The biological impact of technology: connecting digital habits to health

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Abstract

The widespread availability of digital technology altered people's routines, particularly their approaches to education and entertainment. There are several positives about the latest technological digital advances, but when misused, they may degrade people's physical, mental, and social health. This mini review explores the most recent findings on the health effects of digital technology, focussing on changes in neurobiology, hormone levels, and sleep patterns. This paper highlights the ergonomic innovations and digital detox methods, importance of technology in tracking overall health and providing mental health treatment. Increased tension, worry, and physical discomfort are some of the negative outcomes linked to excessive technology usage. The paper discusses a number of practical methods that may be taken to increase digital well-being, including mindfulness practices, ergonomic modifications, and the adoption of enabling policies. Legislators, healthcare practitioners, educators, and tech developers must collaborate to ensure the ethical use of digital technologies. Collaboration and teamwork is crucial for lowering risks and making the internet and digital space a better, safer place for all users.

Keywords: Digital wellbeing, technology use, biological responses, mental health, physical health, neurobiology, digital de-toxification, ergonomics, screen time management.

1. Introduction

Digital technology has become an integral part of modern life, influencing how people work, communicate, learn, and entertain. The widespread use of smartphones, computers, and the internet has transformed daily routines, providing unparalleled access to information and connectivity. Despite the many advantages these technologies offer, excessive or improper use can result in adverse health effects. Digital wellbeing refers to the balance of physical, mental, and social health in relation to digital technology usage (Vanden Abeele, 2020). This review aims to consolidate current research on the biological effects of technology, examining both the positive and negative neurobiological impacts, hormonal shifts, disruptions in sleep, and their broader implications for physical and mental health. By exploring these connections, the article seeks to offer insights into strategies that promote a healthy and balanced digital lifestyle.

1.1 Overview of Digital Wellbeing
A) Definition and Scope

Digital wellbeing refers to the pursuit of a balanced and intentional relationship with technology, aimed at optimizing its benefits while mitigating risks to mental and physical health (World Health Organization [WHO], 2019). It includes several key dimensions:

1.   **Mental Health:** Involves managing the psychological effects of technology, such as stress, anxiety, and digital addiction, while also using technology to support mental health (Firth et al., 2019).

2.   **Physical Health:** Focuses on addressing issues like musculoskeletal discomfort, eye strain, and sleep disturbances, alongside utilizing digital tools for health monitoring (Piwek et al., 2016).

3.   **Social Health:** Maintains the importance of in-person contacts while encouraging the growth of meaningful connections via the use of digital means. (Nowland et al., 2018).

4.   **Behavioral Health:** Encourages the development of healthy technology usage habits to prevent adverse effects and promote positive behaviours (Vanden Abeele, 2020).

1.2 Technological Advancements and Usage Patterns

1.2.1 Evolution of Digital Devices and Applications

a.   **Early Computing and the Internet**
The rise of personal computers in the 1980s and 1990s, followed by the expansion of the World Wide Web, revolutionized communication, education, and the sharing of information on a global scale (Castells, 2010).

b.   **Rise of Mobile Technology**
In the early 2000s, smartphones and tablets became ubiquitous, transforming technology into an omnipresent aspect of daily life. Devices like the iPhone, introduced in 2007, combined communication, internet access, and applications into one portable solution (Goggin, 2011).

c.   **Social Media and Communication Platforms**
Since they allowed users to engage in real-time conversations, social media sites like Instagram, Twitter, and Facebook revolutionised the way people communicate. There are new concerns about privacy and mental health, despite the fact that they develop community and networking. (Keles et al., 2020).

d.   **Wearable Technology and Health Apps**
Wearable devices, such as fitness trackers and smartwatches, now monitor various health metrics, encouraging users to make informed decisions about their lifestyle based on real-time data (Piwek et al., 2016).

