SPORT SCIENCE AND HEALTH PROMOTION

ISSN 3144-1548

Vol.1, No.1, July 2026

VIVICOSMOS PUBLISHING LLC

ss-hp.com

CONTENTS

1 George Hackenschmidt's Philosophy of Physical Culture and Its Modern Significance
Jiang Tang

9 The Role of Kayak Rolling Techniques in Developing Proprioception
—— A Case Study of Sweep Roll, C-to-C Roll, and Hand Roll
Owen

16 From Fear to Psychological Growth: The Mechanisms by Which Rappelling Promotes Mental Health
Dong Rui

23 The Industrial Revolution and the Birth of Modern Tennis
—— A Historical Examination Based on Technological Innovation, Social Transformation, and the Development of Sports Institutions
Tan Shanchao

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

George Hackenschmidt's Philosophy of Physical Culture and Its Modern Significance

JIANG Tang
（Shandong Yinglong Outdoor Club, Ji'nan 250000,China）

Abstract: At the beginning of the 20th century, the European physical culture movement catalyzed a significant shift in modern sports thought—from a narrow focus on athletic performance to an emphasis on physical education, health promotion, and personal development. George Hackenschmidt, a prominent figure in this movement, exerted profound influence not only in strength training and professional wrestling but also developed a systematic philosophy of physical culture centered on the body, mind, education, and health. Drawing on his representative works such as *The Way to Live*, *Man and Cosmic Antagonism*, and *The Three Memories and Forgetfulness*, this article integrates theories of physical culture, sport philosophy, and health promotion to trace the intellectual background of Hackenschmidt’s physical culture philosophy. It analyzes the theoretical dimensions of his views on bodily ontology, mind-body unity, physical education, natural health, and personality development, and further explores their practical implications for public fitness, school physical education, health promotion, and the evolution of sport philosophy.
Keywords:George Hackenschmidt; physical culture; sport philosophy; physical education; health promotion

Introduction

In recent years, the focus of sports research has gradually expanded from competition to areas such as physical culture, healthy lifestyles, physical education, and quality of life, re-establishing the body as a central concern shared by sport philosophy and health sciences.

Physical culture, an essential component of modern Western sports thought, emerged during the period of social transformation in Europe from the late 19th to the early 20th century. While the Industrial Revolution rapidly advanced social productivity, it also transformed people's work patterns and lifestyles. Mechanized production and urban living led to a significant decline in physical activity, resulting in deteriorating physical functions, rising chronic diseases, and increasing bodily alienation—issues that gradually drew public attention. Against this historical backdrop, the movement promoting natural living, regular exercise, physical education, and character development gained momentum, becoming a foundational source for modern mass fitness and health promotion.

George Hackenschmidt (1877–1968) was one of the most representative practitioners and thinkers of physical culture during this era. As a world-renowned wrestling champion, pioneer of strength training, and advocate of physical culture, he achieved remarkable success not only in competitive sports but also systematically articulated his views on physical training, healthy lifestyles, physical education, and personal development through works such as T*he Way to Live* and *Man and Cosmic Antagonism*. He argued that physical training should not merely aim at building strength, but rather serve human holistic development, achieving harmony among body, mind, and morality [1,2,3]. This perspective broke away from the traditional performance-centered values of competitive sports and provided significant intellectual resources for contemporary sport philosophy and health promotion theory.

1 Historical Context of George Hackenschmidt’s Physical Culture Philosophy

George Hackenschmidt's philosophy of physical culture did not emerge in isolation; rather, it was shaped by the convergence of European social transformation, the modernization of sports, and the rise of physical culture movements from the late 19th to the early 20th century. The Industrial Revolution not only drove economic and technological progress but also profoundly altered human labor, lifestyle, and bodily existence. In response to declining physical health, growing health problems, and the estrangement between humans and nature brought about by industrial civilization, a physical culture

movement arose across Europe, centered on physical education, natural living, and health promotion. Within this context, Hackenschmidt absorbed classical ideas of physical education, naturalist philosophy, and modern conceptions of physical culture, gradually developing a comprehensive and integrative philosophy of physical culture.

1.1 Development of the European Physical Culture Movement

Modern physical culture movements originated in 19th-century Europe, driven by nation-building, industrialization, educational reform, and advances in public health. Germany, Sweden, and Britain each developed distinct models of physical education, laying the foundation for modern sports thought.

Friedrich Ludwig Jahn promoted German gymnastics, emphasizing the use of systematic physical training to strengthen national physique, cultivate discipline, and foster national consciousness. Jahn believed that physical education was not merely about enhancing strength and endurance, but also a vital means of shaping character and instilling social responsibility [4]. His ideas integrated physical training into the modern national education system, exerting a profound influence on the development of physical education throughout Europe.

Per Henrik Ling established the Swedish gymnastics system, which emphasized anatomical, physiological, and medical foundations, advocating scientific and standardized physical training to improve bodily function and promote health [5]. Compared to German gymnastics, Swedish gymnastics placed greater emphasis on the scientific nature and rehabilitative functions of physical activity, laying an important foundation for the development of modern sports medicine and rehabilitation sports.

Meanwhile, Britain gradually developed a modern sports system characterized by school physical education and competitive sports. In the mid-to-late 19th century, sports such as football, rugby, athletics, and rowing rapidly expanded, with fair competition, teamwork, and rule awareness becoming key features of British sports culture. During this period, British sports not only advanced competitive sport but also reinforced the value of physical education in character development and social responsibility.

Building upon the developments of German gymnastics, Swedish gymnastics, and British competitive sports, Europe gradually formed a body culture movement with broad social influence. Body culture emphasized regular exercise, strength training, natural diets, outdoor activities, and healthy lifestyles, advocating that physical training should be accessible to the general public rather than limited to military personnel or professional athletes [10]. Numerous body culture magazines, fitness schools, and training institutions emerged, making body culture an essential component of public health initiatives.

During this era, Eugen Sandow, Bernarr Macfadden, and George Hackenschmidt jointly promoted the growth of the body culture movement. While Sandow focused on muscular aesthetics, George Hackenschmidt placed greater emphasis on the significance of physical training for personal development, spiritual growth, and a healthy lifestyle. He believed that strength was merely an outward expression of body culture; its true value lay in achieving balanced development of body, mind, and morality through sustained training. This philosophical orientation elevated George Hackenschmidt beyond the role of an ordinary fitness advocate, shaping a body culture thought imbued with deep philosophical meaning.

1.2 The Physical Crisis of the Industrial Age and the Response of Body Culture

The Industrial Revolution of the 19th century profoundly transformed human society and reshaped the human body. Mechanized production increased labor efficiency, yet much manual labor was replaced by machines, leading to significantly reduced physical activity among urban populations. Factory systems and office work popularized sedentary lifestyles, prompting growing societal concern over obesity, cardiovascular diseases, and neurasthenia [6]. At the same time, rapid urbanization brought air pollution, deteriorating living conditions, and accelerated life rhythms, intensifying the conflict between modern civilization and the body’s natural attributes.

In response to the physical crisis brought about by industrial civilization, the body culture movement offered proactive solutions. George Hackenschmidt argued that many health problems in modern society were not due to inherent bodily defects but resulted

from disconnection from natural ways of living. In The Way to Live, he asserted that health stems from regular exercise, sufficient sleep, balanced nutrition, fresh air, and active labor—rather than relying solely on medical treatment. In his view, physical activity not only strengthens the body but also restores the harmonious relationship between humans and nature.

This perspective clearly reflects preventive medicine principles. George Hackenschmidt stressed that health management should prioritize prevention, enhancing the body's adaptability through improved lifestyle habits rather than treating illness after it occurs. This viewpoint aligns closely with contemporary health promotion theories and the principles of lifestyle medicine [7]. In recent years, extensive evidence-based research has shown that regular physical activity and healthy lifestyles significantly reduce the risk of chronic non-communicable diseases and improve quality of life [8], further confirming the scientific foresight of George Hackenschmidt's belief that "exercise promotes health."

1.3 Intellectual Origins of the Philosophy of Physical Culture

George Hackenschmidt's philosophy of physical culture is characterized by distinctive comprehensiveness, and its theoretical origins span multiple domains including ancient Greek sports thought, naturalistic education, philosophy of life, and modern physical culture movements.

The ancient Greek concept of Kalokagathia emphasizes the unification of physical beauty and moral beauty, and holds that physical education should facilitate the all-round development of human beings. Both Plato and Aristotle maintained that physical education, together with intellectual education and moral education, constitutes a complete education system [9]. George Hackenschmidt inherited this tradition, and regards physical training as a crucial foundation for personality shaping rather than a technical activity independent of education.

The ideology of naturalistic education exerted a profound influence on George Hackenschmidt. Jean-Jacques Rousseau emphasized in *Emile* that education should be carried out in accordance with the laws of nature, and argued that children should promote their all-round development through physical activities and practical experience. George Hackenschmidt's viewpoints on natural diet, outdoor sports, sunlight, fresh air and manual labor are highly consistent with the concepts of naturalistic education.

Furthermore, the understanding of the holism of life in 19th-century philosophy of life further enriched George Hackenschmidt's view of the body. He rejected the mechanical separation of the body and mind, and emphasized that the body, will and spirit together constitute the complete life of a human being. This holistic view of life was further developed in modern philosophy of the body, embodied cognitive theory, and physical literacy theory [10].

2 George Hackenschmidt's Philosophy of Physical Culture

If the European physical culture movement at the end of the 19th century provided the historical context for George Hackenschmidt's philosophy of physical culture, then his genuine theoretical contribution lies in elevating physical training to a philosophical practice concerning life, education and personality development. Through the study of works such as *The Way to Live*, *Man and Cosmic Antagonism*, and *The Three Memories and Forgetfulness*, it can be found that George Hackenschmidt did not simply understand sports as competitive activities or strength training, but constructed a holistic ideological system with the body as the core, covering health, education, spirit and the development of civilization. This paper argues that his philosophy of physical culture mainly includes five interrelated theoretical dimensions: the ontology of the body, the unity of mind and body, the view of physical education, the view of natural health, and the view of personality construction.

2.1 The Body as the Foundation of Existential Life: The Ontology of the Body

George Hackenschmidt's philosophy of physical culture is first and foremost established on a positive ontology of the body. He holds that the body is neither an accessory of the mind nor an instrument for achieving social goals, but the foundation of human existence. Human thinking, emotion, will and social activities all depend on a healthy and energetic body; therefore, physical training carries a life significance that transcends sport itself.

In *The Way to Live*, George Hackenschmidt explicitly states that health is the prerequisite for a happy life and personality development, and it is difficult for a person with a frail body to fully realize their intellectual and creative potential. This viewpoint breaks through the dualistic tradition that separates the body and mind that has dominated modern thought, and aligns more closely with the ideological stance of the holistic view of life. The body not only has biological significance, but also serves as an important medium for individuals to participate in social life and realize self-worth.

Modern sociology of the body holds that the body is not only a natural entity, but also a key object of socio-cultural construction. Although George Hackenschmidt did not adopt the discourse system of modern sociology, his discussion on the value of the body has already gone beyond the mere physiological level, and interprets the body as an important foundation for personality development and civilizational progress, which is to some extent consistent with the understanding of body subjectivity in modern sociology of the body.

2.2 The Principle of Holistic Development Through the Unity of Body and Mind

George Hackenschmidt's philosophy of physical culture emphasizes the indivisible unity between the body and the mind. He rejects the interpretation of physical training merely as the growth of muscle strength, and argues that genuine physical culture should simultaneously facilitate the development of the body, mind and will.

In *Man and Cosmic Antagonism*, George Hackenschmidt points out that physical training not only changes human physiological conditions, but also influences individuals' mental qualities and moral cultivation. He argues that individuals who persist in regular training often demonstrate stronger self-discipline, a more positive life attitude, and a more stable psychological state. Therefore, physical training is essentially a form of mental training.

