Characterising sedentary and screen-based behaviour in adults

Danielle Lauren Harvey

Doctor of Philosophy

University of East Anglia

School of Health Sciences

August 2023

Abstract

The evolution of technology has increased the breadth of sedentary and screen-based behaviours available, with many adults now spending a large amount of time engaging in sedentary activities. However, the trends, correlates, and measures of these different types of behaviours are poorly understood. This thesis presents four interlinked studies that aim to advance the understanding of contemporary patterns in sedentary and screen-based behaviours in adults to inform population surveillance, measurement and the design of behaviour change interventions. Study 1 explores temporal trends in screen-based behaviours internationally using data from a global market research company. In Study 2 data from the United Kingdom Time Use Survey are used to describe the diurnal patterns of different types of sedentary and screen-based behaviours and their associated secondary activities. Study 3 examines the association of country-level factors with self-reported sitting time using four waves of data from the European Commission Eurobarometer Survey. This chapter also explores whether these associations vary over time and by individual factors. Finally, the review conducted in Study 4 describes the characteristics of questionnaires used for national surveillance of sedentary behaviour and identifies the types of behaviours being measured. This thesis has provided insight into sedentary and screen-based behaviours in relation to trends, patterns, correlates, and measures whilst acknowledging the challenges facing researchers in the future. Findings demonstrate the evolution of screen-based behaviours over time, highlighting the increasingly prevalent use of mobile phones and online TV viewing. Sedentary and screen-based behaviours peak in the evenings and occur alongside other behaviours, suggesting that interventions should be time and behaviour specific. Additionally, the cross-level interactions observed between country and individual level factors highlight the potential benefit of employing multi-level interventions. Despite the increasing engagement particularly with screen-based behaviours, these are not typically measured within national surveillance systems.

Contents

Tables

Figures

Acknowledgements

Firstly, I would like to thank my supervisors Dr Andrew Atkin, Dr Karen Milton and Professor Andy Jones for their guidance and patience over the last four years. Your knowledge and feedback has challenged and developed me as a researcher.

I would also like to thank Dr Victoria Warburton, whose support and mentorship has been critical throughout my degrees. Thank you for your wise words and belief in me.

Thank you to Elli and Shelby, our chats about work and life have been much appreciated and reminded me I was not alone in this journey.

Thanks to my friends who have always been there when I needed them. You provided laughter and support when I needed it the most.

Finally, I would like to thank my Mum and Dad for their encouragement, belief, and unconditional support and to Caitlin, your honesty and sense of humour never failed to brighten my day.

Publications and statement of authorship

Publications arising from this thesis:

Harvey, D.L., Milton, K., Jones, A.P. and Atkin, A.J. (2022) International trends in screen-based behaviours from 2012 to 2019, *Preventive Medicine,* 154, pp.1-9. https://doi.org/10.1016/j.ypmed.2021.106909

Harvey, D.L., Milton, K., Jones, A.P. and Atkin, A.J. (2023) A review of sedentary behaviour assessment in national surveillance systems, *Journal of Physical Activity and Health,* 20(4), pp.348-357. https://doi.org/10.1123/jpah.2022-0334

Statement of jointly authored publications

Chapter 1: Written by Danielle L Harvey. Reviewed by Andrew Atkin and Karen Milton.

Chapter 2: Written by Danielle L Harvey. Reviewed by Andrew Atkin and Karen Milton.

Chapter 3: Danielle L Harvey was the lead author of a temporal trends analysis published as: Harvey, D.L., Milton, K., Jones, A.P. and Atkin, A.J. (2022) International trends in screen-based behaviours from 2012 to 2019, *Preventive Medicine,* 154, pp.1-9. doi: https://doi.org/10.1016/j.ypmed.2021.106909

Danielle L Harvey, Karen Milton, Andy Jones, and Andrew Atkin designed the study. Danielle L Harvey conducted the analysis and drafted a manuscript which was critically reviewed by Karen Milton, Andy Jones, and Andrew Atkin.

Chapter 4: Danielle L Harvey, Karen Milton, Andy Jones, and Andrew Atkin designed the study. Danielle L Harvey conducted the analysis and drafted a manuscript which was critically reviewed by Karen Milton and Andrew Atkin.

Chapter 5: Danielle L Harvey, Karen Milton, Andy Jones, and Andrew Atkin designed the study. Danielle L Harvey conducted the analysis and drafted a manuscript which was critically reviewed by Karen Milton and Andrew Atkin.

Chapter 6: Danielle L Harvey was lead author of a review published as: Harvey, D.L., Milton, K., Jones, A.P. and Atkin, A.J. (2023) A review of sedentary behaviour assessment in national surveillance systems, *Journal of Physical Activity and Health,* 20(4), pp.348-357. https://doi.org/10.1123/jpah.2022-0334

Danielle L Harvey, Karen Milton, Andy Jones, and Andrew Atkin designed the study. Danielle L Harvey conducted the analysis and drafted a manuscript which was critically reviewed by Karen Milton, Andy Jones, and Andrew Atkin.

Chapter 7: Written by Danielle L Harvey. Reviewed by Andrew Atkin and Karen Milton.

Chapter 1: General introduction

1.1 Overview

This thesis is structured into seven chapters, of which this is the first. This chapter introduces the topic of sedentary behaviour and provides an overview of the research field, concluding with the thesis and individual chapter aims. Chapter 2 critically analyses the current evidence in relation to sedentary behaviour in the adult population, considering health outcomes, measurement, prevalence, and correlates and concludes with the contextualisation of the thesis aims within the wider literature. Chapters 3-6 detail the individual studies conducted as part of this thesis and Chapter 7 critically discusses the thesis findings and provides suggestions for future research.

1.2 Introduction

Sedentary behaviour is part of a group of movement behaviours that take place during the course of the day, which also includes physical activity and sleep (Tremblay *et al.*, 2017). Early studies in the field often used the terms “sedentary” and “inactive” interchangeably but subsequent research has differentiated these terms (Tremblay, 2012). Sedentary behaviours are typically performed awake whilst lying or sitting, requiring low energy expenditure (Tremblay *et al.*, 2017) and can occur in various domains including leisure, work, and transport (Owen *et al.*, 2011). Physical inactivity, in comparison, is defined as not meeting the public health guidelines for physical activity (Tremblay *et al.*, 2017).

Public health research examining physical activity was first published in the 1950s, with studies assessing health outcomes, measurement, trends, correlates and policy growing exponentially in the subsequent 70 years (Varela *et al.*, 2018). In comparison, research assessing sedentary behaviour has only recently emerged within the last two decades (Stamatakis *et al.*, 2019). One early piece of research assessing the potential health effects associated with physical activity was by Morris *et al.* (1953). This study revealed that men in more physically active occupations (e.g., postmen and bus conductors), had a lower incidence of coronary heart disease than men in jobs where the predominant posture was sitting (e.g., office-based postal workers and bus drivers) (Morris *et al.*, 1953). Whilst this work was conceived to examine the associations of differing activity levels and health, it

may alternately be interpreted as indicating the possible health detriments of occupational sitting.

Subsequent research has assessed the potential impact of sedentary behaviour on various health outcomes, including all-cause and cardiovascular mortality and incidence of type 2 diabetes, amongst other things (Biswas *et al.*, 2015; Patterson *et al.*, 2018). Healthcare costs attributable to sedentary behaviour are substantial. One United Kingdom (UK) based study estimated that costs attributable to prolonged sedentary behaviour (≥6 hours per day) were £677 million across a one year period, which accounted for 1.2% of the total national health system expenditure in 2016/2017 (Heron *et al.*, 2019). The health effects of sedentary behaviour are discussed further in section 2.3.

Given the potentially harmful health outcomes associated with sedentary behaviour, it is necessary to monitor trends in behaviour to ascertain the likely burden on population health. Surveillance data show that in the UK, for example, just under one third of men and women are sedentary for an average of six hours or more on weekdays (Scholes, 2017). This figure increases to 40% for men and 35% for women on weekends (Scholes, 2017). Societal changes such as the shift from manual occupations to more sedentary based jobs and the increased use of technology for various tasks (Woessner *et al.*, 2021) have meant that sitting is now the main posture in many domains (Chastin *et al.*, 2018).

Leisure is one domain in which sedentary behaviour can occur with research suggesting that 90% of adults' leisure time is spent sedentary (Chau *et al.*, 2012; Loyen *et al.*, 2019). Early epidemiological research into sedentary behaviour primarily focussed on television (TV) viewing (Hu, 2003; Jakes *et al.*, 2003). The adverse health effects of TV viewing have been widely recognised, with one study reporting that higher levels of TV viewing time were associated with an increased risk of type 2 diabetes incidence and all-cause and cardiovascular disease mortality (Patterson *et al.*, 2018). Whilst there remains a strong focus on TV viewing as an important type of sedentary behaviour, there is increased interest in a broader range of sedentary behaviours such as computer use, reading, videogame use and transport related sedentary behaviour (Biddle *et al.*, 2017; Owen *et al.*, 2020).

Developments in technology have led to an increased presence of screens in everyday life, with devices including smartphones, tablets, and games consoles

now firmly embedded within society (Biddle *et al.*, 2017; LeBlanc *et al.*, 2017). It has been estimated that 53% of the time reported in leisure pursuits is spent on a screen (Chau *et al.*, 2012). These devices can promote individuals to engage in sedentary behaviour (Biddle *et al.*, 2017). The prevalence of sedentary and screen-based behaviours is discussed in more detail in section 2.6.

In addition to population surveillance of sedentary behaviour, it is necessary to understand how levels of sedentary behaviour vary within the population and what factors may facilitate or inhibit engagement. Various factors can influence someone to be sedentary, therefore it is important to identify these factors so they can be targeted within interventions (O'Donoghue *et al.*, 2016; Prince *et al.*, 2017a). The Ecological Model of Health Behaviours suggests that health behaviours, of which sedentary behaviour is one, are influenced by factors at multiple levels (Sallis, Owen and Fisher, 2008). Typically, studies have investigated socio-demographic factors associated with sedentary behaviour, such as age, sex, and occupation. In comparison, much less research has examined the potential influence of distal environmental factors such as gross domestic product (GDP) and population density (De Craemer *et al.*, 2018). The correlates of sedentary and screen-based behaviours are discussed further in section 2.7.

1.3 Thesis aims

This thesis sought to make a significant contribution to the field of sedentary behaviour research through four interlinked studies to address key gaps in the literature which are highlighted in Chapter 2. The primary aim is to advance understanding of contemporary patterns in sedentary and screen-based behaviours among adults to inform population surveillance, measurement and the design of behaviour change interventions. The study described in Chapter 3 explored the prevalence and secular trends in screen-based behaviours internationally, using data from a global market research company. The following study (Chapter 4) investigated the diurnal patterns and co-occurring activities of different types of sedentary and screen-based behaviours. Chapter 5 examined the association of country-level factors with self-reported sitting time and analysed whether these associations varied over time and by individual factors. In Chapter 6, the characteristics of questionnaires used to measure sedentary behaviour in national surveillance systems were reviewed. Finally, Chapter 7 summarises the main findings and critically analyses these in relation to the wider literature.

Chapter 2: Literature review

In the first part of this chapter, sedentary behaviour is positioned in the context of the Behavioural Epidemiology Framework. Key research and societal developments as they relate to sedentary behaviour are described in section 2.2, followed by an overview of the current state of the evidence on the health impacts of sedentary behaviour (2.3), measurement (2.4) public health guidelines for sedentary behaviour (2.5), prevalence (2.6), and correlates (2.7) The chapter concludes with an overarching rationale for the thesis and aims for each study conducted.

2.1 Behavioural Epidemiology Framework

This thesis and its contribution to the population health research landscape is best understood with reference to the Behavioural Epidemiology Framework (Sallis, Owen and Fotheringham, 2000). The framework provides a sequential structure for classifying phases of health behaviour research, with each element building on the previous phase. However, it is acknowledged that each phase can interlink as described below.

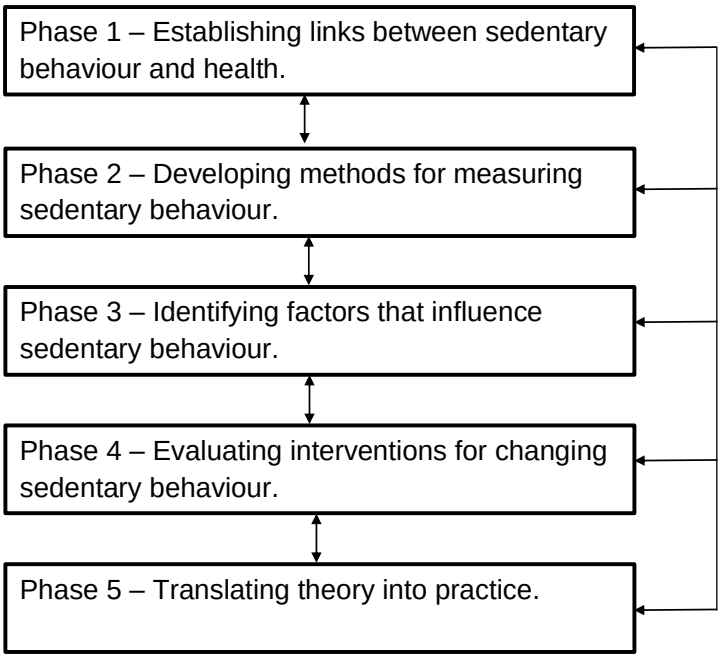


Figure 1. Behavioural Epidemiology Framework applied to sedentary behaviour.

