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Review

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Pathophysiological mechanisms underlying health disorders induced by excessive smartphone use: A systematic review

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Abstract

Background: Smartphones have become indispensable tools in daily life; however, excessive use has been increasingly associated with adverse health outcomes. Problematic smartphone use may disrupt physiological homeostasis and contribute to multisystem dysfunction. **Objective:** To synthesize current evidences on the pathophysiological mechanisms linking excessive smartphone use with human health disorders. **Methods:** A systematic literature search using MeSH terms was performed in PubMed, Scopus, MEDLINE, Web of Science, ProQuest Central, and PsycINFO for English-language studies published up to October 2025. Studies exploring biological or physiological mechanisms associated with smartphone overuse were included. The review followed PRISMA guidelines, and eligible studies were assessed for methodological quality. Findings were synthesized thematically. **Results:** Of 103 records screened, 43 met inclusion criteria. Excessive smartphone use was associated with neuropsychological alterations including GABAergic dysfunction, reduced grey matter volume, and disrupted neural connectivity. Ocular disorders included digital eye strain, tear film instability, and blue light–induced retinal stress. Musculoskeletal issues such as text neck syndrome and tendon strain were linked to poor posture. Endocrine and metabolic effects stemmed from sleep deprivation, circadian

misalignment, and sedentary behaviour, while cardiovascular disturbances involved sympathetic overactivation, reduced heart rate variability, and endothelial dysfunction. **Conclusion:**Excessive smartphone use exerts measurable adverse effects on multiple physiological systems through interconnected neurological, endocrine, cardiovascular, and musculoskeletal pathways. The pathophysiological mechanisms primarily involve neuroendocrine dysregulation, oxidative stress, autonomic imbalance, and inflammatory activation, leading to both physical and psychological health disturbances. Public health strategies promoting digital hygiene, behavioural therapy, ergonomic practices, and screen-time moderation are vital to prevent smartphone-related health disorders.

Keywords: Smartphone addiction; Pathophysiology; Neuroendocrine dysfunction; Oxidative stress; Homeostasis; Public health

Introduction

Smartphones have become indi-spensable in modern society, supporting communication, work, education, and social interaction. As of 2024, more than 4.88 billion people, accounting for about 60.42% of the global population use smartphones, reflecting their pervasive integration into daily life. However, the rising prevalence of problematic smartphone use—estimated at 6.3% globally—has emerged as a major health concern due to its potential to disturb normal physiological balance and contribute to multiple systemic disorders. [1-4]

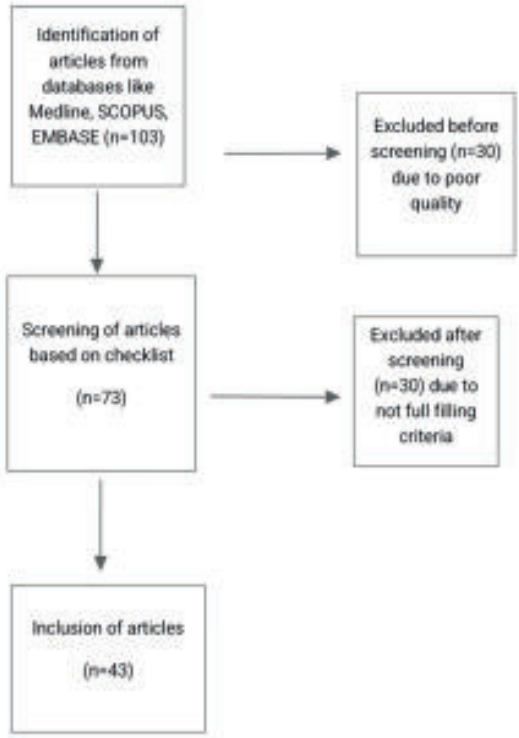
The principle of homeostasis, described by Walter Bradford Cannon in 1929 as the maintenance of internal equilibrium through coordinated physiological functions, can be disrupted by excessive smartphone use.[5] Such disruption has been linked to neuro-psychological, ocular, vestibulo-cochlear, musculoskeletal, endocrine, metabolic, and cardiovascular abnormalities. [6-12]

Although numerous studies have examined the behavioral and psychological consequences of smartphone overuse, few have explored the underlying pathophysiological mechanisms. This systematic review therefore aims to synthesize current evidence on the biological pathways through which excessive smartphone use affects human health, to inform preventive and therapeutic strategies as well as evidence-based public health interventions.