This viewpoint coincides with the ancient Greek concept of Kalokagathia. Ancient Greek education emphasized the unification of physical beauty and moral beauty, and held that an ideal personality must be grounded in a healthy body. George Hackenschmidt inherited and developed this thought, and regards physical training as an important approach to achieving personality perfection rather than a physical activity independent of education.

In recent years, embodied cognitive theory has further demonstrated the close connection between the body and cognition. Scholars such as Varela argue that human cognitive activities are formed in the continuous interaction between the body and the environment, and bodily experience directly influences thinking patterns, emotional states and behavioral decision-making [11]. Although George Hackenschmidt lived long before the proposal of embodied cognitive theory, his discussion on the role of the body in promoting spiritual growth is ideologically consistent with the view on the unity of body and mind in modern cognitive science.

2.3 Physical Education: Sport as an Important Approach to Personality Cultivation

George Hackenschmidt argues that the genuine value of physical culture does not lie in cultivating sports champions, but in cultivating well-rounded individuals. He repeatedly emphasized that sport is first and foremost an educational activity, whose goal is to facilitate personality growth through physical training rather than merely improving competitive performance.

In his view, sustained physical training requires individuals to overcome inertia, endure fatigue, and adhere to their goals, and this process can cultivate a sense of responsibility, self-discipline and resilience. These qualities not only contribute to athletic performance, but can also be transferred to study, work and social life to promote the all-round development of individuals. Therefore, physical education is essentially a form of personality education.

It is worth noting that the physical education proposed by George Hackenschmidt has distinct characteristics of lifelong education. He argues that physical training should not be limited to the school years, but should run through the entire life course of an individual, making sport a life habit and cultural practice. This viewpoint is highly consistent with modern lifelong sports theory and the national fitness concept, and also reflects the foresight of his thought.

2.4 Natural Health Perspective—Body Culture as a Healthy Lifestyle

A key feature of George Hackenschmidt's

philosophy on body culture lies in his understanding of health not merely as physical strength, but as an integrated state of harmonious development between humans and nature, and between body and mind. In *The Way to Live*, he repeatedly emphasizes that human development should follow natural laws, with regular exercise, balanced nutrition, sufficient sleep, fresh air, sunlight exposure, and moderate labor collectively forming a healthy lifestyle—elements that are interdependent.

This idea emerged during the rapid advancement of industrial civilization. At that time, urbanization and mechanized production in Europe accelerated, leading to reduced physical labor, faster-paced lifestyles, and growing environmental pollution. George Hackenschmidt believed that while modern civilization had improved material living standards, it had also weakened the connection between the human body and nature, gradually detaching the body from its natural developmental rhythms. Therefore, he argued that body culture meant not only physical training but also returning to nature and establishing a scientifically sound and healthy way of life.

Notably, George Hackenschmidt placed great emphasis on integrating strength training with natural movement. He believed that strength training enhances bodily functions, while natural activities such as walking, swimming, hiking, and manual labor improve overall adaptability and ensure balanced development across organ systems. This perspective differs from later fitness models that overemphasize specialized training, aligning more closely with contemporary holistic health management principles.

In recent years, Lifestyle Medicine has increasingly become a major direction in international public health. Its core concept is preventing and managing chronic diseases through physical activity, nutritional intervention, sleep management, stress regulation, and behavioral change [12]. Numerous evidence-based studies have shown that adhering to a healthy lifestyle significantly reduces the risk of cardiovascular disease, diabetes, obesity, and certain cancers [13]. From this standpoint, although George Hackenschmidt lived in an era before the full maturity of modern medicine, his ideas about healthy living already exhibit clear characteristics of modern health promotion.

Research on Green Exercise has found that engaging in physical activities in natural environments such as forests, parks, and water bodies can more effectively improve mental health, enhance emotional well-being, and increase motivation for sustained participation in exercise [14]. These findings further validate the significant value of Hackenschmidt’ s advocacy for natural living and outdoor activity, demonstrating the strong practical relevance of his health philosophy.

George Hackenschmidt's natural health perspective in his body culture philosophy does not simply advocate "returning to nature." Rather, it emphasizes building an integrative model of health encompassing physical activity, diet, labor, rest, and psychological adjustment—all grounded in active bodily engagement. This holistic view of health resonates strongly with modern concepts of proactive wellness, bridging a century of intellectual evolution.

2.5 Body Culture as Personality Culture—The Ultimate Value of George Hackenschmidt's Philosophy

If the body ontology answers "why engage in physical training," the mind-body unity perspective addresses "how physical training influences human development," and the views on physical education and natural health explain "how physical training should be conducted," then the ultimate question George Hackenschmid's body culture philosophy seeks to answer is: "What purpose does physical training truly serve?"

An analysis of his major works reveals that George Hackenschmidt consistently understood body culture as personality culture (Culture of Personality). He believed that the ultimate purpose of physical training is neither to build larger muscles nor to win competitions, but rather to achieve personal development through bodily cultivation, fostering qualities such as honesty, self-discipline, courage, responsibility, and respect for others. Thus, physical training carries significant educational and ethical implications.

This perspective breaks away from the traditional view of the body as merely a "tool for competition" or an "object of aesthetic admiration," endowing bodily culture with deeper humanistic meaning. The body is not only the object of athletic

practice, but also a crucial foundation for personality development and life growth. George Hackenschmidt argued that a truly healthy person should possess a sound body, a balanced mind, and a strong sense of social responsibility—these three elements together constitute the ultimate goal of bodily culture.

In recent years, muscle circumference, body fat percentage, and visual appearance have gradually become key criteria for evaluating the body. Some fitness activities have shown clear tendencies toward commodification and aestheticization, treating the body more as a display object than as a subject of life development. In contrast, George Hackenschmidt consistently emphasized that bodily culture should return to health, education, and personal growth, its true value lying in promoting holistic human development rather than meeting external standards of evaluation.

George Hackenschmidt effectively elevated the value orientation of bodily culture. He raised physical training from a technical level to a cultural one, from mere physical improvement to the construction of character, and from athletic practice to life practice, transforming bodily culture into a philosophical inquiry about lifestyle and civilizational progress.

3 The Contemporary Value of George Hackenschmidt's Philosophy of Physical Culture

Any sports philosophy can only demonstrate its theoretical vitality when it continues to offer explanatory power and practical value in real society. Although George Hackenschmidt's philosophy of physical culture originated in the early 20th century, his ideas on physical education, holistic health, lifelong physical activity, and personality development remain highly aligned with the development direction of sports and health initiatives in the 21st century. Re-examining Hackenschmidt's philosophy not only deepens research into physical culture but also provides new theoretical perspectives for promoting sports and health in the new era.

3.1 Implications for National Fitness Strategy—Physical Exercise Should Become a Lifestyle

The "National Fitness Program (2021–2025)" calls for deeper integration between national fitness and public health, aiming to build a higher-level public service system for fitness and improve the physical fitness and health levels of the population. However, in practice, certain mass sports activities still face challenges such as insufficient participation continuity, fragmented exercise behaviors, and overly utilitarian fitness goals. As a result, physical activity has not yet become a stable lifestyle for most people.

George Hackenschmidt's philosophy offers significant insights in this regard. He consistently emphasized that physical training should not be limited to athletes or fitness enthusiasts but must become an integral part of everyday life for ordinary citizens. In *The Way to Live*, he stated: "Health is not the result of short-term training, but rather the expression of a long-term lifestyle." This idea underscores the importance of sustained physical activity over temporary improvements in physical condition.

Modern public health research similarly highlights that consistent, long-term physical activity yields more stable health benefits than short-term, high-intensity training. The World Health Organization's 2020 guidelines on physical activity and sedentary behavior recommend regular physical activity across all age groups and encourage minimizing sedentary time to reduce the risk of chronic diseases and all-cause mortality. These recommendations align closely with Hackenschmidt's advocacy for lifelong physical activity.

Moreover, Hackenschmidt argued that physical culture encompasses not only sports and exercise but also labor, walking, outdoor activities, and overall healthy lifestyles. He integrated physical activity into daily routines rather than confining it to sports venues. This perspective offers valuable reference for China's current initiatives promoting "integration of sports and medicine," integration of "sports and healthcare," and the development of healthy communities. Future progress in national fitness should focus not only on increasing the number of active individuals but also on fostering healthy behaviors and cultivating a supportive physical culture environment, so that physical activity truly becomes a fundamental component of people's lifestyles.

3.2 Implications for Health Promotion and Proactive Health Concepts

As medical models shift from disease-centered treatment toward health promotion, the role of physical activity in public health continues to grow. The concept of proactive health emphasizes that each individual is the primary responsible party for their own health and should enhance quality of life through scientific exercise, balanced nutrition, psychological well-being, and healthy behavior management.

Hackenschmidt's understanding of health clearly reflects proactive health principles. He believed that health is not achieved through medication but cultivated continuously through daily life. Exercise, work, sleep, diet, and positive emotions together form a holistic healthy lifestyle, with all elements interconnected and inseparable.

Numerous evidence-based studies have confirmed this view. Both the American College of Sports Medicine (ACSM) and the World Health Organization have shown that regular physical activity effectively reduces the risks of chronic conditions such as hypertension, diabetes, obesity, coronary heart disease, and depression, while simultaneously improving cognitive function and mental health. Although George Hackenschmidt lived in an era before modern evidence-based medicine had matured, his emphasis on prevention, self-management, and a healthy lifestyle aligns closely with contemporary health promotion principles. Particularly against the backdrop of China's advancement in "integration of sports and medicine," the development of "centers for physical activity promoting health," and community health management, his ideas on bodily culture still hold significant practical relevance today.

3.3 Implications for the Development of Modern Fitness Culture—Rebuilding the Humanistic Value of Bodily Culture

In recent years, the fitness industry has experienced rapid growth, with internet platforms and social media greatly enhancing public engagement in physical activities. However, under the combined influence of commercial capital and digital media, the body has increasingly become an object of consumption and display. Communication strategies such as "perfect bodies," "trending workouts," and "rapid fat loss" have, to some extent, reinforced external appearance as the primary criterion, while undermining the values of health and education.

In this context, George Hackenschmidt offers an alternative perspective. He argues that the core of bodily culture lies not in outward form, but in personal growth achieved through sustained physical practice. Muscle strength is merely an expression of bodily culture, not its ultimate goal; true bodily culture should foster health, self-discipline, responsibility, and a positive attitude toward life.

This viewpoint carries profound implications for reflecting on current fitness culture. From the standpoint of sport philosophy, the body possesses both natural and socio-cultural dimensions. If the body is reduced solely to a consumer object, it risks alienation, leading sports away from their essential purpose of fostering holistic human development. Conversely, if the body is understood as a foundational element for personality development and life growth, sports can reclaim their educational and cultural functions.

3.4 Implications for Sport Philosophy and Bodily Culture Research

Bodily research has become a key focus within international sport philosophy, sociology of the body, and health humanities. Scholars are increasingly concerned with bodily experience, bodily identity, physical education, and the social significance of bodily culture, moving beyond mere athletic performance or physiological metrics.

George Hackenschmidt's philosophical contribution to bodily culture lies in his early transcendence of the instrumentalist view of the body, elevating it to the realms of life philosophy and educational philosophy. He maintained that the body is not merely a vehicle for physical activity, but also a crucial foundation for personality formation, value construction, and social participation. This holistic understanding of the body provides a historically continuous intellectual resource for the development of modern sport philosophy.

For Chinese sport studies, rediscovering George Hackenschmidt's thought holds two important meanings: first, it enriches the theoretical framework of bodily culture research, shifting sport history studies from biographical accounts toward deeper ideological analysis; second, it promotes interdisciplinary integration between sport science, education, medicine, psychology, and health sciences, offering new academic resources

for theoretical innovation in sports and health in the new era.

Conclusion

George Hackenschmidt was not merely a practitioner of physical training, but also a distinctive thinker in the philosophy of bodily culture. His philosophical framework on body, health, education, personality, and civilization reflects the developmental trajectory of European bodily culture movements and provides significant intellectual resources for contemporary sports philosophy, health promotion, and physical education research.