Phase 1 is concerned with establishing evidence of the dose-response relationships between behaviours and health outcomes. Figure 1 highlights that the information from phase 1 can be used to directly influence policy in phase 5. For

example, evidence of the dose-response relationships between sedentary behaviour and health outcomes is used to inform public health guideline development.

Phase 2 of the framework focuses on developing methods for measuring the behaviour. This stage includes the testing of existing measures in relation to their psychometric properties and developing and testing new measures. The use of tools that have undergone psychometric testing, and thus are considered valid and reliable measures, can be used in studies aimed at evaluating interventions (phase 4) and those concerned with assessing the relationships between sedentary behaviour and health outcomes (phase 1).

Phase 3 is related to identifying factors that influence behaviour. The Ecological Model (which is described in detail in section 2.7.1) illustrates how correlates can occur at many different levels. In this stage, the demographic correlates such as sex, age, and socioeconomic status (known as non-modifiable correlates) are identified and described. This stage is essential in identifying specific groups who can be targeted within behaviour change interventions. Meanwhile, modifiable correlates such as individual motivation, social support and the built environment can be targets for intervention strategies to encourage behaviour change.

Phase 4 is focused on evaluating interventions to change behaviour. The information gained from the previous phases is used to develop interventions, which require systematic testing. Interventions found to be effective in this phase can be implemented more widely in phase 5.

Phase 5 is concerned with translating theory into practice. This stage highlights the importance of implementing effective interventions into wider society. This phase also uses the evidence and knowledge gained from the previous phases to inform public policy. The implementation of policies can lead to new research being conducted at any of the previous phases of the framework.

The research presented in this thesis most closely aligns to phases 2 and 3 of the Behavioural Epidemiology Framework, with a primary focus on the measurement and patterns of sedentary and screen-based behaviours (phase 2) and the individual and country-level correlates of sedentary behaviour and how they interact (phase 3).

2.2 The evolution of sedentary behaviour research

The following section briefly describes some of the key societal and scientific developments that have impacted the evolution of sedentary behaviour research. Although not an exhaustive overview, these points are signposted as particularly important context to the research presented in this thesis.

2.2.1 The emergence of sedentary behaviour research

It is generally accepted that the first peer-reviewed epidemiological study on the health benefits of physical activity was published by Morris *et al.* (1953). This study provided evidence that those in more active occupations, such as postmen and bus conductors, had a lower incidence of coronary heart disease than men in less active occupations, such as civil servants and bus drivers (Morris *et al.*, 1953). This study provided early evidence of the risk of cardiovascular events associated with different levels of sitting/physical activity at work; this landmark piece of research was to be the catalyst for many other studies assessing the associations between physical activity and health outcomes (Varela *et al.*, 2018). In the ensuing decades, large amounts of physical activity research would follow in the areas of measurement, trends, determinants, and policy (Varela *et al.*, 2018). However, it was not until the start of the 21st century that sedentary behaviour became a major focus in health research. Studies in the early 2000s provided early evidence of an adverse association between sedentary behaviour and health outcomes, particularly for markers of cardiometabolic health (Owen *et al.*, 2020).

2.2.2 The evolution of the sedentary behaviour definition

Historically, the term 'sedentary' was used to describe individuals who do not meet public health physical activity guidelines (Tremblay, 2012). However, research emerged to suggest that high levels of sitting and insufficient moderate to vigorous physical activity were separate and distinct risk factors for non-communicable diseases (Tremblay, 2012). Consequently, a group of researchers set out to differentiate the definitions of sedentary behaviour and inactivity which had previously been used interchangeably (Tremblay, 2012). It was proposed that 'sedentary behaviour' should be defined as *"any waking behaviour characterised by an energy expenditure ≤1.5 metabolic equivalents (METs) while in a sitting or reclining posture"* (Tremblay, 2012, p.540). In contrast, 'inactive' should be used to define "*those who are performing insufficient amounts of moderate to vigorous*

physical activity (i.e., not meeting specified physical activity guidelines)" (Tremblay, 2012, p.540). The authors argued that differentiating these terms would provide clarity for researchers when conducting their own research or searching for studies in these two areas (Tremblay, 2012).

In 2017, the Sedentary Behaviour Research Network recognised the need to further refine terminology related to sedentary behaviour (Tremblay *et al.*, 2017). A rigorous 10-part process was followed to derive the definitions for 11 terms, which included physical inactivity, stationary behaviour, and screen time (Tremblay *et al.*, 2017). The definition of sedentary behaviour remained largely unchanged, apart from the notable addition of the word 'lying'. Therefore, sedentary behaviour was defined as *"any waking behaviour characterised by an energy expenditure ≤1.5 METs, while in a sitting, reclining, or lying posture"* (Tremblay *et al.*, 2017, p.9).

2.2.3 Societal changes and technological developments

Historically, physical activity was required for many daily activities, including hunting and gathering food, which resulted in energy expenditure (Brown, Bauman and Owen, 2009). However, technologies have continually been developed to improve efficiency in daily tasks at work and home, which have led to a decrease in the need to be physically active (Woessner *et al.*, 2021). Many tasks that were previously undertaken by humans at work, such as lifting and carrying objects, or performing chores at home such as cooking and cleaning, have now been replaced by machines (Woessner *et al.*, 2021). In addition, the latter part of the 20th century saw the start of the "electronic and telecommunications revolution" (Woessner *et al.*, 2021). Marked by the emergence of TV in the 1950s, the personal computer (PC) in the 1980s, and the mobile phone in the 1990s, the breadth and availability of screen-based devices has expanded rapidly in the last 70 years (Woessner *et al.*, 2021). A TV was once the only screen for many (Biddle *et al.*, 2017), which may explain why early research into sedentary behaviour often used TV viewing as one way of measuring sedentary behaviour. However, it should be acknowledged that TV viewing is just one type of sedentary behaviour and it should not be seen as a marker of overall sedentary behaviour (Sugiyama *et al.*, 2008).

Screens are now ever-present in society and contribute to many leisure time sedentary activities, including TV viewing, computer use and video games (LeBlanc *et al.*, 2017). The number and variety of screen-based devices are likely to continue

to grow due to the rapidly evolving rate at which technology develops (LeBlanc *et al.*, 2017). This is likely to pose many challenges to those interested in surveillance, measurement, and prevalence of sedentary and screen-based behaviours. Some of these challenges are alluded to in sections 2.4 and 2.6.

2.3 Sedentary behaviour and health

This section begins with a discussion of evidence for an association between overall sedentary behaviour or sitting time and health outcomes, followed by evidence discussing the health outcomes associated with different types of sedentary behaviours (for example, TV viewing and mobile devices). For brevity, this section discusses review level evidence and concludes with a brief discussion of the limitations of existing knowledge.

2.3.1 Total sitting or sedentary time and health

Research assessing the associations between sedentary behaviour and health began to emerge in the early 2000s (Owen *et al.*, 2020). A systematic review of reviews by Rezende *et al.* (2014) examined the relationship between sedentary behaviour and health outcomes using reviews published between 2004 and 2013, thus summarising early research in this area. Consistent evidence was found for an adverse association between sitting time and all-cause and cardiovascular mortality, cardiovascular disease and metabolic syndrome (Rezende *et al.*, 2014). However, these findings were based mainly on cross-sectional studies using self-report methods and thus causality cannot be inferred. Despite the study design limitations, similar findings were observed in a review which included mainly prospective cohort studies, with all but one study using self-report methods of assessing sedentary behaviour (Biswas *et al.*, 2015). Associations were observed between greater sedentary time (assessed as either daily overall sedentary time, sitting time, TV or screen time or leisure time spent sitting), and an increased risk of all-cause, cardiovascular disease and cancer mortality, as well as incidence of cardiovascular disease and type 2 diabetes (Biswas *et al.*, 2015). Importantly these associations were independent of physical activity, thus demonstrating that irrespective of physical activity levels, increased sedentary time was associated with detrimental health outcomes.

The evidence on the associations between sedentary behaviour and all-cause mortality were reviewed by Biddle *et al.* (2016) to assess whether this relationship

is causal. Causal criteria were based on the Bradford Hill criteria (Hill, 2015), with specific focus on the strength of association, consistency, temporality and dose-response (Biddle *et al.*, 2016). No dose-response relationship was identified, however, based on the criteria of strength of association, consistency and temporality, it was concluded that a likely causal relationship between sedentary behaviour and all-cause mortality exists (Biddle *et al.*, 2016). These findings were extended by systematic review and meta-analytic evidence assessing the dose-response relationship between sedentary behaviour and health markers, adjusting for physical activity (Patterson *et al.*, 2018). It was concluded from prospective cohort studies using both self-report and device-based methods, that the risk of all-cause mortality was strongest when sitting for more than 8h/day, whereas cardiovascular disease mortality was strongest when people sit for more than 6h/day (Patterson *et al.*, 2018). Importantly, a second systematic review and meta-analysis that included prospective cohort studies using device-measured sedentary time, concluded that the risk for all-cause mortality increased when accelerometry measured sedentary time exceeded 7.5h/day (Ekelund *et al.*, 2019). This risk increased further when daily sedentary time exceeded 9.5 hours per day (Ekelund *et al.*, 2019). A considerable strength of this study is its harmonised approach which used standardised definitions of wear time, inclusion criteria, and exposure variables which reduced heterogeneity between studies (Ekelund *et al.*, 2019).

2.3.2 Specific sedentary behaviours and health

The following sub-section summarises review level evidence on the association of different types of sedentary behaviour with health. Recently two reviews were conducted to assess the evidence on sedentary behaviour and health to inform public health guidelines developed by the World Health Organization (WHO) and the Canadian Society for Exercise Physiology (Dempsey *et al.*, 2020; Saunders *et al.*, 2020; World Health Organization, 2020a; The Canadian Society for Exercise Physiology, 2021). An overview of systematic review evidence assessing a range of health outcomes demonstrated there may be beneficial relationships between internet and computer use and cognitive function within older adults, yet no systematic reviews were identified that assessed reading or contemporary behaviours such as smartphone use with health outcomes (Saunders *et al.*, 2020).

Despite the lack of research on contemporary sedentary behaviours, reviews have extensively assessed the associations between TV viewing and health. An

overview of systematic reviews concluded there was strong evidence for an association between TV viewing and screen time and all-cause mortality, fatal and non-fatal cardiovascular disease, type 2 diabetes, and metabolic syndrome (Rezende *et al.*, 2014). Meanwhile, a systematic review and dose-response meta-analysis including data from over one million participants revealed that engaging in more than 3-4 hours per day of TV viewing was associated with an increased risk of all-cause and cardiovascular disease mortality, independent of physical activity (Patterson *et al.*, 2018). Importantly, it was identified that the associations between TV viewing and health outcomes tended to be stronger than for total sitting time (Patterson *et al.*, 2018). One plausible reason is that TV viewing is easier to recall than sitting time due to it being a regularly repeated activity, and thus it may be less influenced by measurement error (Biddle *et al.*, 2016). Nevertheless, this behaviour can be confounded by both socioeconomic status and simultaneous unhealthy eating which may contribute towards the detrimental associations with health (Biddle *et al.*, 2016).

2.3.3 Limitations of the evidence on sedentary behaviour and health

One of the primary limitations of the evidence linking sedentary behaviour with health markers is that the majority of the available evidence is derived from cross-sectional, observational studies (Rezende *et al.*, 2014; Biswas *et al.*, 2015; Saunders *et al.*, 2020). Consequently, cause and effect relationships cannot be established. More evidence assessing the causal relationships between sedentary behaviour and a greater range of health outcomes is needed as currently this evidence is largely based on mortality or cardiometabolic health markers (Dempsey *et al.*, 2020). Specifically, further research is required to assess the links between sedentary behaviour and psychological, neurological and musculoskeletal outcomes as well as specific conditions such as asthma, osteoarthritis and human immunodeficiency virus (Memon *et al.*, 2021). Prospective cohort study designs may provide a better understanding of the associations between sedentary behaviour and health than cross-sectional study designs (Rezende *et al.*, 2014). However, these study designs are still prone to residual confounding (Rezende *et al.*, 2014) which can occur due to measurement error in a confounding variable and/or when confounding variables are not included in the statistical model (Fewell, Davey Smith and Sterne, 2007). Instead, randomised control trials are recommended for establishing causality due to the nature of the study design which involves randomly assigning participants to an intervention group or control group

(Zabor, Kaizer and Hobbs, 2020). However, the feasibility of conducting randomised control trials on sedentary behaviour could be contended due to the challenges associated with controlling the amount of sedentary behaviour people engage in.

