Proceedings of the 2nd International Conference on Modern Medicine and Global Health
DOI: 10.54254/2753-8818/29/20240801

Examining the hazards of sedentary behavior: An overview of the risks of screen-based sedentary behavior

ChuanQi You[1], YuPeng Cui[2, 3]

[1]Department of Physiology and Biochemistry, The Capital University of Physical Education and Sports, Beijing, 100091, China
[2]Prof. Dr. YuPeng Cui, Research interests in sports biochemistry and sports nutrition, Department of Sports Science and Health, The Capital University of Physical Education and Sports, Beijing, 100091, China

[3]cuiyupeng@cupes.edu.cn

Abstract. Screen-based sedentary behaviors (SSB) has become a particularly concerning subset of sedentary behavior. With the rapid advancement of technology, screens have become an integral part of our daily lives. However, the potential health impacts that accompany this trend demand our attention. Increasing evidence suggests that screen-based sedentary behavior, as opposed to traditional sedentary activities like reading, has more severe implications for health. Prolonged SSB in children and adolescents is associated with poorer physical fitness and cardiovascular health, and it poses a higher risk of obesity compared to traditional sedentary behavior. The World Health Organization's sedentary behavior guidelines emphasize the importance of limiting SSB in children and adolescents (aged 5-17) and encouraging adults (aged 18-64) to reduce their screen-based sedentary time. Therefore, this review provides an overview of the health hazards (obesity, type 2 diabetes, mental health and sleep) associated with screen-based sedentary behaviour and its potential mechanisms of action. In addition, interventions to reduce SSB and their benefits are discussed and future research directions are suggested.

Keywords: Sedentary behavior; Screen-based sedentary behavior; Health risk; Interventions

1. Introduction

In modern society, changes in our living environment and shifts in work patterns have led to prolonged periods of sedentary behavior in our daily lives, whether in offices, classrooms, or leisure time spent engrossed in electronic devices. This sedentary lifestyle is closely associated with a range of health issues, including obesity, cardiovascular diseases, bone BMD, and mental health problems. The World Health Organization's "*WHO GUIDELINES ON PHYSICAL ACTIVITY AND SEDENTARY BEHAVIOUR*" particularly emphasizes the evidence of adverse health effects related to sedentary behavior, with screen-based sedentary behavior (SSB) often having a more substantial impact than total sedentary time [1]. The guidelines recommend that children and adolescents should engage in at least an average of 60 minutes of moderate to vigorous-intensity physical activity each day, while adults should aim for a weekly total of 150-300 minutes of moderate-intensity aerobic physical exercise, or at least 75-150 minutes of vigorous-intensity aerobic exercise, or an equivalent combination of moderate and vigorous-intensity activities to gain significant health benefits. Ekelund and others found in their meta-analysis that high levels of MVPA (i.e., 60-75 minutes per day) appear to mitigate the increased risk of mortality associated with prolonged adult sedentary time (i.e., >8 hours per day) [2]. However, this high activity level can only attenuate but not eliminate the increased risk associated with prolonged SSB (i.e., 5 hours or more per day).

As screens have become ubiquitous, the number of scientific publications related to sedentary behavior and screen time has gradually increased in recent years. However, due to the rapid development of technology, screen time is no longer limited to passive activities like watching TV or playing video games; it now involves more interactive screen usage, such as socializing, working, and learning. Studies have found that college students spend an average of over 12 hours each day, with screen-related sedentary behaviors accounting for over 50% of this time [3]. In China, 37% of children and adolescents exceed recommended screen time standards [4]. SSB has become a significant risk factor for health.

Given the rapid proliferation of SSB and the increasing importance of screen technology in our lives. Thus, the aim of this overview was to: 1) to outline the health risks and potential impact mechanisms associated with SSB; 2) to summarize methods for interventions aimed at reducing SSB and the health benefits they yield; 3) to propose future research directions. This study aims to provide essential theoretical references for the understanding and development of the field of SSB research.

2. Screen-based sedentary behaviour and health outcomes

Over the past two decades, screens have played an increasingly prominent role in our lives. With the widespread use of screens, the number of scientific publications related to sedentary behavior and screen time has gradually increased (Figure 1). Passive behavior research has traditionally placed significant emphasis on television viewing time. However, the nature of such studies has undergone significant changes with the evolution of the times. Previously, television viewing was typically the primary screen medium for most people. Nowadays, we engage with highly engaging and sedentary-inducing media, including computers, smartphones, tablets, gaming consoles, and other screen entertainment systems. These media often encourage prolonged periods of sitting. We need to understand the risks associated with SSB and reevaluate the relationship between SSB and health.