Of course, it is important to objectively recognize the historical limitations of George Hackenschmidt's philosophy of bodily culture. Constrained by the conditions of his time, his theories were primarily grounded in personal experience and philosophical reflection, lacking experimental support from modern exercise physiology, sports medicine, and evidence-based research. Moreover, his writings focused predominantly on individual physical development, with limited engagement on critical issues such as gender equality, social class, and cultural differences.□

Refercences

[1] Hackenschmidt G. The Way to Live: In Health and Physical Fitness[M]. London: Athletic Publications, 1928.
[2]Hackenschmidt G. Man and Cosmic Antagonism to Mind[M]. London: Health & Strength Ltd., 1935.
[3] Hackenschmidt G. The Three Memories and Forgetfulness[M]. London: Health & Strength Ltd., 1931.
[4] Jahn F L. Deutsches Volkstum. Berlin: 1810.
[5] Ljunggren J. The Roots of Swedish Gymnastics. Stockholm: Swedish Sports Research Council, 1999.
[6] Shilling C. The Body and Social Theory. 4th ed. London: Sage Publications, 2020.
[7] Rippe J M. Lifestyle Medicine. 3rd ed. Boca Raton: CRC Press, 2019.
[8] Warburton D E R, Bredin S S D. Health benefits of physical activity: a systematic review of current systematic reviews. Current Opinion in Cardiology, 2017, 32(5): 541–556.
[9] Jaeger W. Paideia: The Ideals of Greek Culture. Oxford: Oxford University Press, 1945.
[10] Whitehead M. Physical Literacy: Throughout the Lifecourse. London: Routledge, 2010.
[11] Varela F J, Thompson E, Rosch E. The Embodied Mind: Cognitive Science and Human Experience. Cambridge, MA: MIT Press, 1991.
[12] Rippe J M. Lifestyle Medicine. 3rd ed. Boca Raton: CRC Press, 2019.
[13] Warburton D E R, Bredin S S D. Health benefits of physical activity: A systematic review of current systematic reviews. Current Opinion in Cardiology, 2017, 32(5): 541-556.
[14] Pretty J, Peacock J, Sellens M, et al. The mental and physical health outcomes of green exercise. International Journal of Environmental Health Research, 2005, 15(5): 319-337.
[15] American College of Sports Medicine. ACSM's Guidelines for Exercise Testing and Prescription. 11th ed. Philadelphia: Wolters Kluwer, 2021.

Author Introduction: Jiang Tang, male, physical fitness coach, primarily researching youth physical training, sports rehabilitation, and sports philosophy.
Received: 2026-05-09
Revised: 2026-06-18
Accepted: 2026-07-11

Copyright by the authors.This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

The Role of Kayak Rolling Techniques in Developing Proprioception

—— A Case Study of Sweep Roll, C-to-C Roll, and Hand Roll

Owen

（Qiandao Lake Lakers Kayak Club, Hangzhou 311799,China）

Abstract: Kayak rolling, as a water sport skill, requires not only strength and technical proficiency but also proprioceptive ability, vestibular regulation, and neuromuscular control to restore body posture. This study examines three rolling techniques—Sweep Roll, C-to-C Roll, and Hand Roll—by integrating proprioception theory, motor control theory, and embodied cognition theory to analyze their impact mechanisms on athletes' sensory-motor systems. The findings suggest that kayak rolling may enhance athletes' proprioceptive abilities through mechanisms such as sensory reweighting, vestibular-proprioceptive integration, neuromuscular feedback modulation, and sensory-motor coupling.

Keywords:kayak rolling; proprioception; sensory-motor control; neuromuscular regulation

Introduction

Compared with land-based sports, kayaking is characterized by significant environmental uncertainty, as athletes are subject to multiple constraints, including changes in water currents, shifts in boat posture, and adjustments to body center of gravity. How to enhance athletes' ability to perceive changes in both body state and the external environment has become an important direction in modern kayaking training science.

The roll technique is one of the core skills in kayaking, primarily used by athletes to return to an upright sitting position after the boat has capsized. From the perspective of motor control theory, the roll is not merely a movement accomplished through strength and skill alone, but rather a complex process that heavily depends on the coordination of sensory input, neural processing, and motor output. After the boat has completely overturned, the athlete's visual information is significantly restricted, requiring greater reliance on internal sensory information provided by muscles, tendons, joints, and the vestibular system to determine body position and complete postural adjustments.

Proprioception is an important sensory ability that enables the human body to perceive its own position, movement state, and changes in force, serving as a critical foundation for maintaining motor stability and achieving precise movement control. Existing research has shown that long-term specialized sports training can promote the development of athletes' proprioceptive abilities, enabling them to demonstrate higher levels of postural control and movement regulation in complex athletic environments.

From the perspective of movement characteristics, although the Sweep Roll, C-to-C Roll, and Hand Roll all fall under roll techniques, they exhibit notable differences in motor control requirements. The Sweep Roll involves a longer movement path, emphasizing body rotational coordination and spatial position awareness; the C-to-C Roll is executed at a faster speed and relies more heavily on core stability and dynamic postural control; and the Hand Roll, performed without the assistance of a paddle, places higher demands on the athlete's internal sensory feedback and overall motor coordination.

In recent years, advances in motor control theory and embodied cognition theory have further expanded our understanding of the mechanisms underlying motor skill acquisition. Motor skills are not simply acquired through external movement imitation, but are gradually formed through the continuous interaction among the body, the nervous system, and the environment. Kayak roll training may not only enhance the level of specialized technique but may also promote the development of athletes' bodily cognitive abilities through sensorimotor system adaptation.

On this basis, this paper takes three typical kayak roll techniques—the Sweep Roll, C-to-C Roll, and Hand Roll—as research subjects, and analyzes their movement characteristics, sensory demands, and underlying mechanisms from a proprioceptive perspective, aiming to provide a reference for

kayaking training practice, proprioceptive training methods, and motor skill research. At the same time, this paper acknowledges that current related studies remain predominantly theoretical in nature, and that direct empirical evidence regarding the effects of roll training on proprioceptive abilities still needs to be further accumulated, which also constitutes an important direction for future research.

1. The Concept of Proprioception and Its Significance in Motor Control

Proprioception is an important sensory ability that enables the human body to perceive its own body position, movement state, and changes in muscle force, serving as a critical foundation for maintaining postural stability and achieving fine motor control. Sherrington first introduced the concept of "proprioception" in 1906, proposing that the organism is able to obtain internal feedback about its own state through sensory information from tissues such as muscles, tendons, and joints [1]. With the development of neuroscience and motor control theory, the connotation of proprioception has gradually expanded from a single sensory function to a comprehensive sensory system involving multiple peripheral receptors and central neural regulatory mechanisms.

Currently, it is widely accepted in the academic community that proprioception mainly includes joint position sense, kinesthesia, and force sense, with its information sources primarily consisting of muscle spindles, Golgi tendon organs, joint mechanoreceptors, and cutaneous receptors [2]. Among these, muscle spindles are capable of sensing muscle length and the rate of change in length, playing an important role in body position adjustments during movement; Golgi tendon organs are primarily involved in muscle tension regulation, which is significant for force output control; and joint mechanoreceptors provide information about changes in joint angle and movement direction.

From the perspective of motor control, proprioception does not function as an isolated sensory system, but rather participates in human postural control together with the visual and vestibular systems. Horak et al. pointed out that balance maintenance in complex environments depends on the integrated use of multisensory information, and when a particular sensory input is restricted, the central nervous system is able to adjust the weighting of different sensory channels through sensory reweighting mechanisms to ensure the stability of motor control [3]. Riemann and Lephart noted that proprioception is not only involved in sensory information transmission, but is also an important component of maintaining joint stability and motor control [4].

This theory is of great significance for understanding the kayak roll. Unlike most land-based sports, during a kayak roll the athlete may be in a state of body inversion, limited underwater vision, and rapid changes in spatial orientation; under these conditions, visual information is often unable to provide continuous and effective feedback, and the motor control system must rely more heavily on information from muscles, joints, and the vestibular system. Therefore, roll training may provide sustained stimulation to the proprioceptive system and promote the athlete's ability to perceive and regulate internal body states.

In recent years, motor neuroscience research has further demonstrated that proprioception is not a fixed physiological capacity, but rather possesses considerable plasticity. Long-term sports training can alter the information processing patterns between sensory input and motor output, enhancing the nervous system's ability to recognize and predict changes in body state [5,6]. Therefore, from a theoretical standpoint, specialized sports characterized by high levels of postural change and high sensory dependence may exert a positive influence on proprioceptive development.

2. Biomechanical Characteristics and Proprioceptive Demands of Three Kayak Roll Techniques

2.1 Basic Biomechanical Characteristics of the Kayak Roll

The kayak roll is a typical whole-body coordinated motor skill, the execution of which does not rely on the strength of a single muscle group, but rather forms a complex kinetic chain involving lower limb fixation, core stabilization, trunk rotation, and upper limb movements. Unlike traditional strength-based movements, the key to roll technique does not lie in generating maximum force, but rather in whether the athlete can accurately perceive body state within a limited time frame and achieve the

recovery of boat and body posture through proper force transmission [7,8].

From a biomechanical perspective, the kayak roll primarily involves three levels of control processes.

First, body-boat coupling control. Kayaking is characterized by a distinct human-equipment interaction. The athlete does not perform movements independently, but rather establishes a relatively stable connection with the boat through the hips, knees, and footrest positions. During the roll, the athlete needs to perceive the relative movement between the body and the boat, and adjust body posture to change the direction of boat rotation.

Second, trunk rotation and hip-driven mechanisms. Hip snap is considered a critical factor in successful roll execution. Effective hip movement can utilize the force generated by the lower limbs and core region to propel the boat into rotation, rather than relying solely on upper limb pulling of the paddle shaft for recovery. This process involves coordinated activity among the oblique abdominal muscles, lumbar back muscles, and muscles around the hip joint, placing considerable demands on the athlete's core stability and motor control abilities.

Third, sensory feedback and movement correction mechanisms. Due to the dynamically changing nature of the aquatic environment, athletes find it difficult to complete the roll solely by relying on pre-programmed movement sequences, and instead need to adjust movements based on real-time sensory information. For example, during the roll, the athlete needs to judge the body's rotation angle, the degree of boat tilt, and the timing of hip movement. This information primarily comes from the proprioceptive and vestibular systems.

Therefore, from the perspective of motor control theory, the kayak roll is not a simple process of force output, but rather a closed-loop control process involving continuous sensory input, information integration, and movement adjustment. This cycle repeats continuously, enabling the athlete to gradually establish a stable internal model of the body and improve the level of automatic movement execution [9,10]. Roll training not only improves specialized technique but also promotes the development of the athlete's sensorimotor system.

2.2 Biomechanical Characteristics and Proprioceptive Demands of the Sweep Roll

2.2.1 Movement Characteristics of the Sweep Roll

The Sweep Roll is a relatively common roll technique in kayak instruction and practice. Its main characteristic is the use of a wide sweeping motion of the paddle blade through the water, combining paddle support force, body rotation, and hip movement to complete the boat recovery.

Compared with other roll techniques, the Sweep Roll has a longer movement trajectory and a more pronounced body rotation process, allowing the athlete relatively ample time to adjust movement rhythm. Therefore, this technique is generally considered a more suitable rolling method for beginners to master.

From the perspective of movement structure, the Sweep Roll mainly includes: leaning forward and establishing a preparatory posture; rotating the boat into an inverted position; extending the paddle blade and performing the sweeping motion; and combining with hip snap to restore the boat to stability. Throughout this process, the athlete needs to maintain coordinated relationships between the trunk and the boat, while using sensory feedback to judge the state of body rotation.