A second limitation is that most studies to date have relied on self-report measures of sedentary behaviour (Biswas *et al.*, 2015; Biddle *et al.*, 2016; Patterson *et al.*, 2018; Dempsey *et al.*, 2020; Saunders *et al.*, 2020). Self-report tools are often liable to recall and reporting bias (Aunger and Wagnild, 2022). In comparison, Ekelund *et al.* (2019) summarised evidence from prospective cohort studies that used device-based measures which do not have the same limitations as self-report tools, although, it can be difficult to compare results from different studies due to the differing ways in which data are collected and analysed. Harmonising data by using standardised definitions which are consistent for all included studies reduces this limitation (Ekelund *et al.*, 2019). Additionally, there is variation in how sedentary behaviour was defined across studies, which included sedentary time, TV viewing time and screen time (Biswas *et al.*, 2015; Biddle *et al.*, 2016). It has previously been highlighted that the detrimental associations between TV viewing and health outcomes are stronger than for total sitting time (Patterson *et al.*, 2018). Given this information, it is not feasible to make cross-study comparisons due to the differing ways in which sedentary behaviour is operationalised across studies. Finally, there are a limited number of primary studies that have examined the relationships of different types of behaviours, such as mobile phone and games console use, with various health outcomes (DiPietro *et al.*, 2020; Saunders *et al.*, 2020). Therefore, further research is needed to assess the relationships between contemporary behaviours with markers of health, to increase the evidence base in this area. Additionally, future research that uses both self-report and device-based measures is required to more accurately assess the durations at which different behaviours become detrimental to health (DiPietro *et al.*, 2020).

Evidence from cohort studies on the association of sedentary behaviour with health outcomes may appear contrary to ‘ecological’ evidence on sedentary behaviour levels and health indicators, such as life expectancy. For example, life expectancy at birth is typically greater in Norway compared to Portugal (The World Bank, 2022a), but Norwegian adults appear to accumulate more time sedentary than those in Portugal (Loyen *et al.*, 2017). Similarly, white collar workers tend to have

lower chronic disease risk and greater life expectancy than those in manual occupations, but time spent sedentary is typically greater in white collar workers than manual workers (Loyen *et al.*, 2016; Jelsma *et al.*, 2019). These 'ecological' comparisons, based on group-level data (country and occupation-type in these examples), can be useful for monitoring population health, making cross-country comparisons, and understanding the population-level exposure to risk factors and disease (Morgenstern, 1995; Levin, 2006). However, such designs are not robust for establishing associations between behaviour and health at the individual level, due to the lack of information on exposure at the individual level and the inability to control for confounding factors (Morgenstern, 1995). Ecological studies do not reflect free living conditions where multiple risk factors occur simultaneously to impact health, both at the individual and country-level. A multitude of social, environmental, and cultural differences, such as higher poverty and unemployment, may reduce the life expectancy of those in Portugal compared to Norway, over and above any observed differences in sedentary behaviour (Organisation for Economic Co-Operation and Development, 2021a, 2021b). Similarly, white collar workers are less likely to smoke and more likely to have a healthy diet than those in manual occupations, both of which may increase life expectancy (Väisänen *et al.*, 2020). Accordingly, cohort studies where exposure is assessed at individual level and adjustment for confounding can be handled within statistical models provide more robust evidence of the association between sedentary behaviour and health (Thiese, 2014).

2.3.4 Summary of the evidence on sedentary behaviour and health

Overall, section 2.3 of this thesis has presented findings on the links between sedentary behaviour and health, as well as discussing the limitations of the research to date. Consistent evidence has revealed a link between total sitting time, total sedentary time and TV viewing time with all-cause mortality and cardiovascular disease mortality (Rezende *et al.*, 2014; Biswas *et al.*, 2015). In addition, dose-response relationships reveal that the risk for the health outcomes outlined above increases when sitting or sedentary time reaches approximately 7.5-8h/day (Patterson *et al.*, 2018; Ekelund *et al.*, 2019) and 3-4h/day for TV viewing time (Patterson *et al.*, 2018). Additionally, these associations are independent of physical activity levels, but the negative health effects tend to decrease in severity

in those who engage in higher levels of physical activity compared to individuals who are least active (Biswas *et al.*, 2015; Patterson *et al.*, 2018).

A limitation of the evidence to date is that the majority of studies have been cross-sectional in nature (Rezende *et al.*, 2014; Biswas *et al.*, 2015; Saunders *et al.*, 2020) and thus cause and effect relationships cannot be established. Additionally, most studies have focused on mortality and cardiometabolic health outcomes (Dempsey *et al.*, 2020) with a lack of research assessing psychological, neurological and musculoskeletal outcomes (Memon *et al.*, 2021). Furthermore, self-report measures of sedentary behaviour have typically been used (Biswas *et al.*, 2015; Biddle *et al.*, 2016; Patterson *et al.*, 2018; Dempsey *et al.*, 2020; Saunders *et al.*, 2020), the limitations of which have been previously described (Aunger and Wagnild, 2022). Finally, previous studies have tended to assess total sitting time, total sedentary time and/or TV viewing time, with less attention paid to other types of behaviours and their associations with health (DiPietro *et al.*, 2020; Saunders *et al.*, 2020).

2.4 Measurement of sedentary behaviour

Accurate tools are required for use in surveillance to ascertain compliance with public health guidelines and monitor changes in sedentary behaviour at the individual and population level over time (Atkin *et al.*, 2012; Chastin *et al.*, 2018). Accurate measures of sedentary behaviour are also helpful for determining associations between sedentary behaviour and health outcomes (Bakker *et al.*, 2020) and for evaluating the effectiveness of behaviour change interventions (Atkin *et al.*, 2012). Measures of sedentary behaviour have largely been categorised into self-report measures, for example questionnaires and diaries, and device-based measures, such as accelerometers. These two broad measurement categories will be the focus of this section, with the main focus being on self-report questionnaires, accelerometers and inclinometers due to their frequent use in surveillance and epidemiological studies.

2.4.1 Self-report measures of sedentary behaviour

Historically, self-report questionnaires have typically been used to assess sedentary behaviour in epidemiological studies and population surveillance (Dall *et al.*, 2017; Prince *et al.*, 2020a). These can be sub-categorised into total assessment/single item questionnaires and multi-item domain-based

questionnaires (Aunger and Wagnild, 2022). Single item questionnaires typically ask respondents to report their total sitting time over a given period (Aunger and Wagnild, 2022). One commonly used single item tool is the sedentary behaviour item from the Short Form International Physical Activity Questionnaire, which asks respondents to report their typical duration of time spent sitting on a weekday during the last 7 days (Craig *et al.*, 2003). In comparison, multi-item domain-based questionnaires can be used to provide an estimate of total sedentary time which is often produced by totalling the duration of time spent in specific contexts (Aunger and Wagnild, 2022). The Sedentary Behaviour Questionnaire is one example of a multi-item questionnaire, which contains questions assessing nine types of sedentary behaviour including TV viewing, playing computer/videogames and reading (Rosenberg *et al.*, 2010).

Self-report questionnaires have typically been preferred to device-based measures in large-scale epidemiological studies and surveillance due to their low cost, low participant burden and ease of distribution and use with large numbers of participants (Atkin *et al.*, 2012; Aunger and Wagnild, 2022). However, self-report questionnaires are typically prone to recall and reporting bias, with respondents tending to underestimate the duration of time they spend sedentary in comparison to device-based measures (Atkin *et al.*, 2012; Aunger and Wagnild, 2022). Systematic review evidence reported that on average self-report measures underestimated the duration of time spent sedentary by approx. 1.74 hours per day compared to device-based measures (Prince *et al.*, 2020b). In particular, composite measures based on patterns of behaviour that had an unanchored recall period underestimated sedentary time by 473 minutes per day (Chastin *et al.*, 2018). In contrast, a 245-minute per day overestimation was reported for composite measures using a sum of behaviours and a previous week recall period (Chastin *et al.*, 2018). These findings have important implications for the use of self-report measures in surveillance (Chastin *et al.*, 2018) and suggest that current prevalence estimates may not accurately reflect population levels of sedentary behaviour.

2.4.2 Device-based measures of sedentary behaviour

Device-based measures have increasingly been used to measure sedentary behaviour. Accelerometers measure the frequency and intensity of movement (Byrom *et al.*, 2016) and are one type of device-based measure which are small, lightweight and can be worn on the hip, wrist or lower back. In the past,

accelerometers were commonly used to provide an estimate of total sedentary behaviour volume through movement counts, typically summed over a particular time frame (Healy *et al.*, 2011). However, technological developments have led to devices having a greater memory and battery capacity, wider acceleration range and the ability to provide raw acceleration signals (Troiano *et al.*, 2014). Accelerometers can measure total volume of sedentary time as well as patterns throughout the day (Wijndaele *et al.*, 2015). These advancements have contributed to the increasing use of accelerometers in observational and intervention studies (Wijndaele *et al.*, 2015).

In comparison, inclinometers, which are small devices placed on the anterior midline of the thigh and worn under clothing, were designed specifically to measure different postures (Aunger and Wagnild, 2022). Thigh acceleration is used to provide posture information and proprietary algorithms are used to classify one's posture (Atkin *et al.*, 2012; Aunger and Wagnild, 2022). Inclinometers can also provide information on the number of steps taken, estimates of energy expenditure and transitions between postures e.g., sit to stand (Atkin *et al.*, 2012).

The primary strengths of device-based measures are their ability to quantify and demonstrate accumulation of sedentary behaviour during the day (Atkin *et al.*, 2012; Pfister *et al.*, 2017). Commonly used devices, like the ActiGraph and activPAL, have consistently been shown to be valid and reliable measures of sedentary behaviour (Grant *et al.*, 2006; Kozey-Keadle *et al.*, 2011; Edwardson *et al.*, 2016). However, they are not without limitations. For example, although the devices can distinguish posture, they are not able to determine if someone is asleep or not wearing the device (Winkler *et al.*, 2016). This requires researchers to employ methods to address this limitation, which tend to involve participants recording their wear time and reasons for removing the device in a diary or log (Edwardson *et al.*, 2017). A further limitation of device-based measures is that they cannot provide contextual information including the types of activity undertaken and the domains in which they occur (Bakker *et al.*, 2020). This information can be provided by self-report measures, which can be useful in the design of behaviour change interventions (Bakker *et al.*, 2020).

2.5 Public health guidelines

Public health guidelines, such as those published by the WHO, are recommendations on the amount of physical activity that is required by different population groups to maintain health and reduce the risk of developing non-communicable diseases (World Health Organization, 2022). Guidelines are informed by scientific evidence, synthesised via a rigorous review process conducted by experts in the field (Stamatakis and Bull, 2020). Historically, guidelines have focused on establishing recommendations on the frequency, intensity, and duration of physical activity to reduce the risk of non-communicable diseases (World Health Organization, 2010). However, more recently sedentary behaviour has also been included in national and global guidelines (Bull *et al.*, 2020).

The current UK guidelines recommend that adults aged 19 years and above minimise their sedentary time and break up periods of inactivity (United Kingdom Government Department of Health and Social Care, 2019). Given the previous publications have differentiated the terms 'sedentary behaviour' and 'inactivity', it is questionable why these terms have been used in this way within the sedentary behaviour aspect of the UK guidelines. Additionally, given that research into sedentary behaviour is relatively new, and thus sedentary behaviour has been included in national public health guidelines for less time than physical activity, it is plausible that the term "sedentary" may not be widely understood by the general public. In a review of the literature on perceptions of physical activity and sedentary behaviour guidelines among end-users, simpler terminology and definitions were requested, which could lead to greater adherence to public health guidelines on physical activity and sedentary behaviour (Hollman *et al.*, 2022).

In 2020, sedentary behaviour was included for the first time in the WHO physical activity guidelines (Bull *et al.*, 2020; World Health Organization, 2020a). The guidelines recommend for adults aged 18-64 years, including those with chronic conditions and disabilities that 1) sedentary time should be limited and 2) health benefits can occur from replacing sedentary time with physical activity (World Health Organization, 2020a). The release of the WHO guidelines was a landmark step in sedentary behaviour being recognised in global public health guidelines. However, these recommendations did not provide a specific threshold on sedentary behaviour duration despite increasing calls for quantitative guidelines (Chaput, Olds

and Tremblay, 2020). This decision was based on a lack of research evidencing quantitative thresholds (World Health Organization, 2020a).

2.6 Prevalence of sedentary and screen-based behaviours

This section begins with a brief overview of the purpose of population surveillance and the importance of collecting data on sedentary behaviour prevalence. Thereafter, prevalence data for total sitting or sedentary time, TV viewing and other screen-based behaviours are summarised. For brevity, this commentary focuses on multi-country level evidence on the prevalence of the selected behaviours, supplemented with selected examples from recent surveillance studies in the UK, United States of America (USA) and Canada.