Methods

To comprehensively examine the patho-physiological mechanisms underlying health disorders associated with excessive smartphone use, an extensive English literature search using MeSH terms, was conducted in major scientific databases, including Scopus, MEDLINE, Web of Science, PubMed, ProQuest Central, and PsycINFO. Publications from inception to October 2025 were considered. The review was conducted as the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

Studies were eligible if they investigated health disorders related to smartphone use and



Flow chart of search strategy

described corresponding pathophysiological mechanisms. The selection process involved initial title and abstract screening, followed by full-text assessment. Data extracted from eligible studies included author details, publication year, country, study design, sample size, intervention characteristics, key findings, and study limitations.

A total of 103 records were retrieved, of which 60 were excluded after full-text review for not meeting inclusion criteria. Finally, 43 articles satisfying all eligibility parameters were included for qualitative synthesis. Each study was critically appraised for methodological quality and risk of bias. The extracted data were summarized and analyzed thematically to identify recurring physiological and mechanistic patterns associated with excessive smartphone use.

Discussion

a. Neuropsychological disorders

Excessive smartphone use has been consistently linked to various neuropsychological disturbances, including depression, anxiety, social anxiety, and low self-esteem. These outcomes arise from complex neurochemical and structural changes in the brain, mirroring mechanisms observed in other forms of behavioral addiction. [13- 16]

Possible pathophysiology:

1. GABAergic Dysfunction

Prolonged smartphone engagement may disrupt neurotransmitter balance, particularly the inhibitory system mediated by gamma-aminobutyric acid (GABA). GABA plays a central role in suppressing neuronal excitability, regulating fear and anxiety, and reinforcing reward pathways. Dysregulation of GABAergic transmission has been associated with heightened emotional instability and addictive behavioral patterns, similar to those observed in substance dependence. [17]

2. Reduced Grey Matter Volume

Neuroimaging studies have reported a reduction in grey matter volume (GMV) in brain regions implicated in cognitive control, emotion regulation, and executive function among individuals with smartphone addiction. These morphological alterations, particularly within the orbitofrontal cortex (OFC) and anterior cingulate cortex (ACC), resemble structural deficits seen in individuals with substance-related disorders, indicating impaired inhibitory control and emotional regulation. [16,18]

3. Abnormal Functional Connectivity

Functional MRI (fMRI) and diffusion MRI analyses have demonstrated altered white matter connectivity in the right amygdala and other regions responsible for emotional and reward processing. Excessive smartphone use is

associated with decreased functional connectivity in neural circuits governing self-control and increased coupling between regions linked to arousal and reward reinforcement. These findings suggest that prolonged device engagement promotes maladaptive neuroplastic changes that reinforce compulsive usage behaviors. [19,20]

4. Sleep Disturbances

Late-night smartphone use has been strongly correlated with delayed sleep onset, shortened sleep duration, and poor sleep quality. Pathophysiological mechanisms include circadian rhythm disruption, melatonin suppression from blue light exposure, and heightened cognitive arousal resulting from emotional and informational engagement before bedtime. Such disturbances further exacerbate mood instability, cognitive fatigue, and daytime somnolence, perpetuating the cycle of smartphone dependence. [21,22]

b. Ocular Disorders

Prolonged smartphone use has been strongly associated with multiple ocular disorders, primarily resulting from extended near-vision activity, high screen luminance, and blue light exposure. The most frequently reported conditions include digital eye strain (DES), dry eye syndrome, transient myopia, and potential retinal phototoxicity.

1. Digital Eye Strain (DES)

Digital Eye Strain, also known as Computer Vision Syndrome, encompasses a set of visual and ocular symptoms such as eye fatigue, blurred vision, and headaches arising from continuous screen exposure. The pathophysiological basis of DES involves accommodative stress and extraocular muscle fatigue due to sustained near focusing. Continuous contraction of the ciliary and medial rectus muscles causes accommodative spasm and asthenopia. Additionally, screen glare and flicker increase pupillary instability and micro-ocular adjustments, further contributing to neuromuscular fatigue. [23,24]

