

Innovative Office Furniture for Enhancing Employee Active Health

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With growing interest in employee health, the integration of Active Health into office furniture design has become a significant research focus. Office furniture, as a vital part of the workspace, increasingly incorporates intelligent technologies to address health, comfort, and efficiency. This paper reviews innovations in smart office furniture, highlighting how technologies like big data, IoT, and sensors enhance health functions and user experiences. Advancements in smart furniture not only support physical health but also alleviate mental fatigue and improve efficiency. Applications in health interventions include personalized management, automated fatigue relief, and intelligent interactions. Despite progress, challenges remain, such as inconsistent design standards and limited technology applications in China. Other regions have more standardized and established practices, and there is a need for further coordination of international standards. With continued technological advancements and integration of intelligent systems, smart office furniture is expected to play a crucial role in improving workplace efficiency and promoting employee well-being through real-time health monitoring, personalized interventions, and adaptive features. This study provides theoretical guidance for designing such furniture and offers insights for advancing healthy office environments.

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INTRODUCTION

Active Health is a future-oriented model of health care, first introduced in China in 2015 and formally included in a special plan in 2017. Currently, research on Active Health primarily focuses on the exploration of its management models and conceptual frameworks. The core of this concept lies in the comprehensive health monitoring, analysis, evaluation, and intervention across an individual's entire lifecycle, with an emphasis on self-healing capabilities and proactive participation. The perception of health status relies on relevant devices, while the maintenance of health necessitates the rational utilization of natural, social, and cultural resources within the community (Yang *et al.* 2023). Compared to passive health approaches, Active Health underscores a dynamic perspective on health issues, explicitly rejecting the passive notion of “waiting for diseases to occur.” Instead, it advocates for a proactive attitude, emphasizing crisis awareness and long-term planning. As users increasingly focus on Active Health, their health management capacities and disease prevention outcomes are expected to improve significantly, resulting in more

pronounced health benefits (Chang *et al.* 2024; Yang *et al.* 2024). Health management is a continuous, dynamic system process that includes three basic steps: individual health information collection, health risk assessment, and health intervention (Lakdawalla and Phelps 2020). After the sudden public health crisis of the COVID-19 pandemic, people's attention to health has increased significantly (Babazadeh *et al.* 2024).

With the rapid development of social informatization, intelligence, and digitization, the proportion of intellectual laborers in the employment structure has been steadily increasing. The use of intelligent devices by intellectual workers has greatly reduced physical exertion and improved office efficiency. However, this shift has simultaneously contributed to the growing prevalence of chronic diseases among younger populations in society.

The application of the Active Health concept in the design of office furniture plays a significant role in driving progress. Through integrating new-generation digital technologies, such as big data, cloud computing, artificial intelligence, and machine learning, into design, traditional office furniture is transitioning towards smart office systems (Gao *et al.* 2024). This transformation enables the interconnection, intelligent perception, and virtual-physical interaction of office service systems, creating a smart office environment based on the fusion of Active Health concepts and intelligent technologies. Today, an increasing variety of office furniture is adopting modern technologies to enhance functionality and practicality. Moreover, these pieces of furniture are endowed with new capabilities, offering users more possibilities, particularly in health monitoring and human-computer interaction, thereby further meeting the demands of workplace health and productivity.

Le Gal *et al.* (2000) proposed that an office can be considered a smart office if it automates specific tasks and simplifies interactions between users and devices, enabling users to efficiently accomplish daily work. This concept underscores the importance of Smart Office Furniture in modern work environments, particularly when integrated with Active Health and Health Monitoring technologies. Hall *et al.* (2001) suggested further exploration of the complex relationship between employees' dynamic health status and office functionality. Providing adaptive and targeted health promotion measures for individual employees, while supporting the design and optimization of health-oriented organizational strategies, is recognized as highly advantageous (Holtermann *et al.* 2017). Munoz *et al.* (2018) defined a smart office as a workplace capable of proactively and rationally supporting people's daily tasks. The health promotion potential of this concept is increasingly highlighted in recent research. Krejcar *et al.* (2019) described smart furniture as intricately designed, network-enabled furniture equipped with intelligent or remotely controlled systems to manage user data. By interacting with users through sensors and actuators in the environment, smart furniture can anticipate user needs and provide a more convenient experience (Frischer *et al.* 2020).