2.6.1 Population surveillance

Epidemiological surveillance is defined as *"the ongoing systematic collection, analysis, and interpretation of health data essential to the planning, implementation, and evaluation of public health practice, closely integrated with the timely dissemination of these data to those who need to know"* Centers for Disease Control (1986, cited in Thacker and Berkelman, 1988, p.1). Historically, diet, tobacco use, and alcohol consumption have been regularly monitored in national surveillance systems, yet it is relatively recently that physical activity and sedentary behaviour have been monitored across many countries (Bull *et al.*, 2020; Troiano, Stamatakis and Bull, 2020). Prevalence estimates are vital for monitoring population levels of sedentary behaviour and identifying groups at risk who can be targeted within interventions (Loyen *et al.*, 2016; Lakerveld *et al.*, 2017). One of the many challenges in population surveillance is that modifications to guidelines can require changes to how behaviours are monitored, which may require changes to a surveillance tool and/or the way the data are analysed or reported (Troiano, Stamatakis and Bull, 2020). This can pose methodological challenges as surveillance systems seek to track population compliance over time which may not be possible with changes to tools or data analysis (Troiano, Stamatakis and Bull, 2020).

2.6.2 Prevalence of total sitting and sedentary time

Given the evidence that sedentary behaviour has detrimental effects on health (Biswas *et al.*, 2015; Patterson *et al.*, 2018), there is a need to understand

population levels of sedentary behaviour. In their 2016 study, Rezende and colleagues examined sitting time data collected from 2002 to 2011 in 54 countries across five WHO regions (Rezende *et al.*, 2016). For all countries combined, the weighted mean sitting time was 4.7h/day and prevalence of sitting >3h/day was 61.5% (Rezende *et al.*, 2016). More recently, Mclaughlin *et al.* (2020) identified 62 countries with eligible sitting time data collected between 2008 and 2018. Across all countries, the overall median of mean daily sitting time was 4.7h/day; sitting time was greater in high income countries (4.9h) than lower income countries (2.7h). The International Physical Activity Questionnaire (IPAQ) or Global Physical Activity Questionnaire (GPAQ) were used to assess sitting time in all studies included within Rezende *et al.* (2016) and Mclaughlin *et al.* (2020) apart from one which used an adapted IPAQ. It has previously been reported that the GPAQ under-reports sedentary behaviour by almost 6h/day (Cleland *et al.*, 2014) and almost 5h/day (Aguilar-Farias and Leppe Zamora, 2017) in comparison to device measured sedentary behaviour. Similarly, the Long Form International Physical Activity Questionnaire has been found to underestimate sitting time compared to device measured sedentary behaviour by 2.2h/day for the total week and 4.6h/day at weekends (Chastin, Culhane and Dall, 2014). This suggests the prevalence estimates presented by Rezende *et al.* (2016) and Mclaughlin *et al.* (2020) may be under-estimated and thus may not provide an accurate picture of sedentary behaviour prevalence.

Countries have also collected prevalence data on total sitting and sedentary time through their own national health surveys. The Health Survey for England collects data on weekday and weekend sedentary behaviour through two questions (Scholes, 2017). One question assesses TV viewing time and the other assesses leisure time sedentary behaviour in activities such as reading, studying, and using a computer (Scholes, 2017). Data from these two questions combined in 2016 estimated that on weekdays 29% of respondents spent an average of six hours or more in sedentary time which increased by 11% for men and 6% for women on weekends (Scholes, 2017). On average men were slightly more sedentary than women on both weekdays (4.8h/d vs 4.6h/d) and weekends (5.3h/d vs 4.9h/d). In the USA, data from the 2015-2016 National Health and Nutrition Examination Survey (NHANES) reported that 25.7% of adults ≥18 years of age self-reported sitting for more than 8h/day (Ussery *et al.*, 2018). Participants were asked to report for a typical week, how much time they usually spent sitting or reclining on a typical

day (Ussery *et al.*, 2018). The prevalence estimates reported provide important insights, but in the absence of an agreed quantitative threshold at which sedentary behaviour is considered “harmful” or “prolonged”, researchers have categorised sedentary behaviour into varying thresholds, making it difficult to draw cross country comparisons.

Device-based assessment of total sedentary time is less commonly used in surveillance compared to self-report measures. Despite this, data from over 9,000 participants in four countries indicate that on average 81% were sedentary for >7.5h/day, whilst 23% were sedentary >10h/day (Loyen *et al.*, 2017). Interestingly, almost 90% of respondents in Norway sat for >7.5h/day compared to 67% in Portugal (Loyen *et al.*, 2017). Data from the Health Survey for England in 2008 indicated that both men and women exceeded nine hours of sedentary time on average per day, thus highlighting the marked differences in duration of device measured and self-reported sedentary time (Craig, Mindell and Hirani, 2009). An additional country specific analysis from the national cross-sectional survey ORISCAV-LUX 2 in Luxembourg revealed that participants spent over half (51%) of their day sedentary as measured by accelerometry (Collings *et al.*, 2022). This corresponded to 12.1 hours per day of sedentary time.

2.6.3 Prevalence of TV viewing

Data from the 2016 Health Survey for England indicate that over a quarter of men (26%) and women (27%) exceed four hours per day of TV viewing on weekdays, rising to approx. one third at weekends (men 34%, women 32%) (Scholes, 2017). Direct comparisons are hindered by use of differing thresholds, but findings appear broadly consistent with data from the 2015-2016 NHANES study in the USA; Yang *et al.* (2019) reported that 65% of adults aged 20 years and above spent at least two hours per day watching TV or videos, with higher levels observed in those aged >65 years compared to 20-64 years. In comparison, cross-sectional data from the 2011-2012 Canadian Community Health Survey showed that 31% of adults aged 20 years and above reported >2 hours per day of TV viewing (Herman and Saunders, 2016).

2.6.4 Prevalence of other sedentary and screen-based behaviours

The prevalence estimates for other types of sedentary and screen-based behaviours are less commonly reported. The Health Survey for England published

prevalence estimates in 2016 for the proportion of men and women who spent four or more hours on other (non-TV) sedentary behaviours outside of paid work, such as reading, using a computer or playing video games (Scholes, 2017). It was reported that 16% of men and 14% of women spent four or more hours per day on weekdays in these behaviours. These figures increased slightly to 18% of men on weekends but remained the same for women.

Th prevalence of computer use has been reported by the USA and Canada. The estimated prevalence of using a computer in leisure time for one hour or more per day increased from 29% to 50% in American adults between 2003 and 2016 using data from the NHANES survey, with the greatest increases being observed in adults aged 65 years and above (Yang *et al.*, 2019). Data from the 2011-2012 Canadian Community Health Survey indicate that just under half of adults reported spending over five hours per week in leisure time computer use (Herman and Saunders, 2016). Specifically, men were more likely to engage in higher levels of computer use than women whilst younger adults were more likely to use a computer than adults aged 75 years and above (Herman and Saunders, 2016). Prevalence estimates for other types of screen and non-screen-based behaviours are less common. However, one analysis using data from the 2011-2012 Canadian Community Health Survey indicated that 40% of adults spend five hours or more per week reading, which was higher in older adults and women (Herman and Saunders, 2016). This thesis extends previous work by assessing various sedentary and screen-based behaviours across different global regions and socio-demographic groups.

2.6.5 Trends in sedentary behaviour

The tracking of trends across time is important as this information can be used to inform public health policies (Strain *et al.*, 2020). Data from the Health Survey for England collected in 2008, 2012 and 2016, indicate that total weekday and weekend sedentary time decreased from 2008 to 2016 for both men and women (Scholes, 2017). On weekdays sedentary time decreased from 5h/day to 4.8h/day for men and from 5h/day to 4.6h/day for women (Scholes, 2017). On weekends the durations decreased from 5.6h/day to 5.3h/day for men and from 5.3h/day to 4.9h/day for women (Scholes, 2017). Conversely, trend estimates from the NHANES survey in the USA demonstrated that total sitting time increased from approximately 5.5 hours to 6.5 hours per day between 2001 and 2016 (Yang *et al.*,

2019). Meanwhile Prince *et al.* (2020a) described trends in sedentary behaviours using data from the Canadian Community Health Survey and the Canadian Health Measures Survey, which they stratified by age groups. Device measured total sedentary time assessed between 2007 and 2017 indicated a decline of approximately five minutes per day per survey cycle in youth and adults aged 18-34 and 50-64 years (Prince *et al.*, 2020a). The duration of time spent watching TV has increased over time in adults aged 65 years and above but has declined or remained stable in younger age groups (Prince *et al.*, 2020a). Additionally, survey data indicated both leisure time computer use, and total screen time have increased over time (Prince *et al.*, 2020a). The sporadic monitoring of sedentary behaviour in population surveillance systems creates challenges for establishing trends across time (Strain *et al.*, 2020). This thesis will build on the findings reported previously by using survey data from multiple yearly time points to ascertain trends in screen-based behaviours over time.

2.7 Correlates of sedentary behaviour

The following section provides an overview of The Ecological Model of Health Behaviour and its application to the study of sedentary behaviour. This is followed by a critical overview of current literature on the correlates of sedentary behaviour.

2.7.1 The Ecological Model of Health Behaviour

Ecological Models of Health Behaviour provide a conceptual framework for understanding levels of influence on health behaviours (Sallis, Owen and Fisher, 2008), key features of which are discussed below. A core principle is that health behaviours are influenced by factors at multiple levels (Sallis, Owen and Fisher, 2008), which includes the intrapersonal, interpersonal, organisational, community and public policy levels (Owen *et al.*, 2011) as illustrated in Figure 2. However, most studies to date have focused on individual-level, socio-demographic influences on sedentary behaviour, with less attention given to wider social, environmental, and policy-related factors (O'Donoghue *et al.*, 2016; De Craemer *et al.*, 2018). Additionally, influences interact across levels of the model and work together to influence health behaviours. In practice, a challenge to applying or testing this principle is that there can be many factors across various levels that interact, making identification of which interactions are of greatest importance difficult (Sallis, Owen and Fisher, 2008). Furthering understanding of these interactions is

important for future research and behaviour change intervention development (Sallis, Owen and Fisher, 2008). The model also proposes that interventions incorporating factors across multiple levels will likely be most effective for changing behaviour than interventions that focus on single factors or on only one level (Sallis, Owen and Fisher, 2008). This has been supported by previous evidence indicating that interventions targeting one level of influence have generally demonstrated only short term changes in behaviour (Owen *et al.*, 2011). Finally, it is important that the most relevant factors at each level of the model are identified for individual health behaviours as factors are behaviour specific, such that the correlates of TV viewing may differ from those of computer use or overall sitting time (Sallis, Owen and Fisher, 2008). The summary of evidence will focus on individual and country-level influences, which is informed by the lack of evidence assessing country-level correlates of sedentary behaviour and the potential for cross-level interactions.

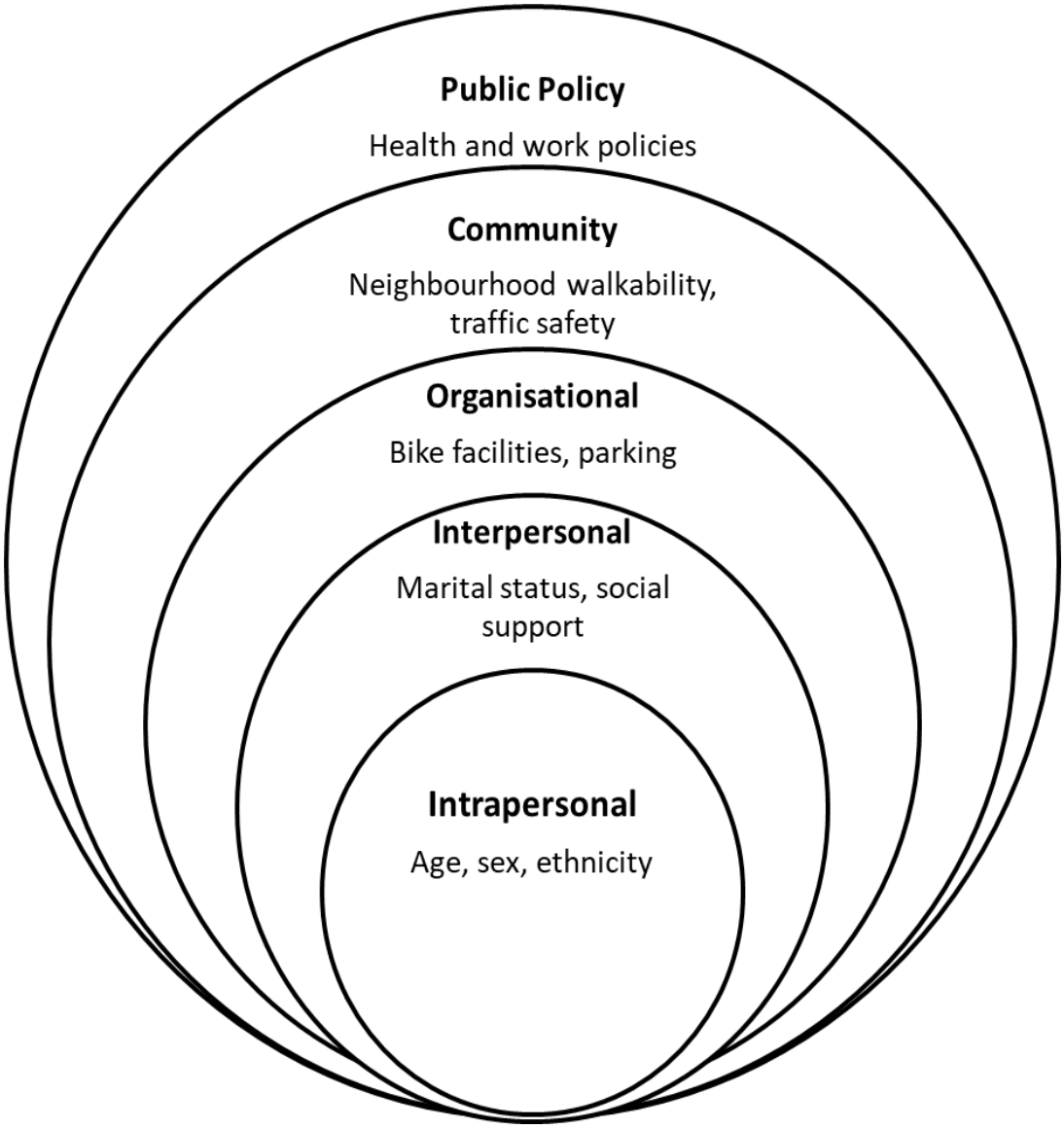


Figure 2. A simplified diagram of The Ecological Model of Health Behaviour.