2. Dry Eye Syndrome

Extended screen use significantly reduces blink frequency, from the normal 15–20 blinks per minute to as few as 5–7. This decrease destabilizes the tear film, leading to rapid evaporation and ocular surface dryness. Tear hyperosmolarity induces inflammation characterized by elevated interleukin-1 (IL-1), tumor necrosis factor-alpha (TNF-á), and matrix metalloproteinases (MMPs), which damage the corneal epithelium and goblet cells responsible for mucin secretion. Persistent inflammation leads to reduced tear quality and chronic ocular surface disease. [25-27]

3. Transient Myopia and Visual Fatigue

Sustained accommodation during near-focus tasks can result in transient myopia, a temporary reduction in distance vision due to prolonged ciliary muscle contraction and lens thickening. Chronic exposure to such near-work strain may contribute to axial elongation of the eyeball, increasing susceptibility to permanent myopia, particularly among children and adolescents. [28]

4. Blue Light Exposure and Retinal Effects

Smartphone screens emit short-wavelength blue light (400–490 nm), which can generate reactive oxygen species (ROS) in retinal pigment epithelial (RPE) cells, inducing oxidative stress and photoreceptor damage. Experimental models have demonstrated mitochondrial dysfunction and apoptosis in RPE cells following chronic blue light exposure, suggesting a potential link between prolonged smartphone use and retinal phototoxicity. [29,30]

c. Auditory and Vestibular Disorders

Excessive smartphone use, particularly through earphones or headphones, has been linked to auditory and vestibular dysfunctions. The most common include noise-induced hearing loss (NIHL), tinnitus, and vestibular imbalance, arising from prolonged exposure to high sound intensity and electromagnetic radiation (EMR).

1. Noise-Induced Hearing Loss (NIHL)

Listening to audio at high volumes via smartphones can deliver sound levels exceeding 100 dB, surpassing the World Health Organization's safe threshold of 85 dB for eight hours. Chronic exposure damages cochlear hair cells through mechanical stress, oxidative injury, and mitochondrial dysfunction, leading to irreversible sensorineural hearing loss. [7, 31]

2. Tinnitus

Persistent exposure to loud sounds can cause tinnitus, perceived as ringing or buzzing without external stimuli. This condition results from maladaptive neuroplasticity in the auditory cortex following cochlear injury, where excessive glutamate release induces neuronal hyperactivity and abnormal auditory signaling. [32]

3. Vestibular Dysfunction

Emerging evidence suggests that prolonged exposure to smartphone-emitted EMR may alter vestibular function, particularly affecting the utricle and saccule. Such exposure may disrupt ionic balance and neuronal excitability, leading to symptoms such as dizziness, imbalance, and spatial disorientation, especially in users holding devices close to the ear for extended periods. [8,9]

d. Musculoskeletal Disorders

Excessive smartphone use contributes to musculoskeletal discomfort, primarily affecting the neck, shoulders, upper back, hands, and wrists. These effects result from poor posture, repetitive movements, and prolonged static muscle loading.

1. Neck and Shoulder Pain

"Text neck syndrome" is a common outcome of persistent neck flexion while viewing screens. Each degree of neck tilt increases the gravitational load on cervical structures, reaching up to 27 kg at 60° flexion. This sustained strain leads to muscle fatigue, stiffness, and, in severe cases, cervical spondylosis. Forward head posture also shortens anterior neck and pectoral muscles, weakens posterior stabilizers, and alters spinal curvature, promoting chronic pain. [10,11]

2. Upper Back and Shoulder Disorders

Continuous smartphone use induces static muscle contraction in the trapezius, levator scapulae, and rhomboids, reducing blood flow and triggering ischemic pain. This condition activates inflammatory mediators such as interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF-á), perpetuating stiffness and myofascial discomfort. Prolonged strain may lead to fibrosis and restricted shoulder mobility. [33,34]

3. Hand and Wrist Disorders

Repetitive thumb and finger movements during texting or gaming predispose users to De Quervain's tenosynovitis and carpal tunnel syndrome. Continuous flexion and extension increase tendon pressure and nerve compression, resulting in pain, tingling, and reduced grip strength. Small device size and awkward hand postures further aggravate ligament strain and microtrauma in the wrist and thumb joints. [35]

e. Endocrine and Metabolic Disorders

Excessive smartphone use has been linked to endocrine and metabolic disturbances, largely driven by sedentary behavior, sleep disruption, and circadian rhythm misalignment. These factors collectively promote obesity, insulin resistance, and related metabolic syndromes.