e. **Artificial Intelligence and Machine Learning**

Advancements in AI have enabled more personalized digital experiences, including mental health chatbots and virtual health consultations. These technologies analyze user data to offer tailored recommendations and interventions (Topol, 2019).

f. **Virtual Reality (VR) and Augmented Reality (AR)**

VR and AR technologies have broadened the scope of immersive experiences in sectors like gaming, education, and therapy. These tools have potential applications in learning enhancement, rehabilitation, and stress management (Riva et al., 2019).

g. **Internet of Things (IoT)**

The IoT connects everyday devices, integrating technology more deeply into daily life. From smart homes to wearable health monitors, IoT offers convenience but also raises concerns about data privacy and security (Sicari et al., 2015).

1.2.2 Patterns of technology use across different populations

a. **Children and Adolescents**

The younger generation relies largely on technology for things like gaming, social networking, and education. Parental monitoring and digital literacy instruction are crucial since excessive screen time may lead to decreased physical activity and sleep difficulties (Radesky et al., 2020).

b. **Young Adults**

For young adults, technology plays a critical role in communication, work, and entertainment. Multitasking with digital devices can affect productivity and cognitive performance (Junco & Cotten, 2012).

c. **Middle-Aged Adults**

Middle-aged adults rely on technology for both personal and professional tasks, making ergonomics and time management critical for reducing strain and maintaining balance (Xie et al., 2016).

d. **Older Adults**

Older generations are increasingly adopting digital tools to remain connected and access services like telemedicine. Issues like digital literacy and usability remain a challenge, making user-friendly designs essential (Tsai et al., 2015).

e. **Diverse Populations and the Digital Divide**

The digital divide highlights inequalities in access to technology, influenced by socioeconomic status, geography, and education. Bridging this gap is vital for ensuring equal access to digital tools and opportunities (van Dijk, 2020).

1.3 Biological responses to technology use
1.3.1 Neurobiological Impacts
a. **Brain Structure Alterations**
Excessive screen time has been linked to changes in brain structure, particularly affecting regions responsible for cognitive control and emotional regulation (Horowitz-Kraus & Hutton, 2018).

b. **Neuroplasticity Influences**
Interaction with digital technology can influence neuroplasticity, potentially enhancing visuospatial attention through activities like gaming, though it may also impair impulse control (Achtman et al., 2008).

c. **Positive Neurobiological Effects**
Certain digital tools are designed to enhance cognitive functions, such as problem-solving and memory, contributing to neurorehabilitation and cognitive development (Kuhn et al., 2014).

d. **Dopamine System Stimulation**
Activities like gaming and social media use activate the brain's reward system, releasing dopamine and reinforcing behaviour, which may lead to addictive tendencies (Montag et al., 2019).

1.3.2 Hormonal and Endocrine Responses
a. **Elevated Cortisol Levels**
Constant connectivity and the expectation for immediate responses can lead to heightened cortisol levels, the body's primary stress hormone. Studies have shown that excessive mobile phone usage is linked to increased stress and sleep disturbances (Thomée et al., 2011).

b. **Melatonin Suppression:**
Exposure to blue light emitted from screens, particularly in the evening, suppresses melatonin production. This disruption in melatonin can interfere with the sleep-wake cycle, delaying sleep and reducing next-day alertness (Chang et al., 2015).

c. **Hormonal Imbalances and Metabolic Effects**
Sedentary behavior from prolonged technology use has been associated with insulin sensitivity issues and metabolic regulation disturbances, contributing to chronic conditions like obesity and type 2 diabetes (Owen et al., 2010).

d. **Sleep Patterns and Circadian Rhythms**

i) Sleep Quality Reduction
Studies have shown that using electronic devices in the hours leading up to bedtime causes sleep to start later and is associated with worse quality sleep overall. We get less sleep overall because cognitive arousal is affected by blue light and compelling material. (Hale & Guan, 2015).

ii) Circadian Rhythm Disruption

Late-night use of digital devices can disturb the body's natural circadian rhythm, resulting in sleep disorders and reduced overall health (Fobian et al., 2016).