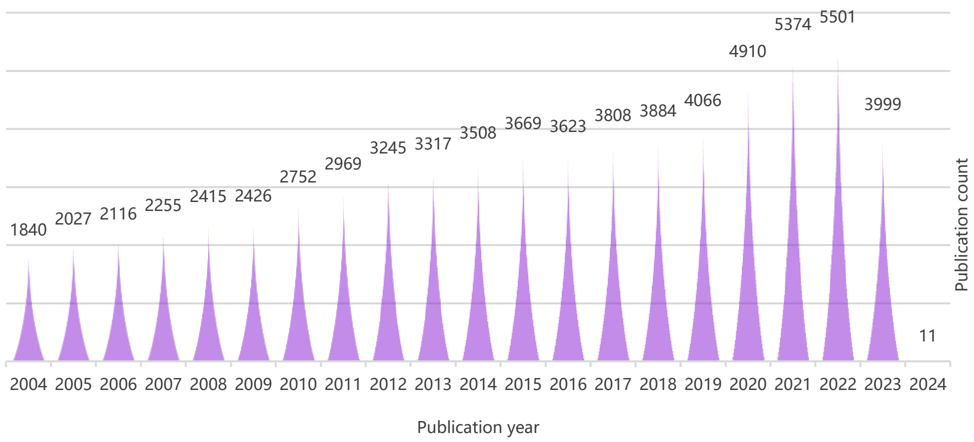

Figure 1. Sedentary behaviour and screen time related publications, 2003-2023. Source: PubMed. Search query: screen-based sedentary+computer + games + or + video + games + or + screen + time + or + television

2.1. Screen-based sedentary behaviour and obesity

Obesity is a widely prevalent chronic non-communicable disease globally and a significant risk factor for many metabolic and non-communicable diseases (e.g., cardiovascular diseases, diabetes, and certain forms of cancer) [5, 6]. With the widespread use of electronic devices such as televisions, computers, and smartphones, people have started spending more time in front of screens, prompting research into the relationship between SSB and health. Early studies may have focused on how sedentary behavior affects physical activity levels and body weight and how reducing sedentary behavior can prevent obesity. Over time, research has delved deeper into the more complex mechanisms and causal relationships between sedentary behavior and obesity. These studies encompass not just the element of time but also multiple aspects, including lifestyle, diet, metabolism, genetics, and more, to comprehensively understand the relationship between sedentary behavior and obesity.

Early research showed an association between adult television viewing and obesity, where women who watched television for four hours or more each day had more than twice the obesity rate compared to women who watched television for less than one hour daily [7]. Similarly, men who watched three or more hours of television daily had double the risk of obesity compared to others. Moreover, these associations persisted after controlling for other variables, suggesting that television viewing might lead to obesity [8]. However, these early studies did not establish causality. Subsequently, Hu et al. [9] found a significant increase in the risk of obesity associated with sedentary behavior, particularly television viewing, in over 50,000 women in the Nurses' Health Study. Shibata et al. [10], their longitudinal investigation also observed a connection between the increase in waist circumference in Australian adults aged 25 and older and the frequency of television viewing over 12 years.

In current research, there is also the perspective that factors related to messages transmitted through screens (e.g., advertisements for unhealthy food) and unhealthy behaviors induced while in front of screens should be considered [11, 12]. Screen-based sedentary behavior may be combined with unconscious eating (a distraction-based activity) in front of screen devices, leading to overconsumption of food and, thus, an increased risk of obesity. This perspective suggests that the obesity-related factors might not be the act of sitting in front of a screen itself but rather the lifestyle and dietary habits linked to a range of unhealthy behaviors related to screen viewing (e.g., snacking, consuming high-calorie foods, irregular eating patterns, and lower intake of fruits or vegetables). In Saunders et al.'s study [13], it was also concluded that, in comparison to total sedentary time, SSB is more strongly associated with cardiovascular and metabolic diseases (CMD). It is not SSB that increases the risk of obesity, but rather the interaction of additional behaviors within SSB that leads to an increased risk of obesity, thereby increasing CMD risk.

However, Biddle et al. stated in their 2017 study that while there is some evidence of an association between sedentary behavior (screen time) and obesity in adults, this relationship is complex and largely inconclusive [14]. Existing evidence does not establish a direct link between sedentary behavior and adult obesity. Nevertheless, research has shown a "cumulative effect" or "lifecycle effect" where sedentary behavior during childhood and adolescence increases the risk of obesity in adulthood, and screen time (primarily leisure screen time) and sedentary behavior before maturity consistently correlate with an increased risk of obesity in adulthood. In a recent study by Chantal et al. [15], it was also found that leisure screen time was positively correlated with BMI, waist circumference, triglycerides, fat mass, and lipid accumulation products, as previously suggested by Biddle et al. The relationship between sedentary behavior and obesity markers is complex. Still, based on available evidence, there appears to be a stronger and more consistent association between screen time and obesity than with other types of sedentary behavior when predicting obesity.