Li *et al.* (2024) applied the KANO model in the design process of e-sports chairs, meticulously categorizing user needs and enhancing comfort and health experiences through the optimization of features such as adjustability and breathability. Research on sustainability, eco-friendly materials, and the enhancement of material properties has also provided valuable insights for the innovation of health functions in smart office furniture (Zhu *et al.* 2024; Liu *et al.* 2024). As a key application of ambient intelligence, the smart office offers a novel pathway for integrating work and health. However, no unified and widely accepted definition currently exists (Zhang *et al.* 2022). Other studies describe it as furniture capable of collecting information from its surroundings and providing users with

convenient operations. Essentially, smart furniture utilizes Internet connectivity as a control mechanism, integrating multiple functionalities to assist users in effortlessly managing various devices.

In summary, Smart Office Furniture is defined as a precisely designed furniture system that integrates network connectivity with automated control systems. Through sensors and actuators, it perceives the user's surrounding environment, enabling proactive support and simplification of daily tasks. The management and processing of user data can be achieved *via* built-in systems, allowing interaction and prediction based on user needs. Studies (Gao *et al.* 2024) indicate that these features can help reduce sedentary behavior, improve posture, and support overall physical and mental health, thereby demonstrating its substantial potential in promoting the concept of Active Health.

The evolution of office spaces has progressed from the open factory layouts of the 1920s to single-person offices in the 1980s and, more recently, to more flexible and collaborative work environments in the 21st century. This evolution is primarily reflected in the design and arrangement of workstations—including desks, chairs, and partition furniture—whose functionality has shifted from supporting traditional clerical tasks to accommodating personal computer usage (Aryal *et al.* 2019). With advancements in Human-Computer Interaction technologies, desks have been developed into interactive devices supporting multiple input methods, such as touch, gestures, and voice commands. These innovations accelerate information retrieval, reduce paperwork, and enhance team collaboration. Simultaneously, driven by the need to prevent occupational injuries and promote employee health, ergonomic design has made significant strides (Yang *et al.* 2024; Egeonu and Jia 2024). Examples include height-adjustable sit-stand desks, ergonomically designed chairs, and active furniture incorporating walking or cycling functions. These advancements not only optimize work efficiency but also highlight the potential for applying the concept of Active Health in office spaces.

This paper aims to systematically review the current literature on the design of health-oriented intelligent systems integrated into office furniture, addressing the health needs of office workers. The review seeks to underscore the significance of Smart Office Furniture in modern work environments and explores this topic from multiple perspectives. First, existing research findings are consolidated to expand the understanding of how intelligent office furniture can promote health, providing innovative design concepts for healthier workspaces. Second, by synthesizing relevant studies, a theoretical framework is constructed for an intelligent office furniture system equipped with functions for alleviating psychological and physiological fatigue and enabling health monitoring and management. Finally, the proposed framework offers targeted recommendations for mitigating the direct harm of office environments on the human body and achieving healthier office practices.

INNOVATIVE TRENDS AND FUNCTIONAL DEVELOPMENT IN SMART OFFICE FURNITURE

Health Functions of Office Furniture

Current research on healthy office environments primarily focuses on two aspects of employee well-being: physical activity (physiological health) and mental health (psychological health) (Fig. 1). The figure illustrates the role of office furniture in health functions, showing the various types of fatigue employees experience during the

perception, decision, and action stages. These fatigues can be categorized into three types: integrated fatigue, psychological fatigue, and physiological fatigue. These fatigue sensations are transmitted through sensory organs to the central nervous system, affecting the motor organs and, in turn, impacting the overall health and work efficiency of employees. Smart office furniture has the potential to alleviate these fatigues and improve employee health. Additionally, most studies explore the impact of various health interventions on office workers in different workplace settings and under different interactions with office products. These health interventions predominantly center on exercise-based strategies.