2.2.2 Proprioceptive Demands of the Sweep Roll

Although the Sweep Roll is relatively slow in execution, it still places considerable demands on proprioception. First, the athlete needs to possess good joint position sense. When the boat is overturned, visual information is restricted and the athlete cannot directly observe body orientation, thus requiring reliance on trunk rotation sensation, shoulder joint position changes, and hip pressure changes to judge current posture. Second, the Sweep Roll requires the athlete to develop good inter-segmental coordination. The roll movement is not completed by the shoulders driving the body into rotation, but rather requires the pelvis, trunk, and upper limbs to form a continuous movement chain. If coordination among different body parts is lacking, insufficient movement amplitude or recovery failure may occur. Third, the Sweep Roll can help beginners establish bodily adaptation to the aquatic environment.

When beginners first encounter roll training, they often experience inversion fear and difficulty in directional judgment. This actually reflects their insufficient ability to utilize internal bodily sensory information. Sweep Roll training can play a certain role in establishing fundamental body awareness.

2.3 Biomechanical Characteristics and Dynamic Sensory Control of the C-to-C Roll

2.3.1 Movement Characteristics of the C-to-C Roll

The C-to-C Roll is a roll technique that emphasizes rapid movement transitions. Its name derives from the body's transition from a "C-shaped tucked posture" to a "C-shaped posture" in the opposite direction during the movement.

Compared with the Sweep Roll, the C-to-C Roll has the following characteristics: smaller movement amplitude but faster execution speed; greater reliance on rapid contraction and release of the core region; and higher demands on the timing of hip drive.

During actual execution, the athlete first needs to establish a stable posture through body tucking, then utilize rapid hip rotation to drive the boat into recovery. The C-to-C Roll is not simply a reduction in movement amplitude, but rather an improvement in movement control efficiency, placing higher demands on the nervous system's ability to rapidly integrate sensory information [11].

2.3.2 Proprioceptive Demands of the C-to-C Roll

Compared with the Sweep Roll, the C-to-C Roll places greater emphasis on proprioceptive ability in dynamic states. The athlete not only needs to know the current position of the body, but also needs to predict: the direction of body rotation, the timing of hip force generation, and the speed of boat recovery. This means that the C-to-C Roll relies not only on static position sense, but on the combined effect of kinesthesia and force sense.

For example, when the athlete performs hip drive, they need to accurately judge: "Has the optimal rotation angle been reached?" "Has the force been effectively transmitted to the boat?" "Is further adjustment of body posture needed?" These judgments generally cannot be accomplished visually, but rely on internal motor models formed through long-term training. To a certain extent, the C-to-C Roll can be regarded as an important training stage in the transition from basic body perception to dynamic motor control.

2.4 Biomechanical Characteristics and Advanced Body Control of the Hand Roll

2.4.1 Movement Characteristics of the Hand Roll

The Hand Roll is a technically more demanding form of kayak roll technique, with its most distinctive feature being the elimination of paddle assistance, relying solely on the athlete's own body movements to complete the roll. In the absence of external support, the Hand Roll requires the athlete to complete boat recovery through body rotation, water interaction, and hip drive. From a biomechanical perspective, the Hand Roll reduces external mechanical assistance, requiring the athlete to enhance the precision of their own motor control.

2.4.2 Hand Roll and Advanced Proprioceptive Ability

The Hand Roll places higher demands on proprioceptive ability. First, the athlete needs to possess highly developed body spatial awareness. Since the paddle cannot be used to determine orientation, the athlete must rely on internal bodily sensations to judge: whether the body is approaching the recovery position; whether rotation has reached an effective angle; and whether the hip action has been completed. Second, the Hand Roll requires the athlete to possess precise force control ability. Insufficient force may lead to roll failure, while excessive force may disrupt movement coordination. Therefore, the athlete needs to adjust force output based on real-time sensations. Third, the Hand Roll demonstrates a highly automated level of sensorimotor control.

Experienced athletes typically do not analyze the movement process step by step, but rather rely on bodily experience formed through long-term training to execute the movement. This ability reflects a high degree of neural integration of motor patterns [12].

3. Mechanisms by Which Kayak Roll Training Promotes the Development of Athletes' Proprioceptive Ability

3.1 Sensory Reweighting Mechanisms Under Visually Restricted Conditions

Human motor control does not rely on a single sensory system alone, but rather results from the joint participation of multiple sensory inputs, including vision, proprioception, and the vestibular system. In normal movement environments, the visual system can provide relatively intuitive external spatial information, while the proprioceptive system is primarily responsible for reflecting internal body states, including limb position, movement direction, and changes in force. Through dynamic integration among the three sensory systems, human

postural stability and motor coordination are jointly maintained.

However, the kayak roll has special environmental characteristics that distinguish it from general land-based sports. After the boat capsizes, the athlete is typically in an underwater or laterally inverted state, with visual information significantly restricted and unable to continuously provide accurate spatial localization information. Under these conditions, the motor control system needs to increase its reliance on other sensory information to complete body posture judgment and movement adjustments.

This process can be explained by the theory of "sensory reweighting." Horak et al. pointed out that when a particular sensory input is restricted, the central nervous system can adjust the weighting of different sensory channels according to changes in the movement environment, thereby maintaining postural stability [13]. Therefore, during the kayak roll, the importance of visual input decreases, while the role of information from muscles, tendons, joints, and the vestibular system may be relatively enhanced.

Taking the Sweep Roll as an example, during the roll the athlete cannot directly observe the boat's rotation angle and must rely on trunk rotation amplitude, the positional relationship between the shoulder joint and pelvis, changes in contact pressure between the hip and the boat, and perception of body rotation speed to judge the current movement state. This continuous reliance on internal bodily information for spatial localization may promote the athlete's efficiency in utilizing proprioceptive signals.

Long-term training in an environment of sensory information redistribution may promote the formation of more stable sensory prediction patterns in the nervous system, enabling the athlete to complete motor control with less reliance on visual feedback. Therefore, kayak roll training possesses a potential mechanism for developing proprioceptive ability.

It should be noted that current experimental research on whether "roll training can directly improve proprioceptive sensitivity" remains relatively limited. Therefore, the above mechanisms are more reasonably interpreted as theoretical deductions based on motor control theory, and still require further validation through long-term training experiments.

3.2 Vestibular-Proprioceptive Integration and Mechanisms of Spatial Orientation Ability Development

The kayak roll not only involves changes in body posture, but is also accompanied by pronounced rotational movements and accelerational changes, thus making the vestibular system play an important role in the motor control process.

The human vestibular system is mainly composed of semicircular canals and otolith organs, with the semicircular canals primarily sensing rotational movements of the head, while the otolith organs are responsible for sensing linear acceleration and changes in spatial orientation. When the athlete completes a roll movement, the head, trunk, and boat all rotate together, and the vestibular system continuously transmits information about the body's movement state to the central nervous system.

However, relying solely on vestibular sensation is insufficient for achieving precise motor control. Athletes also need to integrate proprioceptive information from muscles and joints to make comprehensive judgments about body position. Therefore, the roll movement essentially embodies a process of information fusion between the vestibular system and the proprioceptive system [14].

For example, during the C-to-C Roll, the movement duration is relatively short, and the athlete needs to rapidly complete: body tucking, directional judgment, hip drive, and boat recovery. This process requires the nervous system to quickly integrate head movement information with body position feedback. If there is a lack of coordination between vestibular information and proprioceptive information, the athlete is prone to directional judgment errors or insufficient timing of movement execution.

Human postural control depends on information fusion among multiple sensory systems, rather than the independent action of a single sensory channel. Kayak roll training may enhance athletes' spatial orientation ability in complex environments through continuous stimulation of vestibular-proprioceptive interaction.

From a training practice perspective, this mechanism also explains why experienced kayakers can still complete rolls quickly even under visually restricted conditions. They do not "not need

sensation," but rather have developed more efficient sensory integration capabilities.

3.3 Muscle Spindle–Spinal Cord–Cerebellum Feedback Mechanisms and Precise Motor Control

The development of proprioceptive ability essentially depends on effective interaction between peripheral sensory information and central neural regulation.

During the kayak roll, muscle spindles, Golgi tendon organs, and joint mechanoreceptors continuously monitor body state and transmit relevant information to the spinal cord, cerebellum, and motor areas of the brain. Subsequently, the central nervous system adjusts muscle activity based on feedback information to achieve movement correction.

Among these, muscle spindles play a particularly important role in motor control. Muscle spindles are capable of sensing changes in muscle length and the rate of change, providing the nervous system with essential information about body movement states. For example, during the hip drive phase, the muscles around the hip and trunk generate force rapidly, and muscle spindles can provide timely feedback on muscle status, enabling the motor system to adjust force output accordingly.

The cerebellum is primarily involved in movement prediction and error correction. Human motor control does not rely solely on instantaneous feedback, but rather uses internal models to predict movement outcomes and continuously optimizes movement strategies by comparing predicted results with actual outcomes. This theory can explain why elite athletes are able to rapidly complete high-difficulty roll movements such as the Hand Roll. After long-term training, athletes may have developed relatively stable internal motor models, enabling them to predict body rotation trends and boat movement states in advance and complete movement adjustments quickly.

Thus, kayak roll training may improve the efficiency of the nervous system in processing bodily information and regulating motor output through repeated stimulation of sensory feedback loops.

3.4 Sensorimotor Coupling and Mechanisms of Movement Automatization

The development of motor skills typically undergoes a transition from cognitive control to automatic control. When beginners learn roll techniques, they need to rely heavily on conscious control: "Is the body rotating sufficiently?" "Is the paddle positioned correctly?" "Is the hip movement timely?" At this stage, motor control primarily depends on explicit cognitive involvement.

With increased training, athletes gradually establish stable sensorimotor associations, and motor control begins to rely more on automatic regulation. Skill automatization does not mean that sensory information becomes less important, but rather that the motor system can utilize sensory information more efficiently to accomplish movement control. During the kayak roll, experienced athletes are typically able to adjust movements rapidly based on changes in boat pressure, body tension, and rotation sensation, without needing to analyze each movement component step by step.

This ability reflects an improved level of sensorimotor coupling, in which: the sensory system is responsible for providing body state information, the central nervous system is responsible for information processing, and the motor system is responsible for executing adjustments. These three components form a continuous cycle that enables the athlete to adapt to the complex aquatic environment. The value of roll training lies not only in mastering a particular technical movement, but more importantly in promoting the establishment of more efficient sensorimotor control patterns in athletes.

3.5 Mechanisms of Bodily Wisdom Formation from the Perspective of Embodied Cognition

Traditional sports training theories often emphasize technical movement learning and motor program formation, while embodied cognition theory further points out that the body itself participates in cognitive processes, and that motor ability is gradually formed through continuous interaction between the body and the environment [15].

The kayak roll has distinct embodied movement characteristics. The athlete does not face a fixed environment, but rather constantly changing water currents, dynamically changing boat states, postural changes, and variations in external resistance. The athlete cannot rely entirely on fixed

movement programs to complete the roll, but must continuously adjust movement strategies according to environmental changes.

During the Hand Roll, the athlete cannot rely on the paddle to provide clear support, but must judge movement status through bodily sensations. This ability is not simply a result of muscle strength, but rather a form of movement wisdom formed through the combination of bodily experience, sensory information, and environmental interaction.

From the perspective of embodied cognition, kayak roll training may promote the development of more refined body awareness in athletes, enabling them to quickly understand their own state and adopt appropriate actions in complex environments.

Conclusion

Kayaking roll is a highly complex motor skill that relies heavily on sensorimotor integration. Athletes need to coordinate visual, proprioceptive, and vestibular inputs to achieve effective postural control. Different roll techniques reflect varying levels of proprioceptive demands: the Sweep Roll primarily emphasizes the establishment of body spatial awareness; the C-to-C Roll emphasizes dynamic postural control; and the Hand Roll demonstrates advanced sensory integration capabilities. Kayak roll training may promote the development of athletes' body control abilities through mechanisms such as sensory reweighting, vestibular-proprioceptive integration, neuromuscular feedback regulation, and motor automatization. Introducing proprioceptive theory into kayak training research can help broaden the traditional perspective on technical training, shifting training objectives from mere skill execution to the cultivation of athletes' comprehensive body control capabilities.□

Refercences

[1] SHERRINGTON C S. The integrative action of the nervous system[M]. New Haven: Yale University Press, 1906.