2.2. Screen-based sedentary behaviour and type 2 diabetes

Type 2 diabetes is a chronic disease characterized by the pathological process of relative insulin insufficiency or insulin resistance, leading to impaired glucose utilization. There is an absolute insulin deficiency in its later stages, resulting in sustained elevated blood sugar levels. Numerous studies in recent years have suggested that it may be influenced by sedentary behavior [16-19]. While type 2 diabetes typically manifests symptoms in adulthood, it is a progressive condition often accompanied

DOI: 10.54254/2753-8818/29/20240801

by years or even decades of insulin resistance [20]. Therefore, the impact of this disease might begin during adolescence.

Excess body fat may be one of the reasons why sedentary behavior or other sedentary behaviors are associated with diabetes risk. However, from an epidemiological perspective, we must consider independent mechanisms beyond body mass index and weight. Skeletal muscle insulin resistance is a critical factor in the development of type 2 diabetes, and prolonged sedentary behavior suggests reduced muscle tissue contraction activity over time, resulting in decreased skeletal muscle engagement. Modern society's screen-based sedentary behavior is clearly one of the more common reasons people remain seated and inactive (non-contracting) for extended periods. A study employing objective measurements has revealed a negative relationship between sedentary time and insulin sensitivity [21]. Significantly, groups with the most and least sedentary time showed around a 40% difference in insulin-stimulated glucose uptake range when there was a 4-hour difference between them, independently of MVPA. Furthermore, as mentioned in the context of the relationship between sedentary behavior and obesity, SSB can be combined with unconscious eating in front of screens, potentially leading to unhealthy postprandial responses (i.e., elevated insulin postprandial responses) [22]. Thus, Balkau et al. proposed the hypothesis that type 2 diabetes may be caused by continuous acute inactivity, perpetually inducing exaggerated high postprandial insulin responses and tissue lipid disturbances due to inadequate muscle contractions.

Early research indicated that the risk of developing type 2 diabetes and cardiovascular diseases increased linearly with prolonged television viewing time [19]. For every additional 2 hours of daily television viewing, there was a 20% increase in the risk of type 2 diabetes. More recent analyses of data from the 1970 British Birth Cohort Study by Scandiffio et al. found that individuals who exceeded four hours of leisure screen time each day at 16 had an increased risk of type 2 diabetes [23]. Conversely, computer and non-screen sedentary behavior were unrelated to the risk of type 2 diabetes. However, as lifestyle and habits evolve with the changing times, television viewing is no longer the sole screen medium for individuals. Computers, smartphones, tablets, gaming consoles, and other highly engaging screen entertainment systems have become more prevalent, encouraging extended sedentary periods in front of screens. Hence, we must pay more attention to the relationship between SSB and type 2 diabetes.

2.3. *Screen-based sedentary behaviour and mental health*

The impact of screen-based sedentary behavior on mental health has been a focus of research in recent years. Most studies have indicated that high-frequency SSB is associated with lower mental health indicators. In a study involving adolescent girls, higher screen time was found to be related to depression and poor social support [24]. Additionally, research on Chinese adolescents showed that those with low moderate-to-vigorous physical activity (MVPA) and high SSB had significantly higher levels of depression, anxiety, and self-harming behaviors. High screen-based sedentary behavior was associated with a lower risk of depression in young women, with a more significant negative impact on boys [25].

Researchers have attempted to analyze the underlying mechanisms and have proposed three explanatory hypotheses for the impact of SSB on mental health: the Displacement Hypothesis, the Upward Social Comparison Hypothesis, and the Reinforcing Spirals Hypothesis.

The Displacement Hypothesis suggests that increased screen time may displace other activities beneficial for mental health [26]. This includes reducing the time spent on exercise, social interactions, or other positive activities. This displacement effect could lead to worsened mental health as these beneficial activities are replaced by screen time. The Upward Social Comparison Hypothesis posits that increased screen time may lead people to compare themselves to others on social media [27]. Such social comparisons often show individuals to compare themselves with those who appear more successful and happier, affecting their self-esteem and potentially resulting in depression or other mental health issues. The Reinforcing Spirals Hypothesis suggests that there may be a bidirectional relationship between screen time and depression [28]. This means that increased screen time may lead to an increase in depressive symptoms and vice versa. This mutual reinforcement could lead to a cyclical interaction between depressive symptoms and screen time, reinforcing each other.