1.3.3 Physical Health Implications

a. **Musculoskeletal Issues:**

i. Poor Posture and "Tech Neck"

Frequent use of digital devices often leads to poor posture, causing neck and back pain—commonly known as "tech neck." Ergonomic setups are essential to prevent such physical strain (Xie et al., 2016).

ii. Repetitive Strain Injuries (RSIs)

Excessive typing and repetitive motions can result in RSIs, such as carpal tunnel syndrome. Users of computer keyboards, in particular, are at a higher risk for these injuries (Keller et al., 1998).

iii. Prevention and Management

Implementing ergonomic interventions such as adjustable workstations and regular breaks helps in managing and preventing musculoskeletal issues (Hoe et al., 2018).

b. **Vision and Eye Health:**

i. Digital Eye Strain

Long hours spent staring at screens can lead to digital eye strain, manifesting as dryness, irritation, and headaches. Protective measures such as adjusting screen brightness and taking regular breaks are recommended (Rosenfield, 2011).

ii. Blue Light Exposure and Eye Health

Exposure to blue light from digital screens can contribute to long-term retinal damage and disrupt sleep cycles, prompting the use of blue light filters and protective eyewear (Hagan et al., 2016).

c. **Effects on Cardiovascular Health:**

i. Sedentary Lifestyle Risks

Extended screen time and a sedentary lifestyle are closely associated with an increased risk of cardiovascular diseases (Owen et al., 2010).

ii. Metabolic Syndrome Development

Prolonged inactivity can lead to the development of metabolic syndrome, characterized by excess body fat and abnormal cholesterol levels. Studies have shown a correlation between increased screen time and metabolic risk factors (Grøntved & Hu, 2011).

1.3.4 Mental Health and Psychological Effects

a. Increased Stress and Anxiety Levels

Constant information consumption and the need to always be connected may lead to digital overload, which in turn can increase levels of stress and anxiety. (Thomee et al., 2011).

b. Comparison and Self-Esteem Issues

Regular users of social media are more likely to suffer from depression and poor self-esteem because of the platform's tendency to encourage them to compare themselves to others. (Vogel et al., 2014).

c. Cognitive Function and Attention

When humans attempt to take in more data than the working memory that they can handle, and exhausts brain's processing capacity. Mental exhaustion, a weakened capacity to focus and remember, and impaired knowledge retention are all symptoms of cognitive overload. (Ophir et al., 2009).

d. Reduced Attention Span

Short attention spans might be the result of all the time spent glued to screens. Researchers have shown that people's ability to focus for lengthy periods of time decreases after being exposed to fast-paced digital stimuli. (Loh & Kanai, 2015).

e. Social Interactions and Loneliness

i. Online vs. Offline Social Interactions

While digital technologies facilitate communication, they can also reduce face-to-face interactions, contributing to feelings of loneliness (Nowland et al., 2018).

ii. The Paradox of Connectivity

ii.a Enhancing Social Wellbeing Through Technology

According to Primack et al. (2017), people who face similar problems might find support and a feeling of belonging in online groups that facilitate meaningful social relationships. Online interactions may still be superficial, leading to unfulfilled emotional needs, even when people have more connections than ever before (Hunt et al., 2018).

Table 1: Biological Responses to Technology use and Key Studies

Biological Response Category	Specific Impact	Description	Key Study (Reference)
Neurobiological Impacts	**Brain Structure Alterations**	Excessive screen time associated with changes in brain structure affecting cognitive control, language, and literacy skills.	Horowitz-Kraus & Hutton (2018)
	Neuroplasticity Influences	Technology interaction can enhance or impair neural pathways; video gaming may improve visuospatial skills but impact impulse control.	Achtman et al.,(2008)
	Dopamine System Stimulation	Activation of reward pathways leading to dopamine release; social media use	Montag et al. (2019)