1. Sedentary Lifestyle and Energy Imbalance

Prolonged smartphone engagement reduces physical activity, leading to positive energy balance and fat accumulation. Reduced muscular glucose uptake via GLUT4 transporters contributes to hyperglycemia and increases the risk of insulin resistance and type 2 diabetes mellitus. Concurrent snacking during screen use further amplifies caloric surplus and weight gain. [36-39]

2. Sleep Deprivation and Hormonal Dysregulation

Late-night smartphone use disrupts normal sleep patterns, altering the secretion of leptin and

ghrelin, hormones regulating appetite. Reduced leptin and elevated ghrelin levels promote overeating and carbohydrate cravings. In addition, chronic sleep loss elevates cortisol through HPA axis activation, enhancing gluconeogenesis and visceral fat deposition, which contribute to metabolic dysfunction. [36-39]

3. Circadian Rhythm Disruption

Exposure to blue light at night suppresses melatonin and desynchronizes circadian clock genes (BMAL1, CLOCK, PER, CRY). This misalignment impairs insulin sensitivity, lipid metabolism, and β-cell function, leading to postprandial glucose intolerance and dyslipidaemia. [36-39]

4. Thyroid and Reproductive Hormonal Effects

Preliminary studies suggest that chronic exposure to electromagnetic radiation (EMR) from smartphones may affect hypothalamic–pituitary signaling, potentially altering thyroid-stimulating hormone (TSH) and testosterone levels. Although current evidence is limited, these findings highlight a possible link between long-term EMR exposure and endocrine imbalance. [40]

f. Cardiovascular Disorders

Excessive smartphone use has been associated with multiple cardiovascular disturbances, primarily mediated by sympathetic overactivation, oxidative stress, endothelial dysfunction, and altered autonomic regulation. These mechanisms collectively increase the risk of hypertension, tachycardia, and vascular abnormalities.

1. Sympathetic Overactivation

Continuous digital engagement and frequent notifications stimulate the hypothalamic–pituitary–adrenal (HPA) axis, increasing the secretion of cortisol, adrenaline, and noradrenaline. Persistent sympathetic dominance elevates heart rate, blood pressure, and myocardial oxygen demand, predisposing to hypertension and arrhythmias. [12, 41, 42]

2. Reduced Heart Rate Variability (HRV)

Heart Rate Variability (HRV), an indicator of autonomic balance, tends to decrease in individuals with excessive smartphone use, particularly before sleep. Reduced HRV reflects diminished parasympathetic modulation and increased sympathetic arousal, signifying higher cardiovascular stress and reduced adaptability. [12, 41, 42]

3. Oxidative Stress and Endothelial Dysfunction

Chronic psychological stress from smartphone overuse elevates reactive oxygen species (ROS) production, reducing nitric oxide (NO) bioavailability essential for vasodilation. This imbalance leads to endothelial dysfunction, arterial stiffness, and an increased risk of atherogenesis. Prolonged electromagnetic radiation (EMR) exposure may further enhance oxidative and inflammatory vascular responses. [12, 43]

4. Sleep Deprivation and Cardiometabolic Risk

Late-night smartphone use contributes to **sleep loss** and **circadian disruption**, which elevate nocturnal blood pressure and sympathetic tone while impairing baroreflex sensitivity and endothelial repair. Chronic deprivation also worsens lipid metabolism, raising LDL and triglyceride levels, thereby compounding cardiovascular risk. [12, 41-43]

Conclusion

Excessive smartphone use exerts measurable adverse effects on multiple physiological systems through interconnected neurological, endocrine, cardiovascular, and musculoskeletal pathways. The pathophysiological mechanisms primarily involve neuroendocrine dysregulation, oxidative stress, autonomic imbalance, and inflammatory activation, leading to both physical and psychological health disturbances.

The evidence underscores the importance of responsible smartphone usage, particularly in minimizing screen exposure duration, night-time

use, and improper posture. Public health interventions should prioritize awareness programs, digital hygiene education, behavioral therapy, ergonomic guidance and digital policy reforms to mitigate these emerging health risks.

Further longitudinal and mechanistic studies are essential to elucidate causal relationships and develop targeted preventive strategies against smartphone-induced physiological disorders.

Conflict of interest

There is no conflict of interest pertaining to this study.

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