2.7.2. Individual-level correlates of sedentary behaviour

Research assessing factors that influence sedentary behaviour is essential for the development of behaviour change interventions to target particular sub-groups and settings (Loyen *et al.*, 2016). With regard to sex, findings from a review in 2012 suggested that sex was associated with videogame play, specifically men spend more time playing videogames than women (Rhodes, Mark and Temmel, 2012). However, sex differences were not identified for TV viewing, computer use, reading and sitting. Inconclusive findings have been reported for sex, with one study identifying that men are more likely to report high sitting (>7.5h/day) than women (Jelsma *et al.*, 2019). However, a second study reported that sex differences were context dependent, for example, women who had a white-collar job or whose job was manual based were at a greater risk of high sitting (>7.5h/day) whereas men who were retired or self-employed appeared to sit more than women (Lakerveld *et al.*, 2017). With regard to age, the associations appear dependent on the outcome of interest, specifically TV viewing increases with age, whereas computer use decreases (Rhodes, Mark and Temmel, 2012). Additionally, a more recent review conducted in 2016 found that older individuals tended to be more sedentary (O'Donoghue *et al.*, 2016).

The associations between markers of socioeconomic status, such as income, occupation or education and sedentary behaviour, appears dependent on the domain or type of sedentary behaviour assessed (Rhodes, Mark and Temmel, 2012; O'Donoghue *et al.*, 2016). TV viewing and 'television and screen entertainment' were negatively associated with education (Rhodes, Mark and Temmel, 2012; O'Donoghue *et al.*, 2016). In comparison, self-reported or device measured total sedentary time (O'Donoghue *et al.*, 2016) and computer use were positively correlated with education (Rhodes, Mark and Temmel, 2012). When considering occupation, cross-sectional studies using Eurobarometer data have consistently reported that occupation is associated with self-reported sitting time (Loyen *et al.*, 2016; Lakerveld *et al.*, 2017; Buck *et al.*, 2019; Jelsma *et al.*, 2019). Specifically, those in white collar occupations are more likely to engage in high levels of sitting than manual workers (>7.5h/day) (Loyen *et al.*, 2016; Jelsma *et al.*, 2019). In comparison, review evidence from Prince *et al.* (2017a) found a negative association between employment status and leisure-time sedentary behaviour.

2.7.3 Country-level correlates of sedentary behaviour

Country-level factors have the potential to influence individual behaviour (Moreno-Llamas, García-Mayor and De la Cruz-Sánchez, 2020) and to explain between and within country differences in health behaviour patterns and prevalence (Cameron *et al.*, 2013). Despite this, limited research has assessed the associations of country/macro-level factors, such as economic development and population density, with physical activity and sedentary behaviour (Bauman *et al.*, 2012; Van Cauwenberg *et al.*, 2018). One study reported that national economic development (measured by GDP per capita) was related to both within and between country differences in leisure time physical activity (Cameron *et al.*, 2013). However, the available research has shown mixed findings for sedentary behaviour, with GDP, a measure often used to describe a country's wealth, being shown to have both a positive association (Van Cauwenberg *et al.*, 2018) and no association (Werneck *et al.*, 2020) with self-reported sitting time. Meanwhile, human development index (HDI) , which is a composite measure of factors related to education, life expectancy and country wealth, has demonstrated no association with markers of sedentary behaviour (Werneck *et al.*, 2020; Ferrari *et al.*, 2022). In comparison, a country's digital development measured by the Digital Economy and Society Index (DESI), is positively associated with sitting >4.5h/day (Moreno-Llamas, García-Mayor and De la Cruz-Sánchez, 2020). Additionally, cross-sectional analyses assessing population density showed that an additional 1000 inhabitants/km2 was related to a 1.14 higher odds of reporting high levels of sitting (>7.5h/day) (Van Cauwenberg *et al.*, 2018). These findings combined demonstrate the limited but important findings on the country-level correlates of sitting time. Nevertheless, further research is needed to assess the associations between a greater range of country-level factors and sitting time and to assess whether these vary by individual factors, in line with the Ecological Model. Additionally, it is important to assess whether country-level factors can explain between country differences in sedentary behaviour.

2.8 Thesis rationale, aims and structure

The overall aim of this thesis is to advance understanding of contemporary patterns in sedentary and screen-based behaviours among adults to inform population surveillance, measurement of sedentary behaviour and the design of behaviour change interventions. This thesis comprises four interlinked studies, each with different aims and research questions, that contributed towards the overall aim of

the thesis. Each study is presented in its entirety in the appropriate chapter, comprising a rationale, methods, results and accompanying discussion. The final chapter summarises the main findings and discusses these in relation to the wider literature. This also includes methodological reflections, suggestions for future research and concluding statements.

The rapidly evolving rate at which technology is developing, and the various devices and associated behaviours that occur, pose challenges for the measurement and monitoring of these behaviours. Currently, there is limited evidence on the contemporary sedentary and screen-based behaviours that are being undertaken and the duration of these activities daily and over time. Therefore Chapter 3, sought to characterise patterns of contemporary screen-based behaviours, describing temporal trends by region, age, sex, and education. Data were obtained from GWI, a global market research company. Chapter 4 aimed to further examine the diurnal patterns of different types of sedentary behaviours and secondary activities associated with sedentary and screen-based behaviours in adults. Data were obtained from the 2014-2015 UK Time Use Survey.

Given the marked between-country differences in prevalence and duration of sedentary behaviour across countries, it is valuable to examine whether factors at the country level can provide possible explanations for these differences. Therefore, Chapter 5 examined the association of country-level factors with self-reported sitting time. A second aim was to explore whether these associations varied over time and by individual factors, such as age, sex, and occupation. This study used data from four waves of the European Commission Eurobarometer Survey (2002, 2005, 2013 and 2017).

Finally, it is currently unknown if, and to what extent, contemporary screen and sedentary behaviours are being monitored in population surveillance systems. As reported in section 2.6, there is limited evidence on the patterns and trends of contemporary sedentary behaviours. Therefore, the aim of Chapter 6 was to describe the characteristics of questionnaires used for national surveillance of sedentary behaviour and to identify the types of behaviours being measured.

Chapter 3: International trends in screen-based behaviours from 2012 to 2019.

3.1 Background

Across numerous contexts, many adults accumulate considerable time in screen-based behaviours, such as watching broadcast or streamed content on TV, playing computer and videogames or using a smartphone or tablet (Birken *et al.*, 2011; Sivanesan *et al.*, 2020). A growing body of predominantly observational research has linked higher amounts of screen time with negative physical and psychological health outcomes, including cardiovascular disease, all-cause mortality and depression (Stamatakis, Hamer and Dunstan, 2011; LeBlanc *et al.*, 2017; Wang, Li and Fan, 2019). However, not all forms of screen time may have the same associations with health. There is evidence of differential associations between screen use and some health markers depending on whether screen use was mentally active or passive (Kikuchi *et al.*, 2014).

Early research on sedentary behaviour and its association with obesity and chronic diseases used screen-based behaviours as a proxy for sedentary time and tended to focus primarily on TV viewing (Biddle *et al.*, 2017). In recent years, the way in which people watch TV has changed, with traditional forms of viewing (broadcast via cable or satellite) being replaced or supplemented with internet streaming services, such as Netflix and YouTube (Prince *et al.*, 2017b). In addition, there have been considerable developments in the volume and accessibility of screen-based devices, some of which may promote sedentary behaviour (Biddle *et al.*, 2017). In particular, mobile phones have transformed into multifunctional devices that can be used for browsing the internet, engaging in social networking, playing videogames and streaming content (Lepp *et al.*, 2013). Despite these developments, there is little empirical evidence on temporal changes in the type and duration of screen device use.

The rapid evolution of technology has led some researchers to question whether current academic research on sedentary behaviour accurately reflects contemporary behaviour patterns (LeBlanc *et al.*, 2017). In particular, self-report questionnaires still tend to measure time spent watching broadcast TV or using a computer rather than time spent on contemporary behaviours, such as using a mobile phone or tablets and accessing associated streaming services (LeBlanc *et*

al., 2017). Self-report questionnaires, such as the Sedentary Behaviour Questionnaire (Rosenberg *et al.*, 2010), the Past Day Adults' Sedentary Time Questionnaire (Clark *et al.*, 2013) and the Longitudinal Ageing Study Amsterdam Sedentary Behaviour Questionnaire (Visser and Koster, 2013) all include items about TV viewing and computer/video game use but do not capture the full breadth of screen-based activities undertaken today. One recently developed questionnaire, the International Sedentary Assessment Tool (Prince *et al.*, 2017b) does attempt to address this issue by capturing a wider range of sedentary behaviours, but this remains a limited example.

Data collected in non-academic sectors, often for commercial or regulatory purposes, may better reflect contemporary behaviour patterns than that from academic studies as these data can be collected more rapidly. Companies such as Ofcom and Nielsen routinely collect data that provide useful insights into the technology market (Nielsen, 2020; Ofcom, 2020). Academic use of industry data may further understanding of the use of screen-based technology, providing an up-to-date picture of which screen-based behaviours are prevalent and how usage may have changed over time. The aims of this study were to utilise industry data to characterise contemporary patterns of screen-based behaviours, describe temporal trends in screen-based behaviours by region, age, sex, and education, and consider implications of the findings for future research.

3.2 Method

3.2.1 Data source

Data for this study were extracted from a dataset created and maintained by GWI (previously known as Global Web Index), a market research company that provides global insights into the use of electronic media by adults (GWI, 2021a,b,c). Data from GWI were used due to its longitudinal nature and the breadth of screen-related behaviours that were assessed. To date, no dataset available within the commonly used data repositories (e.g. the UK Data Service) is comparable in terms of timespan of assessment, range of behaviours measured or sample size. GWI conduct biannual or quarterly surveys as part of their ongoing market research activity into global electronic media usage, recruiting from 46 countries across five continents. Surveys include items pertaining to use of a range of screen-based activities including the use of PCs, laptops and tablets, mobile phones and traditional TV (GWI, 2021c; further details below). Data collection was via online

self-report questionnaires administered through panel providers including Dynata and Toluna (GWI, 2020). The full methodology of the surveys is available elsewhere (GWI, 2020). GWI are a corporate member of the European Society for Opinion and Market Research (ESOMAR) and adhere to the International Chamber of Commerce/ESOMAR International Code on Market, Opinion and Social Research and Data Analytics (European Society for Opinion and Market Research, 2021). They are also a corporate member of the Market Research Society, the Interactive Advertising Bureau (IAB) Europe and IAB UK, which demonstrates their commitment to follow ethical procedures when conducting research (Interactive Advertising Bureau Europe, 2021; Interactive Advertising Bureau United Kingdom, 2021; Market Research Society, 2021). This study involved secondary analysis of existing data; thus, ethical approval was not required.

3.2.2 Sample

Recruitment into GWI surveys was conducted by the panel survey providers, with the target population being internet users aged 16-64 years in each country. Quotas were set on age, sex and education status of participants, whose responses were weighted to ensure that the sample was representative of a country's online population aged 16-64 years (GWI, 2020). To ensure the target sample size was reached, participants were over-recruited in each sub-group as between 5 and 15% of respondents were removed during data cleaning. The final global sample size for each year was: 2012, n=60,200; 2013, n=153,650; 2014, n=166,600; 2015, n=193,750; 2016, n=204,500; 2017, n=364,500; 2018, n=438,750; 2019, n=550,500; 2020, n=689,000. Details on the most recent sample size for each country can be found at https://www.globalwebindex.com/data-coverage (GWI, 2021d).

3.2.3 Survey

The data used in the current study were collected from 2012-2019. The annual data comprised bi-annual surveys combined for 2012 and quarterly surveys combined for each year from 2013 to 2019. Time spent in selected screen-based activities was assessed using the following question, which remained unchanged throughout the period of study: "On an average day how long do you spend on the following types of media?". Five screen-based behaviours are examined in this study: online via a PC/laptop/tablet; online via a mobile phone; traditional TV; online TV; and games consoles. For each activity, participants selected from the following

response options: less than 30 minutes; 30 minutes to 1 hour; 1 to 2 hours; 2 to 3 hours; 3 to 4 hours; 4 to 6 hours; 6 to 10 hours; more than 10 hours; and 'do not use'. Mean duration of each screen-behaviour was derived using response category mid-points (for example, less than 30 minutes = 15 minutes). An estimate of total screen-time was derived as the sum of the five individual screen behaviours. Prior to data being made available for the current analysis, survey responses were cleaned to ensure good data quality following the GWI methodology. This included checking survey completion time, detection of patterned answers and using logic traps to identify illogical or contradictory responses. The survey was completed in each respondents' local language. However, in some countries, for example Austria, Canada, and Egypt more than one language was available.