[2] PROSKE U, GANDEVIA S C. The proprioceptive senses: Their roles in signaling body shape, body position and movement, and muscle force[J]. Physiological Reviews, 2012,92(4):1651-1697.

[3] Fohanno V, et al. Biomechanical determinants of kayaking performance: Current evidence and future directions. Applied Sciences, 2022.

[4] RIEMANN B L, LEPHART S M. The sensorimotor system, part I: The physiological basis of functional joint stability[J]. Journal of Athletic Training, 2002,37(1):71-79.

[5] Fleming N, Donne B. Biomechanics of flatwater kayaking: A review. Sports Biomechanics, 2022.

[6] Begon M, et al. Wearable sensor applications in kayaking performance analysis. Sensors, 2021.

[7] Kent Ford.The Kayak Roll: Transforming Your Fear into Confidence.Globe Pequot Press, 2017.

[8]E.J. Del Vecchio.Eskimo Rolling.Ragged Mountain Press, 1998.

[9] Wolpert DM, Ghahramani Z, Jordan MI. An internal model for sensorimotor integration. Science, 1995, 269(5232): 1880-1882.

[10] Wolpert D M, Diedrichsen J, Flanagan J R. Principles of sensorimotor learning. Nature Reviews Neuroscience, 2011, 12: 739-751. DOI:10.1038/nrn3112

[11] Behm D G, Drinkwater E J, Willardson J M, et al.The use of instability to train the core musculature.Applied Physiology, Nutrition, and Metabolism, 2010, 35(1): 91-108.

[12] Aman J E, Elangovan N, Yeh I L, et al. The effectiveness of proprioceptive training for improving motor function. Journal of Athletic Training, 2015, 50(10):1095-1107.

[13] HORAK F B. Postural orientation and equilibrium: What do we need to know about neural control of balance to prevent falls?[J]. Age and Ageing, 2006, 35(S2): ii7-ii11.

[14] Proske U, Gandevia S C. The proprioceptive senses: Their roles in signaling body shape, body position and movement, and muscle force. Physiological Reviews, 2012, 92(4):1651-1697. DOI: 10.1152/physrev.00048.2011

[15] CLARK A. Surfing uncertainty: Prediction, action, and the embodied mind[M]. Oxford: Oxford University Press, 2016.

Author Introduction: Owen, male, aquatic sports coach, specializing in youth posture development, sea kayaking skills, and the history of kayaking.

Received: 2026-06-09
Revised: 2026-06-28
Accepted: 2026-07-10

Copyright by the authors.This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

From Fear to Psychological Growth: The Mechanisms by Which Rappelling Promotes Mental Health

Dong Rui, Freelance Outdoor Coach

Abstract: Rappelling is a typical controlled high-risk outdoor adventure activity. Based on positive psychology, self-efficacy theory, psychological resilience theory, and experiential learning theory, this paper explores the mechanisms through which rappelling promotes mental health. The study suggests that rappelling serves as an experiential intervention that fosters individual psychological growth within a context of manageable risk. Participants go through stages including fear recognition, emotional regulation, behavioral control, and successful feedback, thereby enhancing self-efficacy, building psychological resilience, and improving social trust and teamwork skills. Rappelling can be incorporated into mental health exercise prescriptions, enriching the field of exercise therapy.
Keywords:rappelling; fear experience; adventure education; psychological growth; experiential learning

Introduction

REPORT ON NATIONAL MENTAL HEALTH DEVELOPMENT IN CHINA (2023-2024) shows that anxiety detection rates among adolescents and workplace populations continue to rise, with chronic stress and low self-worth becoming widespread psychological difficulties [1]. Traditional psychological counseling and pharmacological interventions have drawbacks such as poor adherence and long therapeutic cycles. Exercise therapy, with its advantages of low cost, broad accessibility, and synergistic mind-body regulation, has gradually become an important direction for mental health intervention. Conventional aerobic exercise and ball sports primarily alleviate surface-level emotions but lack engagement with individuals' fearful and vulnerable psychological boundaries. In contrast, adventure outdoor activities such as rock climbing, abseiling, and canyoning—characterized by controlled risk—have emerged as effective means for addressing psychological challenges and building psychological resilience [2].

Abseiling is precisely one form of outdoor activity that has attracted increasing attention in this context. Abseiling is a controlled adventure activity that relies on static ropes and protective equipment, under the full supervision of a certified safety officer, to complete a descent along a high-angle slope using gravity. It can be divided into experiential recreational abseiling and professional technical abseiling. The subject of this study is experiential abseiling activities designed for the general population, which feature three key characteristics: objectively safe and controllable conditions, subjectively genuine fear, and a stepwise progression of challenge difficulty. Competitive sports emphasize speed, strength, and technique; in contrast, abseiling focuses more on participants' behavioral responses when facing heights, unfamiliar environments, and psychological pressure, thus possessing distinct psychological training characteristics [3].

1. Theoretical Foundations

1.1 Positive Psychology

Positive psychology is an important school of psychology that emerged in the late 20th century. Its leading proponent, Seligman, proposed that psychology should focus not only on mental illness but also on positive personality traits, positive emotions, and the development of individual potential [4]. Positive psychology emphasizes that human beings possess the capacity for growth, self-improvement, and the pursuit of a fulfilling life, and that sports participation is an important pathway for promoting positive psychological development.

From the perspective of positive psychology, mental health encompasses five dimensions: Positive Emotion, Engagement, Relationships, Meaning, and Accomplishment. Abseiling aligns closely with all five of these dimensions.

After completing an abseil, participants typically experience significant positive emotions, including joy, satisfaction, pride, and relaxation, which can alleviate stress and generate a sense of accomplishment. Secondly, abseiling requires a high degree of concentration, with continuous

adjustments to movement, center of gravity, breathing, and environmental conditions—this state of deep engagement is highly consistent with the experience of "flow" [5]. Research has shown that flow experiences can effectively promote mental health and enhance well-being and quality of life. Thirdly, abseiling has pronounced social interaction characteristics. Participants rely on instructors, safety protectors, and team members to complete the task together, and this cooperative relationship helps foster positive interpersonal interactions. From the perspective of positive psychology, abseiling is not merely a physical activity but also an experiential process that promotes the development of positive personality traits.

1.2 Self-Efficacy

Self-efficacy theory, proposed by Bandura, is one of the important theories for explaining individual behavioral choices and psychological growth. Bandura argues that self-efficacy refers to an individual's judgment of their own ability to complete a given task, and this judgment directly influences behavioral choices, effort expenditure, persistence, and psychological responses when facing difficulties [6]. Bandura pointed out that self-efficacy primarily derives from four sources: mastery experience, vicarious experience, verbal persuasion, and physiological and emotional states.

Abseiling encompasses all four of these sources. First, successful descent is the most direct source of enhanced self-efficacy. When participants overcome fear and reach the ground safely, they re-evaluate their own capability levels, thereby forming positive self-perceptions. Second, while waiting for their turn to descend, participants observe other members successfully completing the task. This vicarious experience can reduce feelings of uncertainty and increase confidence. Third, the continuous encouragement from instructors and team members naturally strengthens participants' courage. Finally, during the descent, participants control their breathing, regulate heart rate, stabilize movements, and improve feelings of fear, tension, and anxiety, further enhancing self-efficacy.

1.3 Psychological Resilience

Psychological resilience generally refers to an individual's ability to maintain positive adaptation and recover quickly when facing pressure, setbacks, and adversity [7]. Psychological resilience is not a fixed personality trait, but rather a psychological capacity that can be continuously developed through learning and training. Challenging outdoor activities are an important means of cultivating psychological resilience.

Abseiling promotes the development of psychological resilience through three mechanisms. First, moderate stress stimulation. During descent, participants experience a certain degree of stress response; however, because the entire process is protected by a professional safety system, this stress is "controllable stress." Second, development of problem-solving skills. During abseiling, participants need to continuously adjust body posture, control speed, and correct errors, thereby promoting the development of problem-analysis and autonomous problem-solving abilities. Third, reinforcement through positive feedback. When participants successfully complete the task, positive memories are formed in the brain, enhancing psychological preparation for facing similar challenges and further improving psychological resilience. It should be noted that abseiling is an important means of long-term psychological capacity development, rather than a one-time psychological breakthrough activity.

1.4 Experiential Learning Theory

Experiential learning theory, proposed by Kolb, is one of the most widely applied theories in the fields of outdoor education, physical education, and adult education [8]. Kolb argues that genuine learning does not merely involve the reception of knowledge, but rather the continuous construction of knowledge through reflection, generalization, and practice based on real experience. Its core process consists of four continuous stages: concrete experience, reflective observation, abstract conceptualization, and active experimentation.

This theory is highly compatible with the learning process of abseiling. Through abseiling, participants not only learn motor skills, but more importantly, develop cognitive patterns for facing difficulties. When individuals come to recognize that fear is not insurmountable, but can be controlled through standardized operations, emotional regulation, and positive action, this learning experience can be transferred to other contexts in study, work, and social life. Experiential learning also emphasizes the importance of reflection. After abseiling, sharing, psychological review,

and experience summarization—as important components of the program—reinforce positive experiences and facilitate the transition from "completing a task" to "promoting growth."

1.5 Adventure Education Theory

Adventure education, as a form of experiential education, intentionally creates outdoor activity settings that contain uncertainty and challenge to promote participants' personal growth and psychological development. Ingman et al. (2025), based on an analysis within the PERMA well-being framework, showed that adventure education experiences can promote participants' overall well-being through the five dimensions of positive emotion, engagement, relationships, meaning, and accomplishment. Through 183 hours of observation and 74 interviews, the study found that adventure education not only has educational value, but also serves as a pathway to psychological well-being [9].

As a typical form of adventure education activity, abseiling—with its unique "vertical space" challenge—provides participants with an embodied experience of confronting fear, making it an ideal vehicle for studying the mechanisms of fear transformation and psychological growth. As a representative adventure education activity, the educational value of abseiling has gradually expanded from motor skill training to the domains of mental health promotion and social competence development.

2. Characteristics and Psychological Experience Mechanisms of Abseiling

2.1 Characteristics of Abseiling

Abseiling (or rappelling) is an outdoor activity that involves controlled descent from a height using specialized equipment such as ropes, descenders, harnesses, carabiners, and belay systems, under the full supervision of a certified safety officer. Abseiling can be divided into experiential recreational abseiling and professional technical abseiling. This study focuses on experiential recreational abseiling designed for the general population.

In terms of movement form, although abseiling is classified as a technical activity, its physical demands do not depend entirely on muscular strength, but rather on body coordination, balance control, movement rhythm, and psychological stability. Particularly during the initial phase of descent, participants need to overcome the tension or even fear induced by visual stimuli, and execute key actions such as leaning back, shifting their center of gravity, and adjusting their footwork. This process is often more challenging than the technical movements themselves.

Abseiling has several distinctive characteristics. First, psychological challenges precede physical challenges. While rock climbing relies primarily on active upward movement, abseiling requires participants to voluntarily shift their body weight beyond the safety platform, creating a movement posture that contradicts everyday experience. This psychological conflict makes abseiling an important subject for studying fear experiences. Second, risk perception is significantly higher than actual risk. Modern abseiling uses internationally standard safety equipment and incorporates rigorous protection systems, resulting in objectively low risk. However, due to participants' innate sensitivity to heights, subjective risk perception is typically much higher than actual risk. This characteristic of "high perceived risk with low objective risk" provides an ideal environment for psychological training. Third, social support runs throughout the entire activity. From equipment inspection and movement guidance to descent protection, abseiling consistently relies on the cooperation of instructors and the team. Therefore, it is not merely an individual activity but also a quintessential team activity. Thus, abseiling possesses psychological training value that is difficult to replicate in other sports.