However, based on existing research, the relationship between the content or type of screen-based sedentary time and mental health indicators differs. One study by Huang Tao and others found that total sedentary time was unrelated to anxiety symptoms, while screen-based sedentary time was associated with anxiety symptoms [29]. Moreover, the association between SSB and anxiety symptoms varied depending on the type of screen time. Longer durations of watching television and movies and using social media were associated with higher levels of anxiety. Boers et al. found negative associations between social media and TV and self-esteem over time but no association between video game use and depression [30]. This result does not support the Displacement Hypothesis, which suggests that all screen time negatively affects mental health. This may be because modern video game players are not socially isolated and have social and emotional benefits. Research also found associations between social media use and adolescent depression. According to the Upward Social Comparison Hypothesis, repeated exposure to idealized images may reduce adolescents' self-esteem, trigger depression, and exacerbate depression over time.

Furthermore, screen use is not entirely without benefits. In a study by Slater et al. [31], playing electronic games was not found to harm the mental health of adolescents, as it has social and emotional benefits. Researchers also found that among children and adolescents, using the internet for communication in individuals who perceived their friendship quality to be lower was associated with reduced depression and fewer internalizing problems [32]. However, using the internet for non-communication purposes (e.g., browsing) was associated with harmful effects on depression and social anxiety. Early research also found a U-shaped relationship between internet use and adolescent mental health [33], where both low and high internet use increased the risk of depression, while moderate internet use appeared to be beneficial.

In conclusion, SSB has both positive and negative effects on mental health. However, we must balance these potential benefits against the known harmful effects of excessive SSB. Current evidence suggests that the detrimental effects of outrageous SSB outweigh the potential benefits. Nonetheless, determining whether the benefits of SSB can balance or offset its negative impacts will undoubtedly be a focus of future research.

2.4. Screen-based sedentary behaviour and sleep

Sleep, a crucial component of life, is paramount in an individual's health and physiological and psychological functions. In today's digital age, people commonly face prolonged screen exposure, primarily involving television, computers, smartphones, and other digital devices. This screen-based sedentary behavior has become a prominent feature of their daily lives, whether used for learning, socializing, or entertainment.

Over the past three decades, the two-process model of sleep regulation has become a primary conceptual framework in sleep research. The two-process model hypothesizes that the interaction between the homeostatic process of sleep and wakefulness (Process S) and the circadian pacemaker-controlled process (Process C) determines significant aspects of sleep regulation. Process S represents sleep debt, increasing during wakefulness and decreasing during sleep, with its values oscillating within the range dictated by the circadian pacemaker's control over the circadian cycle. When S approaches the lower limit of the content, it triggers wakefulness, and when it comes to the upper limit, it starts sleep [34]. Both processes have significant functional implications, such as exposure to bright light in the morning, which promotes circadian oscillations and aids in awakening without affecting NREM sleep slow-wave activity (SWA) [35]. The nighttime sleep preparation is initiated by circadian signals from the nocturnal melatonin release, leading to peripheral vasodilation, thus enhancing the likelihood of falling asleep [36]. For us, the imposed desynchrony protocol is a forced sleep-wake cycle beyond the control of the circadian pacemaker, causing sleep to occur in different circadian phases, which is one of the primary reasons affecting our sleep quality in modern society. Previous research has indicated that high-frequency nighttime screen time can reduce melatonin secretion [37]. This could affect the initiation of circadian signals, resulting in delayed sleep times.

In a study by Chinese scholars Shen Chou and others, found that after lights out at night, continued use of mobile phones for more than 60 minutes was associated with higher PSQI values than those who used it for less than 10 minutes. Moreover, the sleep disorder rate exceeded 30% for those who used their phones for more than 60 minutes, and as the daily phone usage time increased, sleep quality worsened. In the group of students who used their phones for more than 60 minutes after lights out every day, the sleep disorder rate was 30.2% [38]. Additionally, Demirci and colleagues found that excessive smartphone use directly affected low sleep quality and could also have a direct impact on negative emotions such as depression and anxiety, indirectly leading to sleep problems [39]. Kakinami and his team also discovered that every additional hour of television or computer use in SSB increased the likelihood of reporting poor sleep quality by 17% and 13%, respectively [40].

Based on this, it is evident that a significant distinction between screen-based sedentary behavior and non-screen sedentary behavior lies in the increased likelihood of sleep disturbances due to screen exposure.