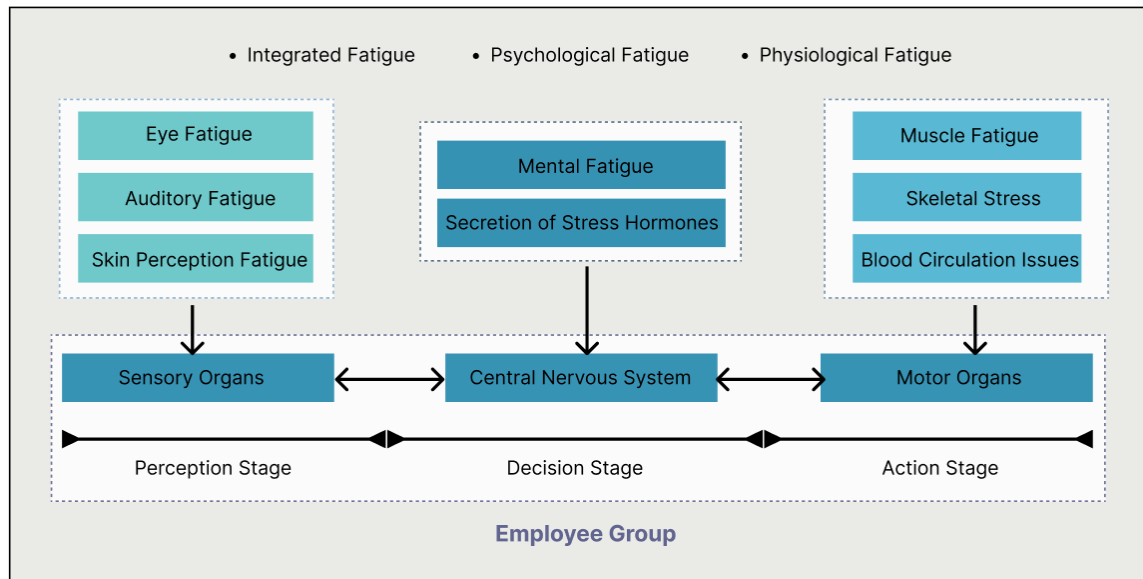


Fig. 1. Mechanism of office fatigue

Fatigue-induced declines in work capacity or physical function are generally temporary and can be restored with adequate rest (Smolders *et al.* 2012). Mahdavi *et al.* (2024) define office fatigue as the temporary reduction in physical and mental efficacy, primarily influenced by the intensity and duration of work demands, which can be alleviated through proper rest. Fatigue is also regarded as a state where tasks that were previously performed effortlessly require greater energy expenditure, with diminishing outcomes over time. Both mental and physical activities can trigger fatigue, underscoring the importance of Active Health interventions and optimized design in office environments. These measures aim to mitigate the effects of fatigue and enhance work efficiency.

Fatigue is typically categorized into two types: mental fatigue and physical fatigue. Mental fatigue is often caused by excessive cognitive work, mental stress, or emotional overexcitement, with a notable characteristic being decreased efficiency in learning and working. Prolonged mental fatigue can negatively impact mental health, manifesting as low mood, irritability, exhaustion, and even symptoms of neurasthenia, such as headaches, memory decline, insomnia, and sensitivity to light. It may also lead to other psychogenic illnesses (Shen *et al.* 2019). In contrast, physical fatigue is generally induced by muscle activity, with symptoms including difficulty concentrating, memory impairment, diminished reasoning ability, and slow, inaccurate cognitive processing (Makki *et al.* 2024). Physical fatigue can be further divided into general and localized fatigue, with

specific symptoms varying by activity type, such as localized or systemic weakness, joint stiffness, limb swelling, and muscle soreness. Although these two forms of fatigue are separately defined, they are often difficult to distinguish in practice, as they frequently occur simultaneously. In office environments, both physical and mental fatigue are typically the result of multiple factors acting together. This underscores the importance of designing integrated interventions to alleviate office fatigue and provides practical evidence for applying the concept of Active Health.