2.2 Risk Perception and Safety Control in Abseiling

Risk is an important feature that distinguishes abseiling from ordinary sports activities, but the risk referred to here is primarily participants' psychological perception rather than objective danger. An individual's judgment of risk is influenced not only by objective facts but also by factors such as personal experience, emotional state, social culture, and environmental stimuli [10]. For most beginners, height itself is a powerful stimulus, and even with reliable equipment and thorough protection, a noticeable sense of insecurity may still arise.

Modern abseiling emphasizes "risk management" rather than "risk avoidance." Risk management mainly includes equipment inspection, standardized safety procedures, dual-protection systems, and

instructor supervision, among other aspects. The goal is to ensure safety while allowing participants to genuinely experience psychological pressure and achieve personal growth through progressive adaptation.

From a psychological perspective, moderate risk holds positive value. Appropriate risk stimulation can enhance an individual's attention, decision-making ability, and behavioral performance, whereas either excessively low or excessively high levels of stress can compromise effectiveness. Abseiling, by controlling the level of risk, enables participants to maintain a moderate state of tension, gradually build confidence through challenges, and enhance psychological adaptability. In fact, the key to abseiling's effectiveness in promoting mental health lies not in creating danger, but in generating challenging situations with growth value within a scientifically safe and controlled environment.

2.3 Fear Experiences in Abseiling

Fear is the most typical and universal psychological experience during abseiling, and it also serves as an important starting point for facilitating psychological growth. Over the course of human evolution, humans have developed an innate vigilance toward heights, and this fear of heights helps individuals avoid falls—a mechanism shaped by long-term natural selection that promotes survival. At the beginning of an abseiling activity, most participants experience varying degrees of tension, anxiety, and avoidance tendencies; this is a normal psychological response rather than a psychological abnormality.

Abseiling training does not require participants to eliminate fear, but rather helps them learn to recognize, understand, and manage it. As participants complete equipment inspections, breathing exercises, and movement practice under instructor guidance, they gradually realize that they are not in genuine danger but are instead accepting a challenge within a highly safe and clearly regulated environment. This cognitive restructuring helps reduce catastrophizing thoughts and enhances the sense of control over one's own actions.

As the descent progresses, participants typically undergo a transition from high tension to gradual relaxation, and finally to positive emotional shifts after completing the challenge. Fear does not completely disappear, but gradually transforms into concentration, composure, and a sense of accomplishment through the process of action. This emotional transformation is an important manifestation of psychological growth and a key psychological characteristic that distinguishes abseiling from general fitness activities.

2.4 The Body–Mind Interaction Mechanism in Abseiling

Embodied cognition theory posits that human cognitive activities are not completed solely by the brain independently, but are formed through continuous interaction among the body, the environment, and action, emphasizing that bodily experience can, in turn, shape cognitive patterns and emotional states [11].

Abseiling serves as an important practical context for embodied cognition theory. During abseiling, participants first experience a change in body posture. When leaning back away from the platform and placing the feet against the rock face, the center of gravity shifts noticeably, and the visual, vestibular, and proprioceptive systems simultaneously receive information from the environment. At this point, the brain not only needs to process visual stimuli from heights, but also continuously integrates sensory feedback from muscles, joints, and skin to maintain balance and movement coordination. This synergistic operation of multiple sensory systems enables participants to gradually establish new body control patterns. As movements are repeated, bodily tension gradually decreases and motor control ability improves, allowing participants to shift their attention from "fearing a fall" to "how to descend stably," "how to control speed," and "how to choose footholds." This reallocation of psychological resources gradually replaces fear with focused attention. This process exemplifies the "action promotes cognition" characteristic emphasized by embodied cognition theory—that is, bodily actions not only accomplish motor tasks but also transform the individual's understanding of risk, their own abilities, and their relationship with the environment. Furthermore, breathing regulation is another important body–mind connection mechanism in abseiling. Beginners under the stimulation of heights often exhibit stress responses such as rapid breathing and muscle rigidity. Through instructor guidance, employing slow breathing, rhythmic control, and movement

relaxation can gradually restore autonomic nervous system balance and reduce physiological arousal levels. This demonstrates that active regulation of bodily states can directly improve psychological states, rather than relying solely on cognitive persuasion to achieve emotional control.

In summary, psychological growth in abseiling is not a result of abstract thinking, but is continuously constructed through bodily practice. This "body changes mind" mechanism provides a solid theoretical foundation for sports-based mental health promotion.

2.5 Team Support and Trust Formation Mechanisms in Abseiling

Although abseiling typically appears as an individual descent activity, the entire process consistently depends on team support throughout. Equipment inspection, safety confirmation, technical guidance, belay operations, and post-activity experience sharing all require the joint participation of instructors and team members. Therefore, abseiling is not only a personal challenge activity but also a quintessential social interaction activity.

When individuals perceive help, understanding, and encouragement from others, their psychological burden when facing stressful events can be significantly reduced. During abseiling, instructors provide technical guidance, safety officers are responsible for protection, and teammates offer encouragement and feedback, collectively forming a comprehensive social support system. This support not only reduces participants' anxiety levels but also enhances their confidence in facing challenges.

It is worth noting that trust in abseiling has a dual nature. On one hand, participants need to trust the safety equipment—believing that the ropes, carabiners, and descenders will function properly; on the other hand, they need to trust their team members—believing that the belayer will strictly follow operational procedures and that the instructor will make sound judgments. This trust relationship, built on shared goals, is highly consistent with the concept of psychological safety emphasized in modern organizational behavior.

Experience sharing after the abseiling activity also holds significant value. By expressing their fears, challenges, and successful experiences, participants not only further consolidate positive psychological experiences but also strengthen emotional connections among team members, forming collective memories of shared growth. Thus, team support runs through the entire abseiling process and is an indispensable factor in its mental health promotion effects.

3. Mechanisms by Which Abseiling Promotes Mental Health

3.1 Fear Management and Enhancement of Emotion Regulation Ability

Fear is the most direct psychological experience in abseiling and serves as the starting point for promoting psychological growth. From a psychological perspective, fear itself is not a negative emotion, but rather an important adaptive mechanism that helps individuals identify danger and protect their own safety. However, when fear exceeds an individual's coping capacity, it tends to evolve into anxiety, avoidance, or even learned helplessness. Therefore, how to manage fear—rather than eliminate it—is key to abseiling's mental health promotion effects.

Abseiling training first helps participants reframe their understanding of fear. Through equipment introductions, safety demonstrations, and movement practice, participants gradually come to realize that while heights may be unnerving, the risks have been effectively controlled. This cognitive restructuring reduces catastrophizing thoughts, transforming fear from "uncontrollable" to "manageable."

Subsequently, during the actual descent, participants continuously engage in breathing regulation, movement control, and attention focusing. When attention shifts from fear itself to specific tasks, psychological resources are reallocated and anxiety levels gradually decline. After completing the challenge, the successful experience further reinforces positive emotions, fostering the psychological belief that "I can face difficulties."

This process can be summarized as the following psychological development pathway:

Risk perception → Fear generation → Safety awareness → Action attempt → Emotion regulation → Successful experience → Psychological growth

More importantly, fear management abilities have a transfer effect. The regulatory skills and

strategies learned during abseiling can be similarly applied to stressful events in real life, such as examinations and occupational competition. The significance of abseiling training is thus even more reflected in psychological adaptability in daily life.

3.2 Mechanisms of Psychological Resilience Development

Psychological resilience typically manifests as an individual's ability to maintain positive adaptation and recover quickly when facing adversity [12]. In recent years, a growing body of research has suggested that psychological resilience is not a fixed personality trait, but can be gradually improved through training.

The key to abseiling's role in promoting psychological resilience lies in its provision of a "moderate stress—successful adaptation" learning environment for participants. Throughout the training process, participants continually cycle through the stages of tension, adaptation, adjustment, and success, with each successful completion of the task accumulating new coping experiences.

From a psychological development perspective, abseiling promotes psychological resilience primarily through three mechanisms. First, it enhances stress tolerance. When facing height-related stimuli, participants do not immediately retreat, but rather remain continuously exposed to the stressful situation within a safe environment, gradually improving their psychological endurance through repeated practice. Second, it improves problem-solving ability. During descent, situations such as movement imbalance or unstable speed control may arise, requiring participants to adjust their strategies promptly under the instructor's guidance. This active problem-solving experience helps strengthen psychological adaptability. Third, it fosters positive attribution styles. When participants successfully complete the challenge, they are more likely to attribute their success to their own efforts, correct methods, and persistence. This positive attribution pattern is precisely an important component of psychological resilience.

Thus, abseiling cultivates not momentary courage, but rather the sustained psychological capacity to act and continuously adjust in the face of difficulties—a quality of significant importance for coping with the pressures of modern society.

3.3 Mechanisms of Social Support and Team Trust Formation

Mental health depends not only on an individual's internal psychological resources, but is also significantly influenced by social support systems. Social support theory holds that emotional support, informational support, and instrumental support from family, friends, teams, and social organizations can effectively buffer the adverse effects of stressful events on mental health. Although abseiling appears as an individual descending activity, it is consistently built upon a foundation of teamwork, thus possessing notable social support effects.

First, abseiling training facilitates the establishment of team trust. Trust is an important foundation for teamwork and a core concept in modern organizational psychology. Edmondson's psychological safety theory points out that when individuals believe they can receive support within the team and will not be negatively judged for failures, they are more willing to attempt new tasks, express their genuine thoughts, and actively participate in team collaboration [13].

During abseiling, participants must entrust their personal safety to the rope system, the belayer, and the instructor. This trust is not an abstract concept, but is gradually formed through jointly adhering to safety protocols, repeated communication, and practical collaboration. As the activity progresses, participants come to realize that their safety depends not only on individual ability but also on the coordinated cooperation among team members. This authentic experience helps strengthen team cohesion and promote the development of interpersonal trust.

Team encouragement enhances positive emotional experiences. Positive feedback can increase participants' confidence in completing challenging tasks and reduce anxiety levels. During abseiling, instructors typically assist participants in adjusting their movements through verbal guidance, action demonstrations, and real-time feedback; teammates provide emotional support through applause, encouragement, and experience sharing. This multi-layered social support not only increases the success rate of the activity but also enhances participants' sense of belonging and collective identity.

Shared experiences of challenge create shared

emotional experiences. Social psychology suggests that facing difficulties together builds deeper interpersonal relationships than sharing success together. During abseiling, every team member undergoes the psychological journey of fear, hesitation, attempt, and success, and this shared experience constitutes an important emotional bond among team members. The debriefing and sharing after the activity further reinforce these positive experiences, enabling team members to gain inspiration from each other's stories and enhance mutual understanding and support.

Abseiling not only promotes individual psychological growth but also improves the group's psychological climate by building a positive social support network, thereby providing external resource guarantees for mental health.

Conclusion

Abseiling possesses the triple attributes of physical exercise, psychological training, and social interaction. Its role in promoting mental health derives not only from the physical activity itself, but also from the dynamic process in which participants continuously engage in psychological regulation, build self-efficacy, and establish social support within contexts of controlled risk. An in-depth exploration of the mechanisms by which abseiling promotes mental health holds significant value for expanding research in outdoor sports psychology, enriching theories of sport-based health promotion, and advancing the practice of outdoor education.□

Refercences

[1]REPORT ON NATIONAL MENTAL HEALTH DEVELOPMENT IN CHINA (2023-2024), Beijing:Social Sciences Academic Press,April 2025, 1-4,26-29.

[2]Ru-Syuan Hsiao1, Ling-Ya Hung, Fang-Wei Lin,et. al. Understanding Psychological Stress and Emotional Reactions in the Experience of Pair Rappelling Participants,Journal of Sports Research, 2025,34(01):27-52.

[3]KOLB D A. Experiential Learning: Experience as the Source of Learning and Development. 2nd ed. Upper Saddle River: Pearson Education, 2015.