3. Interventions to reduce screen-based sedentary behaviors

3.1. Screen-Based Guidelines for Sedentary Behavior

The WHO Physical Activity and Sedentary Behaviour Guidelines for 2020 set limits on screen time for children and adolescents, and there is relative agreement around the world. In 2012, Canada published guidelines on sedentary behaviour in early childhood (0-4 years) [41], which set a limit on screen time in early childhood of less than 1 h/day for preschoolers and no screen time for children under 2 years of age. In June 2016, Canada published the world's first 24-hour activity guidelines for children and adolescents [42], which suggest that recreational screen time should be limited to less than 2 h/d. Children under 2 years of age should ideally avoid screen time. In 2018, the Australian Government built on this by updating the Australian Physical Activity and Sedentary Behaviour Guidelines for Children and Young People, and in April 2019, released the Australian 24-hour movement guidelines for children (5-12 years) and young people (13-17 years): An integration of physical activity, sedentary behaviour, and sleep [43].The screen time limits for young children and adolescents were aligned with the guidelines released in Canada, i.e. children and adolescents aged 5-17 years should spend no more than 2 hours per day on recreational screen time (this excludes screen time required for schoolwork) and should avoid screens for 1 hour before bedtime. The 2017 Chinese Youth Activity Guidelines [44] noted that there are significant cultural and regional differences in sedentary behaviour between children and adolescents in China and abroad, and that the average weekly out-of-school homework time for children and adolescents in China is 5 hours higher than in OCED countries. As daily homework time is higher than screen time, the guidelines not only recommend that children and adolescents limit their daily screen time to less than 2 hours, but also that they avoid prolonged sedentary behaviour due to schoolwork.2022 In January, China issued the Physical Activity Guidelines for the Chinese Population (2021) [45], the first physical activity guideline in China to cover the entire life cycle of people of all ages, including patients with chronic diseases. The guidelines further define screen time for children and adolescents of all ages (no screen time is recommended for children under two years of age; cumulative screen time should be less than 1 hour per day for 3-5 years old; and cumulative screen time should be less than 2 hours per day for 6-17 years old). The difference between the WHO, Australian and Canadian screen time limits is that China's recommended screen time limits for children and adolescents do not specify a particular type of screen time (e.g. recreational screen time).

3.2. Interventions to reduce SSB and Health Benefits

As researchers become aware of the hazards of SSB, they have started to seek methods to reduce SSB and research the health benefits of SSB reduction. Current research indicates optimistic outcomes for

DOI: 10.54254/2753-8818/29/20240801

interventions aimed at lowering SSB, especially in the context of early interventions for overweight children. Epstein and colleagues conducted a two-year intervention experiment; children (ages 4-7) with a BMI more significant than the 75th percentile were subjected to SSB restrictions. The intervention group experienced a reduction of over 300 kcal in energy intake and a decrease of 0.24 units in BMI, with no significant change in physical activity [46]. This suggests that the primary change resulting from SSB control in children is related to energy intake rather than changes in physical activity. Earlier research also found that restricting adolescents' diet of television viewing led to a decrease in energy intake by -463.0 kcal/day and a reduction in fat intake by -295.2 kcal/day [47]. This further confirms the previous statement that the increased risk of obesity associated with SSB is related to unconscious eating in front of screens. Controlling SSB can significantly reduce this phenomenon, effectively preventing early childhood and adolescent obesity. Although this change may have minimal clinical significance at the individual level, it may have a more substantial impact at the population level [48].

If interventions to reduce SSB aim to bring more health benefits, it is evident that merely focusing on obesity is insufficient. In a study by Caldwell and others [49], they implemented interventions involving exercise "snacks" (ES) lasting 20 seconds per hour of sitting. This intervention not only improved femoral artery blood flow and shear patterns but also had no impact on peripheral or cerebrovascular function. In contrast to other methods, this approach involves brief, vigorous, fragmented exercise during prolonged sitting, and previous research has indicated that it significantly enhances vascular health. A recent systematic review and meta-analysis found that light activities (i.e., walking) during screen time are more effective in attenuating blood glucose measurements than continuous exercise [50] Therefore, simply standing up and being more active can alleviate many adverse health consequences associated with high levels of sedentary behavior.

Although the health benefits of interventions to reduce SSB are promising, maintaining their long-term effects has been a persistent challenge for researchers. In a study by Otten and colleagues [51], they used an electronic lockout system to restrict people's screen time. In the experiment, the intervention group experienced reduced energy intake and body mass index, with a significant decrease in SSB. But in reality, people do not keep their screen devices locked. Additionally, screen usage guidelines for adults still need to be clarified, and determining a benchmark for daily SSB is challenging. Dillon and others reduced college students' sedentary behavior through a combination of the Health Action Process Approach and mobile health interventions [52]. This intervention effectively reduces college students' sedentary behavior, can be implemented on a larger scale at a lower cost, and can bridge the gap between intention and action by incorporating post-intentional factors to translate meaning into behavior. It is a more reasonable approach than other methods, with the potential for longer-term maintenance.