3.2.4 Data analysis

During the preliminary analysis, normality was checked for each of the behaviours studied and a sufficient number of outcomes were normally distributed. Therefore, data are reported as mean and standard deviation throughout this study. Data were made available by GWI in aggregated form, comprising the number of participants selecting each response option to each question, stratified by country, and selected social/demographic indicators (described below). As such, data were not amendable to statistical testing for temporal changes or between group differences. Accordingly, this analysis seeks to highlight substantive trends in the data which have significance for public health surveillance and intervention design. Results are presented at the international level and stratified by age (16-24, 25-34, 35-44, 45-54, 55-64 years), sex, education (school to age 16, school to age 18, trade/technical school or college, university degree, postgraduate degree) and global region (Asia-Pacific, Europe, Latin America, Middle East and Africa, North America as defined by GWI; see Appendix 1 for country composition of each region). To establish a total estimate of screen time the aggregated data for each behaviour in a given year was converted to a mean estimate using the mid-point (for example, 1-2 hours = 1.5 hours). The mean estimates for each of the five behaviours in a given year were then summed to establish the overall screen time estimate for each year.

3.3 Results

Table 1. Temporal trends in daily per-capita duration (hr:min) of screen-based behaviours from 2012-2019 (sum of: personal computer/laptop/tablet, mobile, traditional television, online television and games console). Data are mean with standard deviation.

	2012	2013	2014	2015	2016	2017	2018	2019
Region*								
World	9:20 (10:06)	9:49 (10:15)	10:04 (10:46)	10:04 (10:54)	10:27 (11:14)	10:46 (11:35)	10:51 (11:41)	11:15 (11:58)
AP	9:05 (9:41)	9:18 (9:26)	9:40 (10:02)	9:33 (10:05)	10:01 (10:34)	10:33 (11:13)	10:34 (11:14)	10:53 (11:30)
Europe	8:31 (9:41)	9:03 (9:26)	9:09 (10:02)	9:17 (10:05)	9:25 (10:34)	9:30 (10:28)	9:34 (10:38)	10:06 (11:05)
LA	10:38 (10:55)	11:38 (11:33)	12:19 (12:11)	13:10 (12:35)	13:13 (12:30)	13:16 (12:30)	13:12 (12:23)	13:43 (12:59)
MEA	10:14 (10:52)	10:54 (11:27)	11:15 (11:52)	11:44 (12:15)	11:43 (12:30)	12:12 (12:43)	12:23 (12:48)	12:40 (12:46)
NA	10:38 (10:56)	11:36 (12:09)	11:39 (12:06)	11:17 (12:13)	11:48 (12:33)	11:21 (12:19)	11:44 (12:50)	11:56 (13:53)
Age (years)								
16-24	10:12 (10:57)	10:33 (10:53)	11:02 (11:26)	10:46 (11:19)	11:10 (11:38)	12:02 (12:16)	11:48 (12:08)	11:51 (12:09)
25-34	10:02 (10:19)	10:28 (10:22)	10:46 (10:56)	10:54 (11:12)	11:19 (11:30)	11:34 (11:50)	11:40 (12:01)	12:07 (12:21)
35-44	8:42 (9:20)	9:12 (9:31)	9:28 (10:04)	9:33 (10:18)	10:10 (10:55)	10:07 (10:58)	10:24 (11:09)	11:00 (11:36)
45-54	8:06 (8:30)	8:39 (9:02)	8:37 (9:07)	8:46 (9:32)	9:01 (9:49)	9:05 (10:09)	9:20 (10:30)	10:07 (11:12)
55-64	7:49 (7:48)	8:15 (8:21)	8:14 (8:35)	8:02 (8:26)	8:17 (8:53)	8:07 (9:00)	8:34 (9:42)	8:52 (9:56)
Education[Ŧ]								
School to 16	9:41 (11:28)	10:01 (11:28)	10:20 (11:49)	9:47[¥] (10:40)[¥]	9:45 (11:13)	10:15 (12:06)	10:40 (12:17)	10:18 (11:39)
School to 18	9:00 (10:08)	9:33 (10:31)	9:46 (11:00)	9:47 (11:01)	10:02 (11:19)	10:36 (11:50)	10:35 (11:42)	11:05 (12:06)
Trade school/college	9:20 (10:15)	9:54 (10:20)	10:08 (10:53)	10:08 (11:03)	10:22 (11:06)	10:53 (11:24)	11:04 (11:46)	11:28 (12:05)
UG Degree	9:21 (9:42)	9:46 (9:50)	10:05(10:19)	10:10 (10:39)	10:36 (11:06)	10:46 (11:09)	10:51 (11:13)	11:06 (11:23)
PG Degree	9:46 (10:17)	10:17 (10:27)	10:34 (10:56)	10:52 (11:33)	11:36 (11:36)	11:24 (11:34)	11:34 (11:52)	11:41 (12:07)
Sex								
Male	9:21 (10:09)	9:41 (10:01)	10:00 (10:41)	9:59 (10:48)	10:24 (10:49)	10:36 (11:26)	10:49 (11:36)	11:01 (11:48)
Female	9:19 (9:59)	9:57 (10:18)	8:33 (10:48)	10:27 (10:58)	10:29 (11:20)	10:57 (11:42)	10:52 (11:41)	11:18 (12:05)

*AP = Asia Pacific, LA = Latin America, MEA = Middle East and Africa, NA = North America.
[Ŧ]UG Degree = Undergraduate Degree, PG Degree = Postgraduate Degree
[¥]Midpoint used due to anomalous data.

Total screen time, which comprised of PC, laptop and tablet, mobile phone, traditional TV, online TV, and games console use, from 2012-2019 is summarised in Table 1. Internationally, daily mean per capita screen time increased from approximately 9 hours in 2012 to 11 hours in 2019. The greatest increase was observed in Latin America, which exhibited a rise of approximately 3 hours during the period studied. In each survey year, the highest volume of screen time was observed among the 16-24 and 25-34 age groups, with total screen time typically declining with age. Within education groups, there has been a greater increase in usage among the more educated. Throughout the period of study, total screen time was similar in males and females.

Temporal trends in daily duration of time spent in the five behaviours of interest are presented in Figure 3 with numeric values available in Appendix 2. PC, laptop and tablet use declined by approximately 1 hour a day between 2012 and 2019, while daily mobile phone use increased by approximately 2 hours a day over the same period. Use of traditional TV reduced across the seven-year period, whilst there was a slight increase in online TV and games console use.

Figures 4-8 illustrate temporal trends in use of PC, laptop and tablet (Figure 4), mobile phone (Figure 5), traditional TV (Figure 6), online TV (Figure 7) and games console (Figure 8), stratified by region, age, education and sex. Numeric values are available in Appendices 3-7. There is variation in the vertical axis (daily duration hr:min/day) across each of the six figures to highlight trends over time rather than facilitate comparison of absolute durations between behaviours.

Figure 4 shows a decline in the time spent on a PC, laptop and tablet for all regions between 2012 and 2019, with the greatest decrease in the Asia Pacific region. There was also a decrease in the time spent using a PC, laptop and tablet in both sexes and across all age and education groups. Findings show that the 25-34 age group and individuals who have higher levels of education had the highest levels of time spent on these devices.

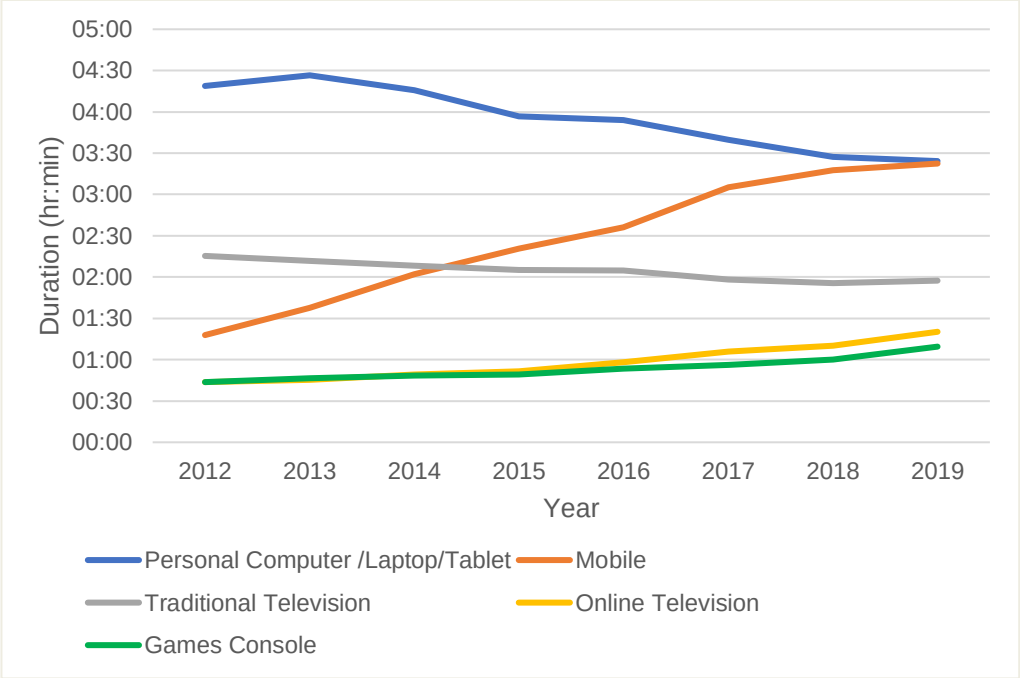


Figure 3. International temporal trends in daily per-capita duration (hr:min) of screen-based behaviours from 2012-2019.

Figure 5 shows that time spent online via a mobile phone increased each year across all regions, with the greatest increases being observed in Latin America (3 hours approximately) and the Middle East and Africa (2 hours approximately). In each survey year, the younger age groups consistently had the highest volume of time spent on a mobile, with findings demonstrating that mobile phone use decreased with age. There was, however, an increase over time in duration of mobile phone use across all age groups and education groups, and among both males and females.

Figure 6 shows that time spent watching traditional TV declined over time across all regions, with the greatest reduction occurring in North America. Nevertheless, North America still had the highest levels of TV viewing time across each survey year. Traditional TV viewing time decreased across all age groups between 2012 and 2019. The oldest age groups consistently had the highest amounts of TV viewing time, with viewing time increasing with age. TV viewing time also decreased for both sexes, with females having higher amounts of TV viewing time than males across each survey year. There were no clear differences between education groups.

Figure 7 depicts an increase in the volume of time spent watching online TV, which was observed in all regions, age groups, education groups and for both sexes. The

most notable differences were observed across age groups with younger people having the highest amounts of time spent watching online TV.

Figure 8 provides a breakdown in games console use over time by region, age, education, and sex. Increases in time spent on a games console were observed for all regions, age groups, education groups and both sexes. Notable differences were observed across age groups with younger people spending a greater volume of time on a games console compared to older age groups. It was also observed that males consistently reported more time on a games console than females across each survey year.