		may result in addictive behaviors similar to substance addiction.	
Hormonal and Endocrine Responses	**Elevated Cortisol Levels**	Increased stress hormone levels due to constant connectivity and mobile phone use, leading to stress and sleep disturbances.	Thomee et al. (2011)
	Melatonin Suppression	Blue light exposure from screens suppresses melatonin production, disrupting sleep cycles and circadian rhythms.	Chang et al. (2015)
Sleep Patterns and Circadian Rhythms	**Sleep Quality Reduction**	Screen time before bed delays sleep onset and reduces sleep quality, leading to daytime sleepiness in children and adolescents.	Hale & Guan (2015)
	Circadian Rhythm Disruption	Irregular sleep patterns from late-night technology use desynchronize circadian rhythms, causing sleep disorders.	Fobian et al. (2016)
Physical Health Implications	**Musculoskeletal Issues**	Poor posture from device use leads to neck and back pain, often referred to as "tech neck."	Johnston et al. (2020)
	Repetitive Strain Injuries	Excessive typing and device use cause conditions like carpal tunnel syndrome and other repetitive strain injuries.	Keller et al., 1998)
Vision and Eye Health	**Digital Eye Strain**	Extended screen time causes symptoms like dryness, irritation, and blurred vision, collectively known as computer vision syndrome.	Rosenfield (2011)
Cardiovascular Risks	**Sedentary Lifestyle**	Prolonged sitting associated with screen time increases the risk of cardiovascular disease and all-cause mortality.	Owen et al. (2010)
Mental Health Effects	**Increased Stress and Anxiety**	Information overload from constant connectivity elevates stress and anxiety levels.	Thomée et al., (2011)
	Anxiety and Depression	Higher rates of sadness, anxiety, and mental discomfort are linked to teens who use social media too much.	Keles et al. (2020)
	Social Isolation	Despite the proliferation of internet connections, those who rely too much on these platforms may find themselves more isolated from others.	Nowland et al. (2018)

1.4   Mitigation Strategies for Digital Wellbeing

A. Digital Detox and Screen Time Management:
i. Implementing Digital Detox
Engaging in regular digital detoxes helps reduce dependency on technology and alleviates stress, creates opportunities for more mindful engagement with the real world (Syvertsen & Enli, 2019).

a. Establishing Screen Time Limits
Using apps to monitor and limit screen time can create a healthier balance between digital and offline activities, contributing to better wellbeing (Radesky et al., 2020).

b.   Creating a Technology-Free Routine
By designating some times or locations as tech-free, you may strengthen your interpersonal ties, concentrate better, and ultimately be happier. (Kushlev & Dunn, 2019).
B. Ergonomic Interventions
a. Optimizing Workspace Ergonomics
Proper ergonomics—adjustable seating, monitor placement, and keyboard positioning—are crucial in preventing physical discomfort (Hoe et al., 2018).

b. Encouraging Regular Movement
Incorporating movement breaks helps prevent the risks associated with prolonged sitting. Reminders from apps can aid in this practice (Dempsey et al., 2018).
c. Encouraging Physical Activity Through Technology
Technology can also encourage physical activity, with fitness apps and wearable devices helping users stay active and track their health progress (Lyons et al., 2014).
d. Promoting Good Posture
Awareness of and correcting poor posture while using devices can prevent tech-related physical issues, with tools like posture trainers helping users stay aligned (Xie et al., 2016).

C. Mindfulness and Relaxation Techniques
a. Practicing Mindfulness
Mindfulness practices, such as meditation and breathing exercises, can reduce anxiety and stress levels, contributing to mental clarity (Firth et al., 2019).

b. Incorporating Relaxation Exercises
Relaxation techniques, including yoga and tai chi, help in relieving stress and enhancing physical and mental wellbeing (Pascoe et al., 2017).