[4]SELIGMAN M E P. Flourish: A Visionary New Understanding of Happiness and Well-being. New York: Free Press, 2011.

[5] CSIKSZENTMIHALYI M. Flow: The Psychology of Optimal Experience. New York: Harper & Row, 1990.

[6] BANDURA A. Self-efficacy mechanism in human agency. American Psychologist, 1982, 37(2): 122-147.

[7] CONNOR K M, DAVIDSON J R T. Development of a new resilience scale: The Connor-Davidson Resilience Scale (CD-RISC). Depression and Anxiety, 2003, 18(2): 76-82.

[8]KOLB D A. Experiential Learning: Experience as the Source of Learning and Development[M]. 2nd ed. Upper Saddle River: Pearson Education, 2015.

[9] Ingman, B. C. (2025). Adventure Education as a Pathway to Wellbeing: Rethinking Adventure through the Lens of PERMA.Journal of Adventure Education and Outdoor Learning, 25(1), 152-165.

[10] SCHWARZER R, JERUSALEM M. Generalized Self-Efficacy Scale. In: WEINMAN J, WRIGHT S, JOHNSTON M. Measures in Health Psychology: A User's Portfolio. Windsor: NFER-NELSON, 1995: 35-37.

[11] LAKOFF G, JOHNSON M. Philosophy in the Flesh: The Embodied Mind and Its Challenge to Western Thought. New York: Basic Books, 1999.

[12] EWERT A, SIBTHORP J. Outdoor Adventure Education: Foundations, Theory and Research. Champaign: Human Kinetics, 2014.

[13] EDMONDSON A C. Psychological safety and learning behavior in work teams. Administrative Science Quarterly, 1999, 44(2): 350-383.

Author Introduction: Dong Rui, male, outdoor sports coach, specializing in rope techniques, sports rehabilitation, and social sports instruction.

Received:2026-06-11
Revised:2026-06-25
Accepted:2026-07-08

Copyright by the authors.This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

The Industrial Revolution and the Birth of Modern Tennis
—— A Historical Examination Based on Technological Innovation, Social Transformation, and the Development of Sports Institutions

Tan Shanchao

Abstract: Against the backdrop of Britain Industrial Revolution in the 19th century, this paper sorts out the evolutionary process of modern tennis transitioning from real tennis to lawn tennis, and analyzes the impacts of the rubber industry, lawn maintenance machinery, wood processing technology, railway networks, and the establishment of sports organizational systems on the formation of modern tennis. On this basis, it further explores how industrial civilization shaped the institutional logic of modern sports, and dissects the historical mechanisms underlying the global spread of modern tennis.
Keywords:Industrial Revolution; Modern Tennis; Lawn Tennis; Sports Culture

Introduction

Since the 19th century, modern sports have gradually replaced traditional folk games to become a significant component of industrial civilization. Although modern tennis can trace its roots back to the medieval French game of "Jeu de Paume," true modern lawn tennis emerged in Britain during the 1870s. In 1873, British officer Walter Clopton Wingfield patented "Sphairistikè," introducing for the first time a form of tennis suitable for grass courts—a milestone widely regarded as the origin of modern tennis [1]. The successful inaugural Wimbledon Championship in 1877 marked the formal establishment of modern tennis competition systems [2].

Notably, Wingfield’ s innovation was built upon the long-term accumulation of technological conditions and social environments brought about by the Industrial Revolution. The development of vulcanized rubber made elastic tennis balls possible; mechanized woodworking improved racket production efficiency; railway transportation facilitated tournament exchanges; and the construction of urban public lawns provided physical spaces for mass participation. Together, these factors drove the historical transformation of modern tennis from an aristocratic pastime into a popular sport [3].

Against this backdrop, this article examines the formation mechanism of modern tennis from the perspective of the Industrial Revolution, integrating technology history, social history, and sports history. It emphasizes the role of material industry, mechanical manufacturing, rail transport, and urban public space development in the emergence of modern tennis, establishing an analytical framework of "Industrial Revolution—technological innovation—institutional restructuring—sports modernization." Using modern tennis as a case study, it explores the general patterns through which industrial civilization shaped modern sports institutions.

1 Development of Tennis Before the Industrial Revolution: From Jeu de Paume to Real Tennis

1.1 Origins and Cultural Characteristics of French Jeu de Paume

The history of modern tennis is typically traced to the medieval French game of "Jeu de Paume," meaning "game of the palm," which originated around the 12th century in northern French monasteries. Early players did not use rackets but struck the ball directly with their hands. As participation grew and ball speeds increased, bare-handed play became inadequate for competitive demands. Players began wearing leather gloves and crafting wooden striking boards, eventually evolving into early rackets with frames and strings. This equipment evolution reflects the fundamental principle that sports technology adapts to competitive needs and laid the foundation for modern racket development [4].

Meanwhile, the playing venues of Jeu de Paume

gradually shifted from open fields to enclosed indoor courts with walls. These walls not only defined the boundaries of the court but also served as rebound surfaces, making the game highly dependent on spatial design. By the 15th century, Jeu de Paume had become a key social activity among the French royal and noble classes. King Henry VIII of England actively participated in the game and constructed courts at Hampton Court Palace, leaving behind a crucial legacy for studying the early history of tennis [5].

It is evident that the evolution of Jeu de Paume not only illustrates the institutionalization of European sports entertainment but also reveals the close ties between sports, religion, court culture, and social hierarchy. However, these associations also limited the game's widespread popularity to a certain extent.

1.2 Formation and Characteristics of Real Tennis

By the 16th century, the French Jeu de Paume had gradually evolved into what later became known as Real Tennis. This term, "Real Tennis," does not refer to modern lawn tennis but rather to an indoor competitive sport popular among European royalty and nobility. The courts of royal tennis were highly regulated, typically enclosed rectangular structures, which was their most distinctive feature. The courts featured walls, sloping eaves, and multiple designated scoring zones. Players not only had to hit the ball over the net but also needed to use wall rebounds to execute tactical plays [6].

In terms of equipment, rackets used in royal tennis were mostly made of hardwood, with small heads and gut strings. The balls used had cork cores wrapped in felt or leather, offering significantly less elasticity than modern tennis balls. Moreover, the rule system of royal tennis was complex—its scoring methods, service areas, and wall rebound rules raised the learning threshold. These intricate rules reinforced cultural identity within the aristocracy, making participation difficult for ordinary people [7].

1.3 Social Reasons Behind the Decline of Royal Tennis

After the 17th century, influenced by profound changes in Europe's social, political, economic, and cultural structures, royal tennis gradually declined. Changes in the aristocratic social structure weakened its social foundation. Following the French Revolution and the English bourgeois revolution, the traditional nobility's monopoly on social resources and cultural life diminished, depriving court sports of stable support. As the emerging middle class grew stronger, people increasingly favored sports that were more affordable and accessible [8].

Secondly, urbanization transformed public spaces. From the late 18th to early 19th centuries, European city populations surged rapidly, land values rose sharply, and the construction and maintenance costs of large indoor royal tennis courts continued to increase. Meanwhile, open grasslands, parks, and other public spaces became popular leisure venues, laying the groundwork for the later development of lawn tennis [9].

Thirdly, the industrial revolution brought new labor systems and fostered a new culture of leisure. Work hours and rest periods became increasingly standardized, and leisure time after work began to form an essential part of urban residents' lives. Sports shifted from court entertainment to mass recreation. However, the complex rules of royal tennis could not meet this new societal demand [10].

2 Technological Foundations of Modern Tennis Driven by the Industrial Revolution

2.1 The Industrial Revolution Reshaped the Material Basis for Modern Sports Development

The Industrial Revolution, beginning in Britain during the mid-18th century, promoted standardized production, transportation, and the development of urban public spaces, creating the material conditions necessary for the widespread popularity of modern sports.

For tennis, this impact was particularly evident. Royal tennis relied heavily on specialized enclosed courts and handcrafted equipment, limiting it primarily to royalty and the aristocracy. After the Industrial Revolution, advancements in mechanical manufacturing, materials science, and commercial distribution enabled the mass production of sports equipment. Sports thus moved away from their traditional role as court entertainment and evolved into activities for the general public.

This transformation reflected a fundamental shift in the logic of sports operation. Industrial

society emphasized standardization, reproducibility, and scalability—concepts naturally introduced into the realm of sports. For example, uniformly sized rackets, standardized court dimensions, and codified competition rules all reflect how industrial civilization shaped the modernization of sports.

2.2 The Development of the Rubber Industry and the Equipment Revolution in Modern Tennis

If the Industrial Revolution provided the social foundation for modern tennis, then the advancement of the rubber industry directly catalyzed the birth of modern lawn tennis.

In 1839, American inventor Charles Goodyear perfected the vulcanization process for natural rubber, greatly improving its elasticity and durability. Subsequently, rubber products entered the field of sporting goods. Modern tennis balls became more consistent and reliable in performance, enhancing match quality and enabling outdoor grass-court play. In 1873, Wingfield introduced the "Sphairistikè" set, which included standardized equipment such as rubber tennis balls, rackets, nets, and posts, all packaged together for sale. This "complete kit" lowered the barrier to entry, enabling any household with a lawn to play tennis.

From the perspective of sports industry development, this marked a significant starting point for the commercialization of modern sports products. Sports consumption gradually evolved into an independent market, becoming a key driver behind the rapid spread of modern sports.

2.3 Lawn Technology and Mechanical Manufacturing Facilitated the Emergence of Grass-Court Tennis

One key reason modern grass-court tennis became distinct from royal tennis was the fundamental transformation in playing space. In 19th-century Britain, middle-class households commonly had lawn gardens, and mechanical manufacturing technologies driven by the Industrial Revolution significantly improved lawn maintenance efficiency. Around 1830, British engineer Edwin Budding invented the mechanical lawn mower, enabling large areas of grass to be kept level and creating stable conditions for grass-based sports. From then on, lawns not only became a significant symbol of British estate culture but also gradually evolved into essential infrastructure for modern sports.

Meanwhile, advancements in woodworking machinery enhanced the precision of racket manufacturing. Mechanical cutting, turning, and standardized processing ensured greater consistency in racket weight, length, and frame dimensions, facilitating uniformity in equipment specifications. Standardization reduced production costs and increased fairness in competition, providing crucial technological support for the development of modern competitive sports. A synergistic effect emerged between lawn maintenance technology and equipment manufacturing: stable playing surfaces demanded more consistent rackets and ball performance, while standardized gear further advanced rule unification and tournament organization. Together, these factors contributed to the establishment of the modern tennis system.

2.4 Railway Transport, Commodity Circulation, and the Rapid Spread of Modern Tennis

By the mid-to-late 19th century, Britain's railway network had largely connected major cities nationwide, drastically reducing transportation costs. Athletes, referees, and spectators could travel across regions quickly, enabling frequent inter-club matches and the emergence of national-level competitions.

Railway transport also boosted the sports goods market. Wingfield's grass-court tennis set could be rapidly distributed throughout Britain via rail and exported to countries such as the United States and Australia. This dissemination speed far surpassed that of the Real Tennis era. The underlying cause was not a sudden shift in sporting culture, but rather the Industrial Revolution's creation of an efficient logistics network and commodity circulation system. The international spread of modern tennis within just a few decades essentially reflected the historical outcome of continuously improving global commerce and transportation systems under industrialization.

2.5 The Industrial Revolution and the Birth of Modern Grass-Court Tennis in 1873

In 1873, retired British officer Walter Clopton Wingfield patented "Sphairistikè" and designed a new form of tennis suitable for grass courts. In reality, Wingfield’s role was more that of an integrator than a sole inventor. Prior to him, outdoor grass-

court tennis had already appeared in certain parts of Britain—Harry Gem, for example, organized grass-court matches in Birmingham. Only Wingfield first combined equipment, rules, court dimensions, and commercial distribution into a complete system, using patents and standardized gear to achieve rapid promotion, thus becoming a pivotal figure in the development of modern grass-court tennis.