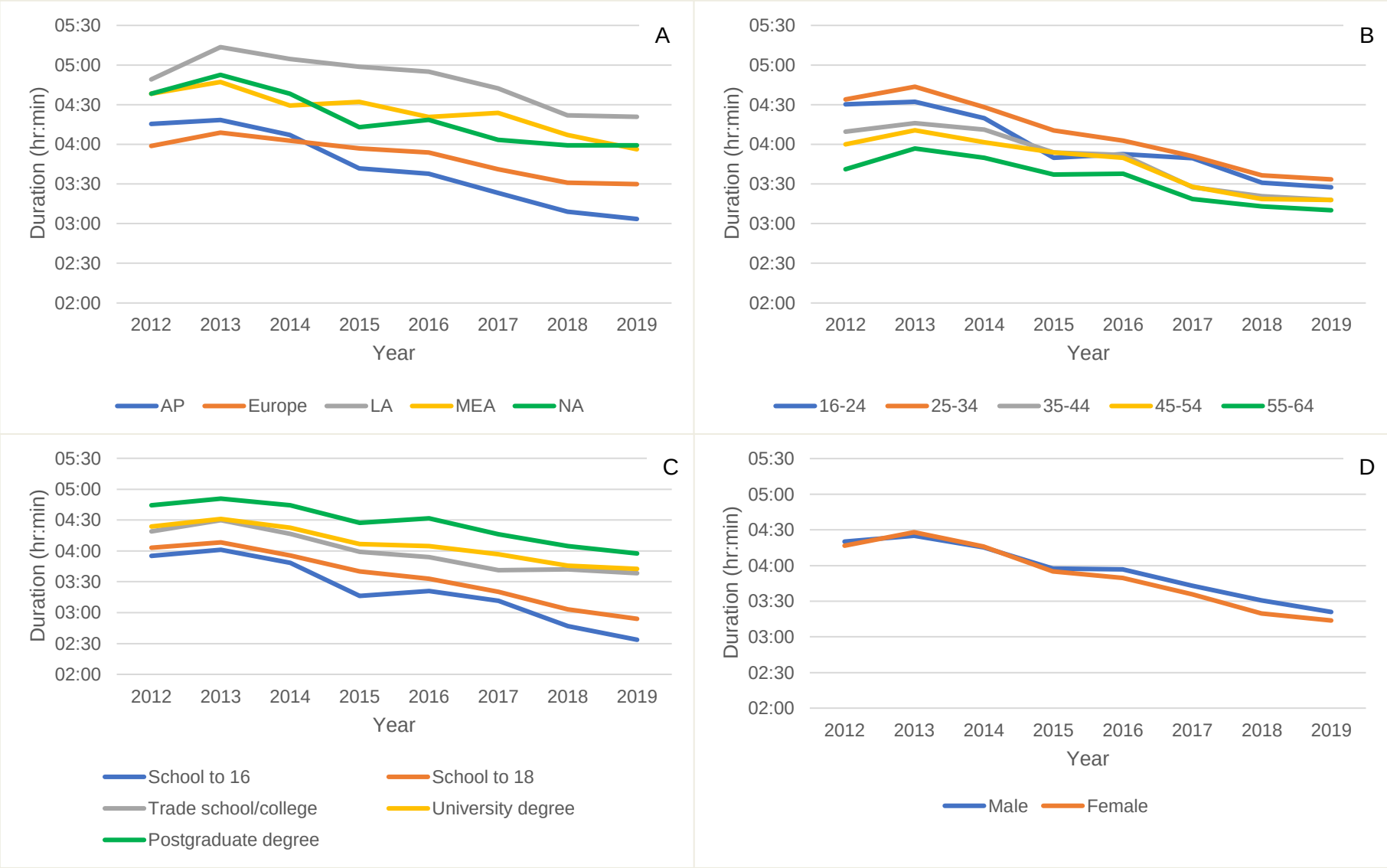


Figure 4. Temporal trends in daily per-capita duration (hr:min) of time spent online (via personal computer/laptop/tablet), stratified by (A) global region, (B) age-group, (C) education, (D) sex.

AP = Asia Pacific, LA = Latin America, MEA = Middle East and Africa, NA = North America

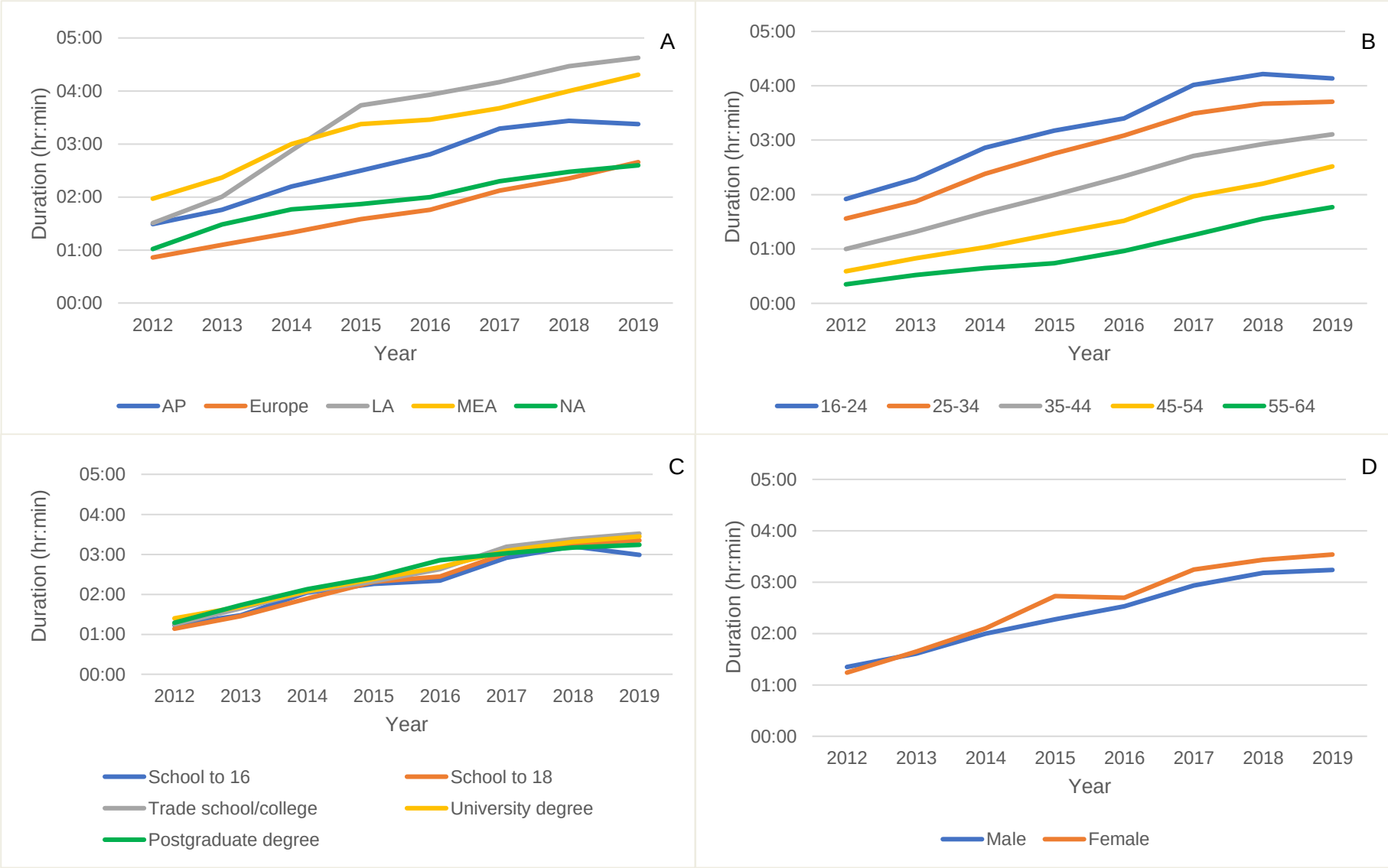


Figure 5. Temporal trends in daily per-capita duration (hr:min) of time spent online (via mobile), stratified by (A) global region, (B) age-group, (C) education, (D) sex.

AP = Asia Pacific, LA = Latin America, MEA = Middle East and Africa, NA = North America

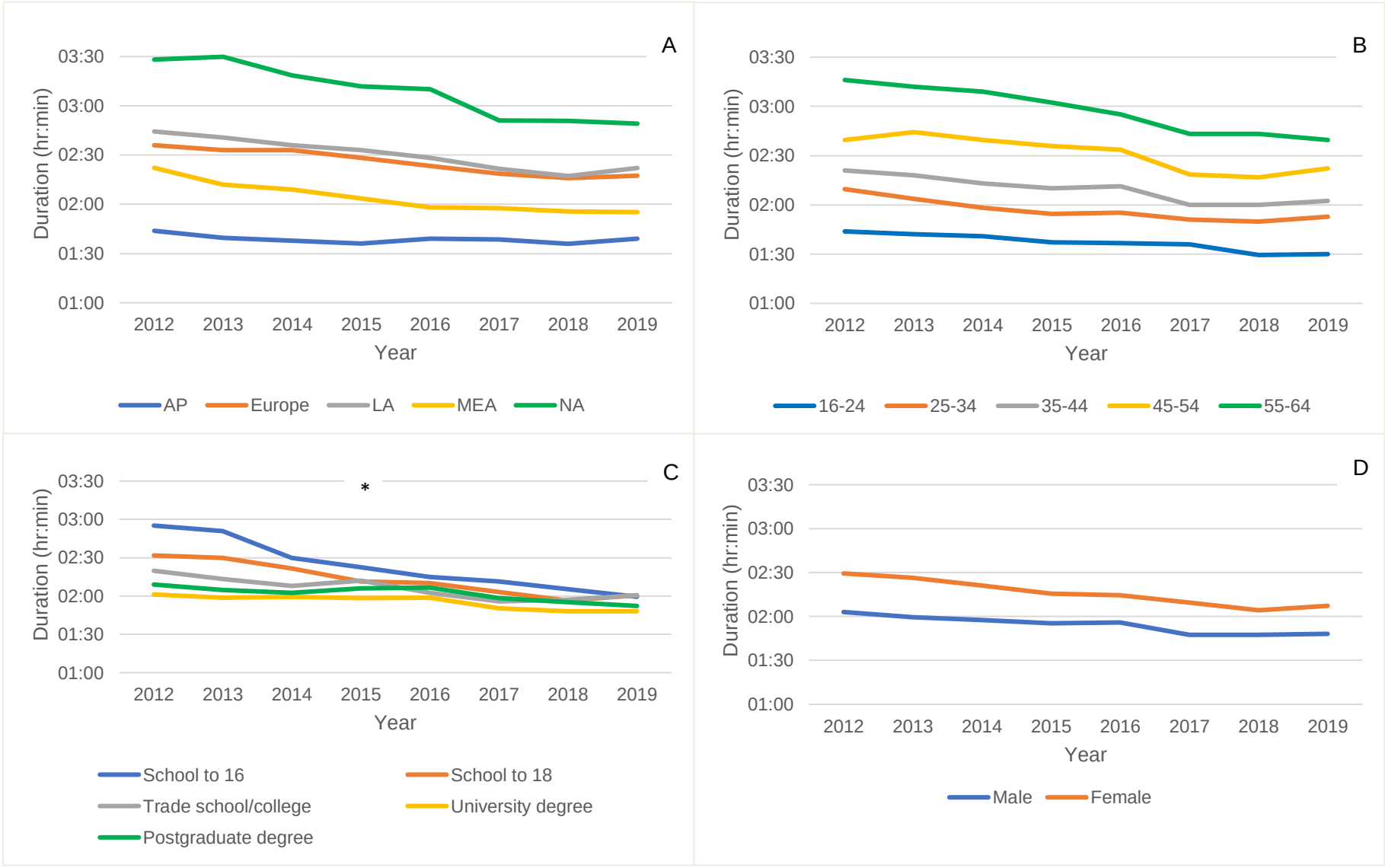


Figure 6. Temporal trends in daily per-capita duration (hr:min) of time spent watching traditional television, stratified by (A) global region, (B) age-group, (C) education, (D) sex.

AP = Asia Pacific, LA = Latin America, MEA = Middle East and Africa, NA = North America.

*Midpoint used for school to 16 group in 2015 due to anomalous data.

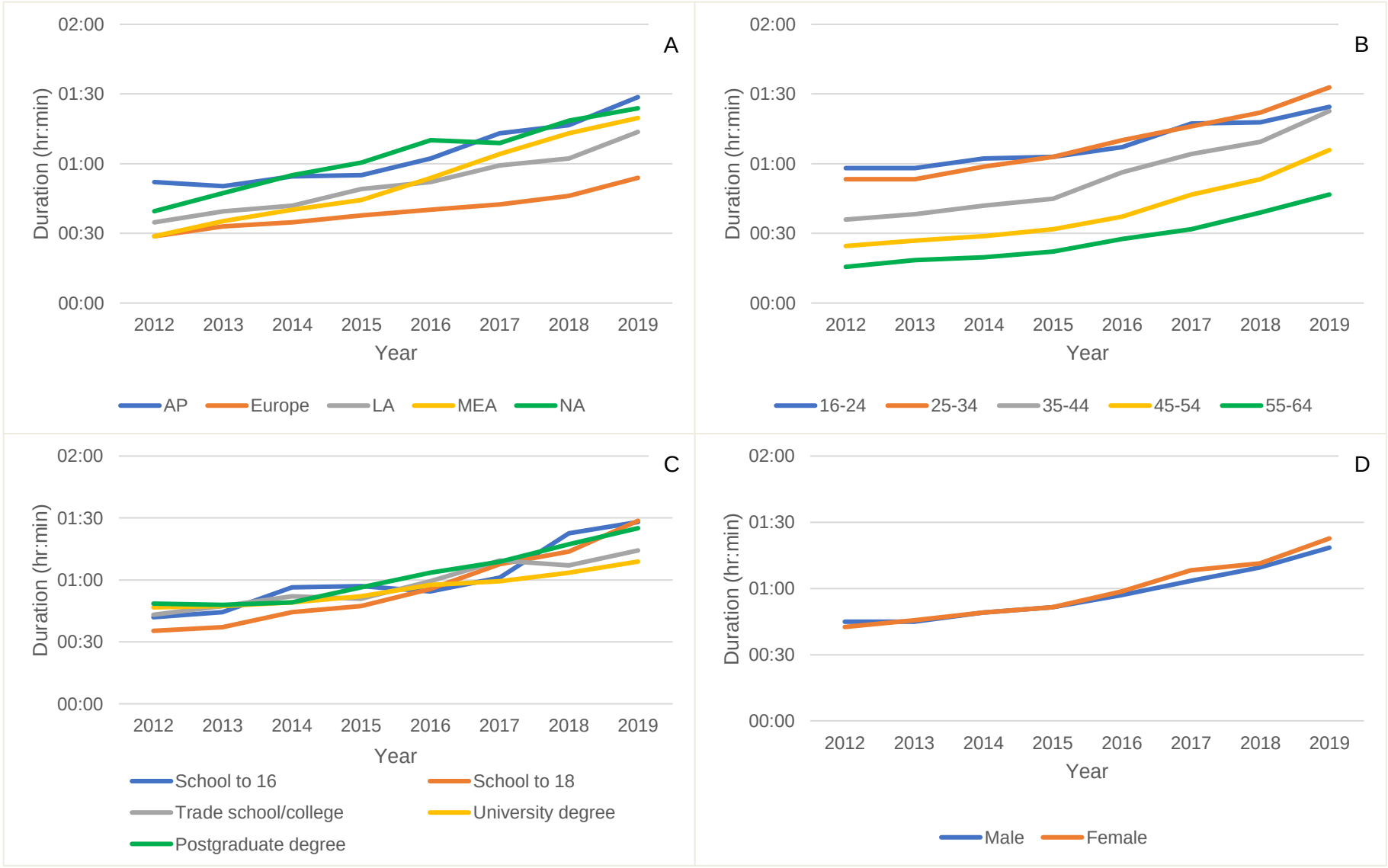


Figure 7. Temporal trends in daily per-capita duration (hr:min) of time spent watching online television, stratified by (A) global region, (B) age-group, (C) education, (D) sex.