4. Future research directions

To date, guidance on screen-based sedentary behaviour in adults and older adults (18-64 years) is unclear. Some international guidelines, such as those from the World Health Organization, Canada, and Australia, have incorporated recommendations for reducing sedentary behavior and screen time into their physical activity guidelines, encouraging people to break up sitting time or reduce cumulative screen time. Therefore, before age-specific guidelines are developed, adults may consider following screen time recommendations applicable to children and adolescents to better manage their screen time in daily life [53]. This field of research may be a potential avenue for future studies to better meet the health needs of different age groups.

It is worth noting that there is a certain contradiction between screen use guidelines and digital technology use. Educational and industry authorities encourage children to use digital technology to prepare them for the digital world. In contrast, health authorities discourage children from using digital technology due to concerns about its potential negative impact on their well-being [54]. Health guidelines emphasize reducing screen time, while educational policies focus on the nature of screen use. This discrepancy arises because health guidelines primarily consider the impact of screen time on physical health while overlooking cognitive and social aspects. How to determine whether the benefits of screen time can balance or outweigh its adverse effects will undoubtedly be a subject of future research.

In summary, SSB is a rapidly growing area of research, and there are many research opportunities for the future: 1) age-appropriate management of SSB to better meet the health needs of people of different ages; 2) assessing the physiological, psychological and socio-cognitive effects of SSB and balancing the risks and benefits of SSB; 3) designing more effective interventions (e.g., using the HAPA model in combination with ES to turn intention into action, while also having a personalized exercise program); 4) exploring how to improve sleep in the digital age; 5) further analyzing the dose-response relationship between SSB and health outcomes; and 6) further analyzing the differences between different SSB contents and types in different age groups.

5. Conclusion

When we summarize the existing research results, we find a strong association between the high frequency of SSB and health risks, and we must recognize the adverse health effects of this risk factor. Despite the positive results of interventions to reduce SSB, we have to acknowledge that SSB has become a regular part of our daily lives. Researchers need to adapt to the rapid development of technology, not only to emphasize the reduction of SSB but also to adapt to the times to maximize the health benefits and to try to balance the potential benefits and negative impacts of screen-based sedentary behavior.

References

[1] World Health Organization. “WHO guidelines on physical activity and sedentary behaviour.” (2020).

[2] Ekelund, Ulf, et al. “Does physical activity attenuate, or even eliminate, the detrimental association of sitting time with mortality? A harmonised meta-analysis of data from more than 1 million men and women.” *The lancet* 388.10051 (2016): 1302-1310.

[3] Carpenter, Chelsea, et al. “An exploration of domain-specific sedentary behaviors in college students by lifestyle factors and sociodemographics.” *International journal of environmental research and public health* 18.18 (2021): 9930.

[4] Chen, Jyu-Lin, et al. “Short-term efficacy of an innovative mobile phone technology-based intervention for weight management for overweight and obese adolescents: pilot study.” *Interactive journal of medical research* 6.2 (2017): e7860.

[5] Lüscher, Thomas F. “Nutrition, obesity, diabetes, and cardiovascular outcomes: a deadly association.” *European Heart Journal* 41.28 (2020): 2603-2607.

[6] Cho, Yoon Jeong, et al. “The Gangwon Obesity and Metabolic Syndrome Study: methods and initial baseline data.” *Journal of Obesity & Metabolic Syndrome* 31.4 (2022): 303.

[7] Tucker, Larry A., and Marilyn Bagwell. “Television viewing and obesity in adult females.” *American Journal of Public Health* 81.7 (1991): 908-911.

[8] Tucker, Larry A., and Glenn M. Friedman. “Television viewing and obesity in adult males.” *American Journal of Public Health* 79.4 (1989): 516-518.

[9] Hu, Frank B., et al. “Television watching and other sedentary behaviors in relation to risk of obesity and type 2 diabetes mellitus in women.” *Jama* 289.14 (2003): 1785-1791.

[10] Shibata, A. I., et al. “Physical activity, television viewing time, and 12-year changes in waist circumference.” *Medicine and Science in Sports and Exercise* 48.4 (2016): 633.

[11] Chaput, J-P., et al. “Modern sedentary activities promote overconsumption of food in our current obesogenic environment.” *Obesity reviews* 12.5 (2011): e12-e20.