D. Positive Mental Health Support
Despite these challenges, digital platforms offer numerous mental health resources, such as online counseling and mindfulness apps, which can provide valuable support (Firth et al., 2019).

i. Cognitive Enhancement through Technology

On the positive side, certain apps and games are specifically designed to improve cognitive functions such as memory, problem-solving, and attention (Kuhn et al., 2014).

ii. Positive Sleep Interventions

On the flip side, technology can also support sleep improvement through apps that promote relaxation and monitor sleep patterns, helping individuals identify and address disturbances (Horsch et al., 2015).

iii. Setting Boundaries for Digital Use

Clear boundaries, like limiting device use during meals or before bedtime, can prevent digital overload and improve sleep quality (Kushlev & Dunn, 2019).

Fig-1: Strategies for digital wellbeing
(Image created using DALL-E AI Image generator through Copilot AI)

E. Policy and Community Interventions

a.   **Policy Recommendations**

To promote digital wellness, governments and organisations play a key part by making rules about things like screen time limits, comfortable working standards, and protecting data privacy. Policies should also control harmful content and abuse online to protect the health and safety of users. (WHO, 2019).

b.   **Community Programs**

Community-led projects can help people learn how to use technology better and make new friends. Programs that give people access to technology can help close the gap and make digital health more accessible to everyone. (van Dijk, 2020).

F. Research Gaps and Future Directions

There is a need for more longitudinal studies to examine how prolonged technology usage affects health, especially neurodevelopment in children and adolescents. These insights will help inform guidelines and effective interventions (Keles et al., 2020). More research is required to uncover the precise biological mechanisms through which technology use impacts neurotransmitters, hormones, and endocrine functions. A deeper understanding will enable the development of targeted therapies (Montag et al., 2019).

It is essential to explore how technology use impacts different demographics, including age, socioeconomic background, and access to technology. Such studies can provide more personalized approaches to addressing digital wellbeing (Tsai et al., 2015).With the growing popularity of technologies like AR, VR, and AI, research must evaluate their potential health be efits and risks. Areas of interest include motion sickness in VR environments and ethical concerns related to AI use (Riva et al., 2019). Future studies should focus on identifying the most effective interventions for promoting digital wellbeing. Evidence-based strategies will be essential in guiding public health initiatives and educational campaigns (Firth et al., 2019).

The impact of current public health policies on digital wellbeing should be assessed to create more effective guidelines. This requires collaboration between policymakers, health professionals, and technology companies (WHO, 2019). As technology advances, ethical issues around data privacy, targeted advertising, and surveillance require urgent attention. Regulatory frameworks must balance innovation with safeguarding individual rights (Zuboff, 2019).

2. Conclusions

More use of digital technology affects brain structure, cognitive performance, and hormonal balance. While certain digital tools enhance cognitive abilities, excessive use may pose risks. Prolonged technology use can lead to musculoskeletal issues, eye strain, and cardiovascular risks, although some digital tools promote health monitoring and physical activity.

Excessive screen time correlates with increased stress, anxiety, and loneliness. Digital platforms offer significant mental health resources. Adopting practices like digital detox, optimizing ergonomic setups, and incorporating mindfulness exercises are crucial for maintaining digital wellbeing.

Long-term studies, understanding of biological mechanisms, diversity in research populations, and the impact of emerging technologies are areas of further exploration. Public health campaigns should inform people about the risks of excessive screen time and encourage balanced use. Schools and workplaces should include digital literacy and wellness into their curriculum, equipping students and employees with the necessary skills to successfully regulate their internet usage from an early age. When crafting rules, lawmakers should think about how digital technology could affect people's health, particularly in areas like data protection and access to mental health services. To address the complicated difficulties related to digital wellness, it is important to have a multi-stakeholder strategy that involves researchers, healthcare experts, educators, and legislators to protect people's lives and their health in the digital age by encouraging a balanced approach to digital wellness.

3. AI Acknowledgement:

Authors acknowledge the responsible use of AI tool ChatGPT to improve the text form, Images by DALL-E through Microsoft Copilot AI).

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