In summary, office furniture and the office environment, as the most frequently interacted elements in employees' daily work activities, exhibit diversified health-related needs. Specifically, users' health needs can be categorized into three types: product health, environmental health, and individual health. Product health primarily involves ergonomic design and interactive functionality; environmental health relates to the health aspects of both natural surroundings and built environments; and individual health concerns encompass both physical and mental well-being. Currently, research on the health intervention capabilities of office furniture predominantly focuses on behavioral interventions, particularly in the realm of physical training. Some studies have also explored modifications to standard office chairs to facilitate power naps, aiming to enhance work efficiency (Maeda *et al.* 2017). More diverse intervention methods, such as those involving music or aromatherapy, remain in the exploratory phase. This indicates a broad potential for future development in the field of health interventions through office furniture.

Innovations in Smart Office Furniture

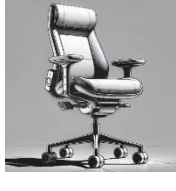
Smart Office Furniture refers to the integration of advanced technologies and concepts into office furniture, enhancing convenience and comfort in the workplace. The intelligent features can be categorized into three main types:

1. *Technological Intelligence* incorporates cutting-edge technologies, such as big data and cloud computing into office furniture, enabling features like intelligent height adjustment of desks and adaptive lighting regulation. These smart systems actively monitor and adapt to the user's health and comfort needs, promoting better posture and reducing fatigue.
2. *Modular Intelligence* enables the customization of furniture through intelligent manufacturing systems based on user requirements and preferences, delivering tailored smart solutions. By leveraging advanced manufacturing techniques, furniture components can be easily adjusted to promote better posture and reduce musculoskeletal strain. This approach aligns with the principles of Active Health by offering personalized ergonomic solutions that enhance workers' comfort and well-being.
3. *IoT-Driven Intelligence* utilizes a big data-powered smart cloud platform as its core, connecting office furniture and environmental control systems with smartphones to facilitate data transmission and functional control.

Additionally, these furniture systems are designed to collect user data, such as sedentary behavior and fatigue levels, offering proactive reminders to users and empowering health management. Based on research into Chinese office furniture brands, standalone furniture primarily focuses on items such as desks, chairs, and filing cabinets. In individual product studies, Chinese office furniture companies emphasize health-oriented designs and CMF (Color, Material, and Finish) design aspects, such as analyzing user sitting posture and the material and structural properties of desks and chairs (Hu *et al.* 2024; Hu Wengang *et al.* 2024; Yu *et al.* 2024). The health research of office furniture is

primarily focused on sit-stand workstations, bicycle workstations, treadmill workstations, and smart chairs, as shown in Table 1.

Table 1. Compendium of Relevant Smart Office Furniture for Active Health Purposes