[12] Pearson, Natalie, and Stuart JH Biddle. “Sedentary behavior and dietary intake in children, adolescents, and adults: a systematic review.” *American journal of preventive medicine* 41.2 (2011): 178-188.

[13] Saunders, Travis J., Jean-Philippe Chaput, and Mark S. Tremblay. "Sedentary behaviour as an emerging risk factor for cardiometabolic diseases in children and youth." *Canadian journal of diabetes* 38.1 (2014): 53-61.
[14] Biddle, Stuart JH, et al. "Screen time, other sedentary behaviours, and obesity risk in adults: a review of reviews." *Current obesity reports* 6 (2017): 134-147.
[15] Vella, Chantal A., Katrina Taylor, and Megan C. Nelson. "Associations of leisure screen time with cardiometabolic biomarkers in college-aged adults." *Journal of behavioral medicine* 43.6 (2020): 1014-1025.
[16] Rezende, Leandro Fornias Machado de, et al. "Sedentary behavior and health outcomes: an overview of systematic reviews." *PloS one* 9.8 (2014): e105620.
[17] Van Uffelen, Jannique GZ, et al. "Occupational sitting and health risks: a systematic review." *American journal of preventive medicine* 39.4 (2010): 379-388.
[18] Wilmot, Emma G., et al. "Sedentary time in adults and the association with diabetes, cardiovascular disease and death: systematic review and meta-analysis." *Diabetologia* 55.11 (2012): 2895-2905.
[19] Grøntved, Anders, and Frank B. Hu. "Television viewing and risk of type 2 diabetes, cardiovascular disease, and all-cause mortality: a meta-analysis." *Jama* 305.23 (2011): 2448-2455.
[20] Fonseca, Vivian A. "Defining and characterizing the progression of type 2 diabetes." *Diabetes care* 32.Suppl 2 (2009): S151.
[21] Balkau, Beverley, et al. "Physical activity and insulin sensitivity: the RISC study." *Diabetes* 57.10 (2008): 2613-2618.
[22] Hamilton, Marc T., Deborah G. Hamilton, and Theodore W. Zderic. "Sedentary behavior as a mediator of type 2 diabetes." *Diabetes and Physical Activity* 60 (2014): 11-26.
[23] Scandiffio, Jillian A., and Ian Janssen. "Do adolescent sedentary behavior levels predict type 2 diabetes risk in adulthood?." *BMC Public Health* 21.1 (2021): 969.
[24] Costigan, Sarah A., et al. "The health indicators associated with screen-based sedentary behavior among adolescent girls: a systematic review." *Journal of Adolescent Health* 52.4 (2013): 382-392.
[25] Liu, Mingli, et al. "Combined patterns of physical activity and screen-related sed-entary behavior among Chinese adolescents and their correlations with depression, anxiety and self-injurious behaviors." *Psychology research and behavior management* (2019): 1041-1050.
[26] Mutz, Diana C., Donald F. Roberts, and DP van Vuuren. "Reconsidering the dis-placement hypothesis: Television's influence on children's time use." *Communication Research* 20.1 (1993): 51-75.
[27] Schmuck, Desirée, et al. ""Looking Up and Feeling Down". The influence of mobile social networking site use on upward social comparison, self-esteem, and well-being of adult smartphone users." *Telematics and informatics* 42 (2019): 101240.
[28] Teh, Jhia Jiat, Wenyi Cai, and Nicole Ellen James. "Association of Media Screen Time Use With Depression in Adolescents." *JAMA pediatrics* 174.2 (2020): 209-210.
[29] Huang, Tao, et al. "Screen-based sedentary behaviors but not total sedentary time are associated with anxiety among college students." *Frontiers in Public Health* 10 (2022): 994612.
[30] Boers, Elroy, et al. "Association of screen time and depression in adolescence." *JAMA pediatrics* 173.9 (2019): 853-859.
[31] Slater, Michael D. "Reinforcing spirals: The mutual influence of media selectivity and media effects and their impact on individual behavior and social identity." *Communication theory* 17.3 (2007): 281-303.
[32] Selfhout, Maarten HW, et al. "Different types of Internet use, depression, and social anxiety: The role of perceived friendship quality." *Journal of adolescence* 32.4 (2009): 819-833.