In other words, the birth of modern tennis did not result from a single technological breakthrough, but rather represented the culmination of long-term industrial advances in the 1870s. The rubber industry provided match balls, mechanical manufacturing enabled standardized equipment, lawn technology improved playing environments, railway transport expanded reach, and the sports consumer market grew rapidly. These factors collectively propelled modern grass-court tennis into a new sport well-suited to industrial society.

3 Formation of Modern Tennis under the Context of the Industrial Revolution

3.1 Industrial Civilization and Standardization of Modern Sports Rules

One of the key distinctions between modern sports and traditional ones lies in the establishment of unified, transparent, and replicable competition rules—this institutional foundation enables modern sports to develop across regions and nations [1]. This principle also applies to the evolution of modern tennis.

During the era of royal tennis, rules varied significantly among different regions and clubs. Court structures, serving methods, wall rebound rules, and scoring systems all bore distinct local characteristics. While such rule diversity satisfied the social and recreational needs of the aristocracy, it hindered large-scale tournament organization and made it impossible to establish a nationwide competitive system.

The Industrial Revolution promoted the widespread application of standardization in manufacturing and social management. Uniform specifications, dimensions, and processes became core principles of modern industrial production, and this mindset gradually extended into the realm of sports. When Wingfield introduced lawn tennis in 1873, he not only designed specialized equipment but also established relatively complete match regulations—including court dimensions, service zones, net height, and basic scoring methods—laying the initial groundwork for the modern tennis rule system. The concept of "uniformity" thus became a crucial starting point for the development of modern tennis.

Standardized rules not only enhanced fairness in competition but also reduced the costs of learning and participation. As matches across different regions could be organized according to consistent rules, athletes, referees, and spectators developed a shared language of competition. This institutional uniformity was a critical prerequisite for transforming tennis from a localized pastime into an international sport. The emergence of modern tennis depended not merely on technological innovation, but also reflected a historical process in which institutional rationality gradually replaced local customs within the context of industrial civilization.

3.2 Club Systems and the Establishment of Modern Tennis Organization

The Industrial Revolution transformed not only sports rules but also the organizational forms of sports.

In the 19th century, rapid urbanization in Britain led to a growing middle class. As working hours became more regulated, weekend leisure evolved into a central aspect of urban life, giving rise to a proliferation of sports clubs. Unlike the court-based activities tied to noble estates during the royal period, these new clubs featured membership systems, independent management, and regular tournament scheduling, gradually becoming the fundamental organizational units of modern sports [3].

The significance of the club system went beyond simply providing playing venues; it also established standardized mechanisms for membership management, event organization, and technical exchange. Through club networks, stable connections emerged across regions, enabling competitions to transcend geographical boundaries and laying the groundwork for national tournaments and international exchanges.

Moreover, the club system facilitated the standardization and dissemination of tennis techniques. Training methods, officiating standards, and match etiquette were continuously replicated and promoted through the club structure, helping to shape a unified tennis culture. The formation of

this organizational network reflected the increasing capacity of industrial society to manage complex social systems.

3.3 Wimbledon Championships and the Establishment of Modern Competition Systems

The inaugural Wimbledon Championships (The Championships, Wimbledon) held in 1877 is widely regarded as a pivotal milestone in the development of modern tennis. Its true value lies not merely in hosting a single tournament, but in advancing the gradual maturation of modern competition systems through practical implementation.

The first Wimbledon attracted 22 male players and adopted a knockout format, while establishing standardized regulations regarding court dimensions, net height, and match procedures. These rules were later refined over time and eventually became foundational elements of international tennis competition [11]. More importantly, Wimbledon established a new model for event management. The tournament is organized by a fixed institution, with clear procedures for entry, a defined officiating system, and audience guidelines, sustained through ticket sales. This institutional design has endowed the sporting event with dual characteristics of modern public cultural activity and socioeconomic engagement.

From a sociological perspective on sport, Wimbledon's success signifies that modern competitive sports have begun to move beyond their status as temporary entertainment events, gradually evolving into enduring brand competitions. These tournaments not only enhance athletic performance but also expand media coverage, sports consumption, and public participation, further amplifying the social influence of modern tennis.

3.4 Middle-Class Leisure Culture and the Transformation of Tennis Social Functions in Modern Society

The Industrial Revolution brought significant changes to Britain's social structure, gradually elevating the middle class to a key force in modern society. As incomes rose and leisure time increased, sports began shifting from exclusive social pastimes for the elite to an essential form of recreation for ordinary families.

Lawn tennis proved particularly suited to this emerging social demand. On one hand, matches could be played on open spaces such as private gardens and park lawns, eliminating the need for expensive dedicated facilities. On the other hand, its relatively simple rules allowed participation by both men and women, making it ideal for family entertainment. These characteristics quickly made lawn tennis popular among the middle class and helped establish its image as a "civilized, healthy, and elegant" sport.

It is worth noting that modern tennis was also one of the few competitive sports in the 19th century to attract early female participation. Compared with contact-heavy sports like football or boxing, lawn tennis was more readily accepted during the Victorian era. Women’s involvement not only expanded the participant base but also contributed to evolving gender perceptions in modern sport. Although societal norms regarding dress and etiquette still constrained women at the time, lawn tennis undoubtedly created new opportunities for women to enter public sporting spaces.

Modern tennis also gradually assumed a role in social interaction. Club tournaments, family gatherings, and local competitions became vital platforms for urban residents to build social connections. This functional evolution indicates that modern tennis has transcended its status as merely a competitive sport, becoming an integral part of public life in industrial society.

Conclusion

The emergence of modern tennis was not driven by a single factor, but rather resulted from the interplay of multiple forces within the context of the Industrial Revolution. This study draws the following conclusions. First, the birth of modern tennis bears distinct attributes of industrial civilization and does not represent a natural continuation of traditional tennis. Rather than a simple evolution of earlier forms, modern tennis constitutes a systemic reconfiguration shaped by industrial society. Second, while the Industrial Revolution provided the technological conditions for modern tennis to develop, technological innovation alone was not the decisive factor. Standardization of rules, the establishment of club systems, and the development of national tournament structures all played indispensable roles. Third, the evolution of modern

tennis reflects how industrial modes of organization profoundly shaped modern sports institutions. The Industrial Revolution facilitated the spread of standardization into the realm of sports. Fourth, the global diffusion of modern tennis resulted from the combined effects of industrialization, social transformation, and cultural exchange. Railways and ocean shipping improved the efficiency of transporting equipment and athletes, mass media amplified the reach of tournaments, international organizations promoted rule harmonization and cross-border cooperation, and the growth of middle-class leisure culture continuously broadened the participant base. Together, these factors propelled tennis into a global phenomenon. This demonstrates that the international spread of modern sports depends not only on technological foundations but also on institutional development and cultural identity.□

Refercences

[1] Wingfield W C. The Major's Game of Lawn Tennis. London: British Library Historical Collection, 1874.
[2] International Tennis Federation. History of World Tennis.
[3] Huggins M, Mangan J A. Disreputable Pleasures: Less Virtuous Victorians at Play. London: Frank Cass, 2004.
[4] Everitt R T, Hillway R A. The Birth of Lawn Tennis. Ronaldson Publications, 2003.
[5] Lake R J. A Social History of Tennis in Britain. Routledge, 2015.
[6] Everitt R T, Hillway R A. The Birth of Lawn Tennis. London: Ronaldson Publications, 2003.
[7] Lake R J. "Social Class and the Development of British Tennis Culture." The International Journal of the History of Sport.
[8] Huggins M, Mangan J A. Disreputable Pleasures: Less Virtuous Victorians at Play. Frank Cass, 2004.
[9] Holt R. Sport and the British: A Modern History. Oxford University Press, 1989.
[10] Vamplew W. Pay Up and Play the Game: Professional Sport in Britain, 1875–1914. Cambridge University Press, 1988.
[11] All England Lawn Tennis Club. The Championships: History and Heritage. 2023.

Author Introduction: Tan Shanchao, male, engineer, primarily engaged in research on sports venue construction, sports economy and the history of sports development.
Received:2026-07-09
Revised:2026-07-18
Accepted:2026-07-20
Copyright by the authors.This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

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

Hou Youwei

(Beijing Haiyuan Publishing Consulting Co., Ltd., Beijing 100872, China)

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.□

Refercences

[1] KAUR K, GURNANI B, NAYAK S, et al. Digital eye strain: A comprehensive review. Ophthalmology and Therapy,2022,11:1655-1680.

[2] MATAFTSI A, SELINIOTAKI A K, MOUTZOURI S, et al. Digital eye strain in young screen users: A systematic review. Preventive Medicine,2023,170:107493.

[3] ALHARBI A, ALMUTAIR A, ALHARBI A, et al. Prevalence of computer vision syndrome during the COVID-19 pandemic: A systematic review and meta-analysis. BMC Public Health,2024,24:640.

[4]HACK G D, KORITZER R T, ROBINSON W L, et al. Anatomic relation between the rectus capitis posterior minor muscle and the dura mater. Spine,1995,20(23):2484-2486.

[5] NETTER F H. Atlas of Human Anatomy[M]. 7th ed. Philadelphia: Elsevier, 2019.

[6] PANJABI M M. The stabilizing system of the spine. Part I: Function, dysfunction, adaptation, and enhancement. Journal of Spinal Disorders, 1992,5(4):383-389.

[7]BOYD-CLARK L C, BRIGGS C A, GALEA M P. Muscle spindle distribution, morphology, and density in longus colli and multifidus muscles of the cervical spine. Spine,2002,27(7):694-701.

[8] KAHKESHAHI K, WARD P J. Connection between the spinal dura mater and suboccipital musculature: evidence for the myodural bridge. Clinical Anatomy,2012,25(4):415-422.

[9] AMIN F S, ABDEL-AAL N M, EL SHATER B S. Effect of Maitland mobilization versus deep cervical flexors muscles training on proprioception in adults with chronic mechanical neck pain: A randomized controlled trial. Bulletin of Faculty of Physical Therapy, 2024,29:34. DOI:10.1186/s43161-024-00200-y.

[10] LUBETZKY A V, HAREL D, KRISHNAMOORTHY S. Decrease in head sway as a measure of sensory integration following vestibular rehabilitation: A randomized controlled trial[J]. Journal of Vestibular Research, 2023,33(3):213-226. DOI:10.3233/VES-220107.

[11] KOUZAKI M, et al. Impact of subclinical neck pain on eye and hand movements in goal-directed upper limb aiming movements. Human Movement Science, 2024,96:103238. DOI:10.1016/j.humov.2024.103238.

[12] ALDAWSARY N, ALMARWANI M. The combined effect of gaze stability and balance exercises using telerehabilitation in individuals with vestibular disorders during the COVID-19 pandemic: A pilot study. PLoS ONE, 2023,18(5):e0282189. DOI:10.1371/journal.pone.0282189.

Author Introduction: JHou Youwei, male, fitness trainer, specializing in exercise-based wellness and physical therapy.

Received:2026-05-15
Revised:2026-06-18
Accepted:2026-07-19

Copyright by the authors.This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

SPORT SCIENCE AND HEALTH PROMOTION

EDITORIAL BOARD

MEMBERS

Li Ke

Lin Chenfeng (USA)

Ma Yan (USA)

Qi Min

Shen Ja

Song Qundong

Xing Xueqian

Xu Jian

Yu Yong

Zhang Youtong

SPORT SCIENCE AND HEALTH PROMOTION

Quarterly
Vol.1 No.1
July 29, 2026

Chief Editor	Shen Ja ce@ss-hp.com
Executve Editor	Deng Yuan Wang Xiaolin
Designer	Jing Jing
Edited & Published by	VIVICOSMOS PUBLISHING LLC
ISSN	ISSN (Print): 3144-1548; ISSN (Online): 3144-1556
Address	30 N GOULD ST STER, SHERIDAN WY 82801, USA
Tel.	1(702)204-7448
E-mail	journal@ss-hp.com
Website	https://ss-hp.com