Picture	Body of Furniture	Functional/Purposes	Reference
	Sit-stand workstations /lifting desk	Reducing perceived discomfort	Karakolis <i>et al.</i> 2014
		Counteract the effects of sedentary work	Karol <i>et al.</i> 2015
		Improved multiple cardiometabolic biomarkers	Carr <i>et al.</i> 2016
		Improve autonomy, sense of control, energy levels, and perceived well-being	Deery <i>et al.</i> 2024
	Bicycle workstations	Increase daily energy expenditure	Straker <i>et al.</i> 2009
		A positive emotional response is experienced	Straker <i>et al.</i> 2009
	Treadmill workstations	Increase physical activity in the workplace	Ohlinger <i>et al.</i> 2011
		Improve the health of office workers	Koepp <i>et al.</i> 2013
		To analyze the effect on lower body movement symmetry during the typing task	Arauz <i>et al.</i> 2021
	Smart chair	Sitting posture was observed, data were collected, processed, and displayed in real time	Vlaović <i>et al.</i> 2007
		Various cardiovascular parameters were evaluated	Zazula <i>et al.</i> 2015
		Assessing activity levels and providing users with reminders to exercise or rest by analyzing sitting posture recognition in sedentary populations	Ma <i>et al.</i> 2017
		Real-time visualization of asymmetric sitting postures	Anwary <i>et al.</i> 2019
		Monitor the user's sitting posture, identify postures that may trigger musculoskeletal conditions or discomfort, and provide real-time alerts to remind users to adjust their sitting posture	Martínez-Estrada <i>et al.</i> 2023
		Monitors the user's physiological parameters (such as sitting position, body temperature, and respiratory rate) and environmental parameters (such as temperature, humidity, carbon dioxide concentration, noise, and light intensity)	Tavares <i>et al.</i> 2023
		Sitting posture classification and ECG monitoring to prevent cardiovascular disease and musculoskeletal problems	Pereira <i>et al.</i> 2023

Karakolis and Callaghan (2014) concluded that sit-stand workstations may effectively reduce perceived discomfort. Among the eight studies reporting productivity outcomes, three indicated that sit-stand work improved work efficiency, four reported no impact on productivity, and one showed mixed results. Karol and Robertson (2015) found that prolonged sitting is associated with numerous adverse health outcomes and sit-stand workstations in offices have emerged as a strategy to mitigate the effects of sedentary work. The use of activity-promoting workstations has been significantly associated with improvements in various cardiometabolic biomarkers (*e.g.*, weight, total fat mass, resting heart rate, and body fat percentage) and work productivity metrics (*e.g.*, focus at work and fewer days absent due to health issues), highlighting the effectiveness of Active Health interventions (Carr *et al.* 2016). Research by Deery *et al.* (2024) indicated that the use of sit-stand workstations has become normalized. Providing the option for sit-stand desks allows employees greater autonomy, control, energy levels, perceived well-being, and improved communication during working hours.

For tasks primarily involving mouse usage, bicycle workstations may be less suitable and more user specific. However, their ability to increase daily energy expenditure makes them a viable solution for addressing workplace sedentary behavior (Straker *et al.* 2009). When individuals work at bicycle workstations, they can experience positive emotional responses, which in turn help encourage the adoption of more physical activities in daily routines (Pilcher *et al.* 2016).

The study by Ohlinger *et al.* (2011) supports the potential of treadmill workstations to increase physical activity in the workplace without impairing cognitive performance. Arauz *et al.* (2021) analyzed the impact of treadmill workstations on lower-limb motion symmetry during typing tasks compared to walking on the ground and on a treadmill. The results indicated that the use of treadmill workstations may influence the kinematic gait symmetry of the lower limbs.

The study by Vlaović *et al.* (2007) describes various sensors applied to chairs, including force-sensitive resistors, heart rate sensors, respiratory monitoring sensors, voice control sensors, and accelerometers. The system, which observes sitting posture, collects and processes data, and displays it in real-time, achieved optimal results as it directly influences users to adjust or maintain their sitting posture. Zazula *et al.* (2015) proposed a smart chair that simultaneously captures photoplethysmogram (PPG) signals and electrocardiogram (ECG) signals, enabling the assessment of various cardiovascular parameters. Ma *et al.* (2017) developed a system based on chair cushions to evaluate activity levels and recognize movements by analyzing the sitting posture of sedentary individuals. This system is suitable for monitoring sitting behavior in workplace settings and can be easily implemented with low-cost embedded devices. It identifies activity and quantifies activity levels, providing reminders for movement or rest, helping to reduce health risks, and offering timely interventions when necessary.