[33] Bélanger, Richard E., et al. “A U-shaped association between intensity of Internet use and adolescent health.” *Pediatrics* 127.2 (2011): e330-e335.
[34] Borbély, Alexander A., et al. “The two-process model of sleep regulation: a reappraisal.” *Journal of sleep research* 25.2 (2016): 131-143.
[35] Dijk, Derk Jan, and Domien GM Beersma. “Effects of SWS deprivation on subsequent EEG power density and spontaneous sleep duration.” *Electroencephalography and clinical neurophysiology* 72.4 (1989): 312-320.
[36] Kräuchi, Kurt, and Anna Wirz-Justice. “Circadian clues to sleep onset mechanisms.” *Neuropsychopharmacology* 25.1 (2001): S92-S96.
[37] Wood, Brittany, et al. “Light level and duration of exposure determine the impact of self-luminous tablets on melatonin suppression.” *Applied ergonomics* 44.2 (2013): 237-240.
[38] Shen Chou, et al. “The impact of mobile phone use on sleep quality among college students in a university in Jiangsu.” *Chinese School Health* 36.5 (2015): 708-710.
[39] Demirci, Kadir, Mehmet Akgönül, and Abdullah Akpinar. “Relationship of smartphone use severity with sleep quality, depression, and anxiety in university students.” *Journal of behavioral addictions* 4.2 (2015): 85-92.
[40] Kakinami, Lisa, et al. “Associations between physical activity and sedentary behavior with sleep quality and quantity in young adults.” Sleep Health 3.1 (2017): 56-61.
[41] Tremblay, Mark S., et al. “Canadian sedentary behaviour guidelines for the early years (aged 0–4 years).” *Applied Physiology, Nutrition, and Metabolism* 37.2 (2012): 370-380.
[42] Tremblay M S, Carson V, Chaput J P, et al. Canadian 24-hour movement guidelines for children and youth: an integration of physical activity, sedentary behaviour, and sleep [J]. *Applied physiology, nutrition, and metabolism*, 2016, 41(6): S311-S327.
[43] Okely A D, Ghersi D, Loughran S P, et al. A collaborative approach to adopting/adapting guidelines. The Australian 24-hour movement guidelines for children (5-12 years) and young people (13-17 years): An integration of physical activity, sedentary behaviour, and sleep [J]. *International Journal of Behavioral Nutrition and Physical Activity*, 2022, 19(1): 1-21.
[44] Zhang Yunting, et al. “Physical Activity Guidelines for Chinese Children and Adolescents.” *Chinese Journal of Evidence-Based Pediatrics* 12.6 (2017): 401.
[45] Zhao Wenhua, et al. “Physical Activity Guidelines for the Chinese Population (2021).” *Chinese Public Health* 38.2 (2022): 129-130.
[46] Epstein, Leonard H., et al. “A randomized trial of the effects of reducing television viewing and computer use on body mass index in young children.” *Archives of pediatrics & adolescent medicine* 162.3 (2008): 239-245.
[47] Epstein, Leonard H., et al. “Influence of changes in sedentary behavior on energy and macronutrient intake in youth.” *The American journal of clinical nutrition* 81.2 (2005): 361-366.
[48] Azevedo, Liane B., et al. “The effectiveness of sedentary behaviour interventions for reducing body mass index in children and adolescents: systematic review and meta-analysis.” *Obesity reviews* 17.7 (2016): 623-635.
[49] Caldwell, Hannah G., et al. “Hourly staircase sprinting exercise “snacks” improve femoral artery shear patterns but not flow-mediated dilation or cerebrovascular regulation: a pilot study.” *Applied Physiology, Nutrition, and Metabolism* 46.5 (2021): 521-529.
[50] Loh, Roland, et al. “Effects of interrupting prolonged sitting with physical activity breaks on blood glucose, insulin and triacylglycerol measures: a systematic review and meta-analysis.” Sports medicine 50 (2020): 295-330.
[51] Otten, Jennifer J., et al. “Effects of television viewing reduction on energy intake and expenditure in overweight and obese adults: a randomized controlled trial.” *Archives of Internal Medicine* 169.22 (2009): 2109-2115.

DOI: 10.54254/2753-8818/29/20240801

[52] Dillon, Kirsten, Scott Rollo, and Harry Prapavessis. "A combined health action process approach and mHealth intervention to reduce sedentary behaviour in university students–a randomized controlled trial." *Psychology & health* 37.6 (2022): 692-711.
[53] LeBlanc A G, Gunnell K E, Prince S A, et al. The ubiquity of the screen: an overview of the risks and benefits of screen time in our modern world [J]. *Translational Journal of the American College of Sports Medicine*, 2017, 2(17): 104-113.
[54] Straker L, Zabatiero J, Danby S, et al. Conflicting guidelines on young children's screen time and use of digital technology create policy and practice dilemmas [J]. *The Journal of pediatrics*, 2018, 202: 300-303.