervical joint position error (JPE), craniovertebral angle (CVA), and dynamic visual acuity (DVA).

Direction 2: Effects of head-eye coordination training on dynamic vision

Target populations requiring high dynamic visual performance, such as athletes (e.g., ball sport players) or drivers, to evaluate the effects of head-eye coordination training on dynamic visual acuity, reaction time, and sports performance, and to explore the application value of this training in sports practice.

Direction 3: Effects of intervention on reading and academic performance

Target student populations to evaluate the impact of the suboccipital muscle intervention protocol on reading fluency, learning efficiency, and subjective visual comfort, thereby providing a basis for health interventions in educational settings.

Direction 4: Mechanistic studies

Employ techniques such as functional magnetic resonance imaging (fMRI) or transcranial magnetic stimulation (TMS) to further elucidate the neural mechanisms by which cervical proprioceptive input influences the integration processes of the visual cortex and cerebellum.

Conclusion

Based on motor neuroscience and sports health theory, this paper analyzes the mechanisms underlying the association between suboccipital muscle dysfunction and visual fatigue, and explores the design and application of exercise interventions. The findings are as follows: the suboccipital muscles are not only important muscle groups for maintaining head and neck stability, but also serve as critical sensory regulatory structures in the human body; the development of visual fatigue is not determined solely by local ocular factors, but may also involve the information integration processes among the visual system, vestibular system, and cervical proprioceptive system; suboccipital muscle dysfunction may, by altering cervical proprioceptive input, affect the coordination efficiency between the cervico-ocular reflex (COR) and the vestibulo-ocular reflex (VOR), thereby reducing head-eye coordination, increasing the compensatory load on the visual system, and consequently promoting the onset of visual fatigue symptoms; exercise intervention may serve as an important adjunctive approach for improving visual fatigue; future research should strengthen the connection between basic mechanisms and clinical applications, further clarify the specific role of the suboccipital muscles in the development and progression of visual fatigue, and establish a more scientific, standardized, and generalizable exercise intervention system.□

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