Anwary *et al.* (2019) investigated the real-time visualization of asymmetric sitting posture (ASP) and developed an automated real-time monitoring system for asymmetric sitting posture based on a multi-layer architecture of flexible pressure sensors. This system, which aligns with human biomechanics, can be embedded into seat covers or chairs and connected to a mobile app for real-time data visualization. Martínez-Estrada *et al.* (2023) proposed a smart office chair equipped with movable capacitive textile sensors to monitor users' sitting postures in real time during work hours. The system uses capacitive detection to identify different postures and alerts users in real time if their posture may lead to musculoskeletal diseases or discomfort, prompting them to adjust their sitting position.

Pereira *et al.* (2023) introduced a smart office chair system capable of classifying sitting postures and monitoring electrocardiogram (ECG) signals without interfering with the user's work. This intelligent chair categorizes five to seven types of sitting postures and can help improve health management in office environments, preventing cardiovascular diseases and musculoskeletal issues, thereby enhancing Active Health and work efficiency.

Active Health Interaction Model

Menheere *et al.* (2020) introduced an office chair named Ivy, which replaces digital charts with a data-physical interface to present sedentary behavior in a qualitative form, aiming to reduce sedentary habits. The study proposes the potential of introducing qualitative interactive interfaces in Active Health and smart office furniture, hoping to draw attention from designers and researchers in the field of human-computer interaction to the application potential of qualitative interfaces in deepening the understanding of user behavior and enhancing feedback constructiveness.

Brombacher *et al.* (2024) explored tangible interactive interventions to improve office health, analyzing how tangible user interfaces can address sedentary issues in office environments and promote healthier, more active work styles. The paper further presents considerations for the design of future tangible office health interventions and provides an overview of current research and future directions to foster a healthier and more active office environment. This research provides theoretical foundations and practical guidance for the design of interactive systems in the fields of Active Health and smart office furniture.

El-Leathey *et al.* (2024) proposed a real-time smart Internet of Things (IoT) system to monitor comfort and health conditions in office buildings. Built on an Arduino development board with various sensors, the system can be expanded or customized based on user needs. This system provides interactive support for real-time monitoring and environmental adjustments in Active Health and smart office furniture, contributing to better health management in office environments.

The Active Health Interaction Model for Office Furniture is primarily divided into four modules: the User Fatigue Recognition Module, the User Fatigue Relief Module, the Real-Time Feedback and Interaction Module, and the User Behavior Adjustment and Feedback Optimization Modules (Fig. 2). The User Fatigue Recognition Module determines the user's fatigue state by collecting physiological signal features. For example, when the user is in an office fatigue state, the Active Health Interaction Module sends feedback commands to the User Fatigue Relief Module. The Active Health interaction model for office furniture aims to automatically activate the fatigue alleviation module. It does this by detecting the user's fatigue levels through physiological and psychological indicators, based on their physiological signals. This allows the system to control the main system services through physiological signal-based commands.

The real-time feedback and interaction module provides users with health status updates and intervention suggestions through various methods, such as visual interfaces, sound cues, and vibration feedback, based on real-time data (Gao *et al.* 2024). Real-time feedback not only helps users adjust their behaviors but also enhances their awareness of health management. The user behavior adjustment and feedback optimization module updates feedback information in real-time based on the user's interaction with the health intervention system and adjusts personalized health intervention plans accordingly. The Active Health interaction model for office furniture combines physiological fatigue recognition and psychological fatigue recognition, allowing the indicators from the

physiological fatigue recognition module and the psychological fatigue recognition module to adaptively match parameters. This enables the model to provide more targeted, accurate, and reasonable health services.

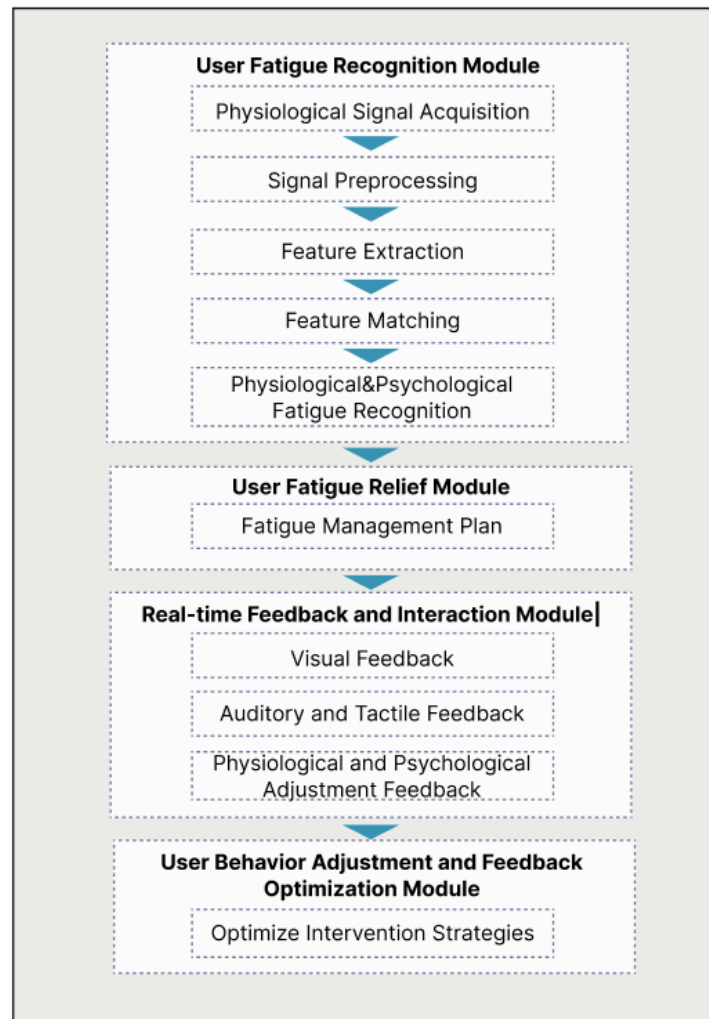


Fig. 2. The framework of the Active Health Human-Computer Interaction Model

CONCLUSIONS AND PROSPECTS

The integration of smart office furniture with the concept of Active Health shows significant potential in addressing the growing health issues caused by sedentary behavior in modern workplaces. As office workers face both physical and psychological fatigue due to prolonged sitting and poor working environments, the development of smart office furniture provides innovative solutions to promote health and well-being. Some promising studies mentioned earlier have shown positive results: lifting desks that promote cardiovascular metabolism and improve work focus, Bicycle chairs that enhance positive emotions, Treadmill workstations that increase physical activity during work hours, and Smart chairs that assess cardiovascular parameters and musculoskeletal conditions while providing reminders to users.

This paper reviews various aspects of designing smart office furniture that supports Active Health. By incorporating advanced technologies, such as sensors, data analytics, and real-time feedback mechanisms, these systems offer personalized health interventions, monitor users' physical and psychological states, and recommend measures to alleviate fatigue or encourage physical activity based on the collected data. The introduction of these systems not only enhances the ergonomic and functional aspects of workspaces but also creates an environment conducive to a healthy and active lifestyle.

The Active Health concept emphasizes the proactive monitoring and management of individual health through technology, which is closely related to the smart design of office furniture. Through monitoring physiological indicators, such as heart rate, posture, and fatigue levels, and providing interventions based on these measurements, smart furniture can significantly reduce the health impacts caused by sedentary behavior and poor office environments.

The shift from traditional office furniture to smart health-support systems requires interdisciplinary collaboration, combining ergonomics, human-computer interaction, and health technology. The future of office furniture design lies in creating systems that are both functionally adaptable and capable of actively improving employee health through dynamic feedback and personalized interventions.

In conclusion, the innovation and development of smart office furniture based on the Active Health concept provide promising solutions to enhance workplace well-being. As these systems evolve, future research and collaboration will be essential to refine these technologies and design frameworks, ensuring that they effectively meet the diverse health needs of office workers and contribute to building a more sustainable and health-conscious work environment.

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