AP = Asia Pacific, LA = Latin America, MEA = Middle East and Africa, NA = North America

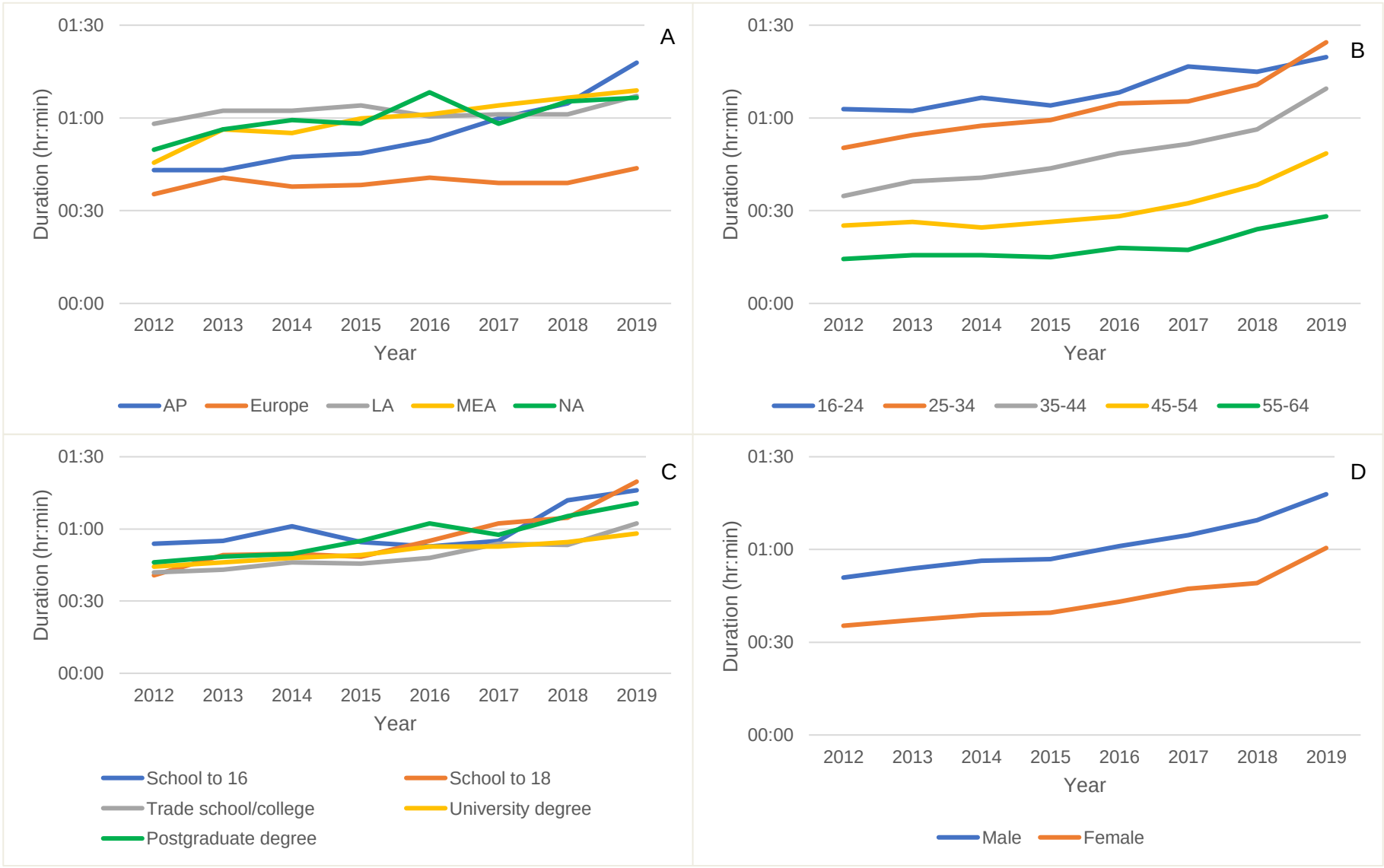


Figure 8. Temporal trends in daily per-capita duration (hr:min) of time spent playing on a games console, stratified by (A) global region, (B) age-group, (C) education, (D) sex.

AP = Asia Pacific, LA = Latin America, MEA = Middle East and Africa, NA = North America

3.4 Discussion

Data collected over the period 2012-2019 from over 2 million participants are used to describe international temporal trends in the duration of screen-based behaviours. Notable increases in the duration of overall screen time across all sub-groups during the period of study were observed, with the greatest increases occurring in Latin America, the Middle East and Africa and among younger age groups. Findings also indicate temporal changes in the types of screen-based activities being undertaken across the globe, with mobile phone use, online TV viewing and games console use increasing across the eight-year period. This has been accompanied by a decrease in PC, laptop and tablet use and traditional TV viewing. These findings have important implications for public health surveillance of screen time and future research exploring the links between screen time and health.

This study has demonstrated a decrease in levels of traditional TV viewing across the eight-year period of study. TV viewing is one of the most researched screen-based behaviours and has consistently been associated with negative health outcomes (LeBlanc *et al.*, 2017; Saunders *et al.*, 2020). The present findings suggest that online TV viewing, or other screen behaviours, may have replaced some of the time previously spent watching traditional TV. At present, it is not clear whether there are postural differences when engaging in traditional versus online TV viewing. There is, however, evidence that traditional TV viewing promotes unhealthy eating through advertisements, which may, in part, be the mechanism linking TV with adiposity (Biddle *et al.*, 2017). Recent evidence indicates that internet streaming services tend to have a lower frequency of adverts than traditional TV (Vizcaino *et al.*, 2020) suggesting that it may not be appropriate to infer that the health detriments associated with traditional TV will be applicable to newer forms of TV. Future research should differentiate these types of TV viewing, in order to establish their specific links with health and well-being.

Time spent online on a mobile increased considerably between 2012 and 2019. This is concurrent with an increase in smartphone ownership during this period and improvements in device capability (Statista, 2021). The extent to which smartphones promote sedentary behaviour or physical activity remains unclear (Lepp *et al.*, 2013; Alley *et al.*, 2017; Biddle *et al.*, 2017). Smartphones and tablets

can be used whilst standing still or moving around (Alley *et al.*, 2017) and new devices such as smart watches and tablets have design features that may discourage or disrupt prolonged periods of sedentary behaviour (Barkley, Lepp and Salehi-Esfahani, 2016). There are also potential positive outcomes associated with certain types of screens with a recent narrative review outlining the usefulness of commercial video games in reducing symptoms of depression and anxiety (Kowal *et al.*, 2021). Collectively, this research highlights the potential benefits that some forms of screens possess and highlights the importance of assessing the associations between contemporary screen-based behaviours and health outcomes.

Given the increasing use of smartphones it is striking that many of the self-report tools currently used to measure screen time focus primarily on TV viewing and leisure time computer use (Vizcaino *et al.*, 2019). A recent review found that amongst questionnaires designed to assess screen-based behaviours, TV viewing was assessed in 72% of questionnaires and computer and/or videogame time in 39% of questionnaires (Prince *et al.*, 2017b). However, no information was included on the percentage of questionnaires that assessed mobile phone use (Prince *et al.*, 2017b). Therefore, it seems timely to review existing physical activity and sedentary behaviour tools to ensure research is capturing the expanding breadth of screen-based behaviours (Gunnell et al., 2018). We concur with the recommendation of Ross *et al.* (2020) that screen time measurement should be expanded in research and surveillance to include a variety of screen-based behaviours and to assess the domain in which use occurs. There is also a need to better assess the postures and co-occurring activities that accompany screen-use. This will help establish potential mechanisms linking screen behaviours with health markers and aid the development of behaviour change interventions. One route to obtaining better measurement of sedentary behaviours is the combined use of wearable devices and participant reports, such as inclinometry or thigh-worn devices to assess posture and diary-based methods to capture behaviour and context. For populations where phone or tablet ownership is high, the use of diary or questionnaire applications is recommended to encourage reporting of activities at specified intervals throughout the day.

A notable increase in screen time over the period of study was observed, consistent with previous research in Australia, Canada, the Netherlands and the USA (Chau *et al.*, 2012; Van Der Ploeg *et al.*, 2013; Yang *et al.*, 2019; Prince *et al.*, 2020a), but the greatest increases in screen time were observed in Latin America and the Middle East and Africa. Many countries within Latin America and the Middle East and Africa are classified as low- or lower-middle income according to The World Bank (World Bank, 2021). These findings are consistent with previous research indicating that access to technology, and in particular screen ownership, is expanding rapidly within developing countries (LeBlanc *et al.*, 2017). For example, smartphone ownership in emerging economies increased from 18% in 2013 to 47% in 2018 (Silver, 2019). This rise in screen-based behaviours in low- and middle-income countries may be reflective of the epidemiological transition (Katzmarzyk and Mason, 2009) and indicates that without intervention, populations in these settings may spend increasing amounts of time engaged in screen-based behaviours, as already demonstrated in high-income countries. Overall, these changes are likely to be detrimental to health, indicating the need for strategies and interventions to focus on low- and middle-income countries.

Perhaps unsurprisingly, it was found that younger age groups, those aged 16-24 and 25-34, had the highest amounts of time spent on each of the behaviours studied, apart from traditional TV viewing. This is consistent with previous research indicating age-related differences in screen-behaviour patterns (Herman and Saunders, 2016). In the USA, in 2018, for example, individuals aged 18-34 spent a greater proportion of their day accessing apps and the internet via a smartphone and engaging with TV connected devices, such as watching DVDs and using games consoles, compared to older age groups (Nielsen, 2018). In the UK, a 2018 survey by Ofcom found that adults aged 55-64 were more likely to report using any type of TV compared to those aged 16-24 (Ofcom, 2018). Comparatively, adults aged 16-24 were more likely to report using a games console compared to those aged 55-64 (Ofcom, 2018). Consistent with Herman and Saunders (2016), the findings from the present study suggest that interventions aimed at changing the time spent using screens should be tailored to age-specific preferences and patterns of use.

A strength of this study is the use of large-scale international data to describe temporal trends in screen behaviours and explore differences for a range of socio-demographic sub-groups. Use of industry data enabled the exploration of trends in contemporary screen-based behaviours, which are often omitted from academic research. A limitation is that country-specific samples were recruited to be representative of the online population rather than be nationally representative of the resident population as a whole. For high income countries, where internet penetration may exceed 90% (Statista, 2023), sampling only from the online population may have relatively limited impact on generalisability of findings. However, the effect is likely to be more pronounced in lower income countries, where internet access is lower and heavily socially patterned (Statista, 2023). In such countries, internet users are more likely to be young, urban and educated (GWI, 2020). In addition, no data were collected in adults over 65 years of age, due to difficulty in recruiting a sufficient number of participants in this age group where internet penetration is low (GWI, 2020).

An additional limitation of this study is that the questionnaire used by GWI to assess screen use has not been formally tested for reliability and validity. The estimate of overall screen-time may be inflated due to possible overlap in questionnaire item coverage (for example, streaming TV on a tablet), failure to account for screen multi-tasking and the use of categorical and non-mutually exclusive response options. One way in which this could be overcome is for participants to report all the screen activities they are engaging in at one time. Alternatively, participants could be asked to report their primary activity and any background screen use, as has been done elsewhere (Vizcaino *et al.*, 2019). Finally, as noted in the methods, the data were provided in aggregated form, such that formal statistical testing of temporal changes or between group differences were not possible. It is worthwhile noting that given the very large sample size, formal hypothesis testing would likely have produced small, notionally statistically significant, p-values in most instances.

3.5 Conclusion

This study used data from over 2 million participants, collected over an eight-year period, to explore international temporal trends in the duration of screen-based behaviours. The results demonstrate that screen time is increasing globally, with Latin America, the Middle East and Africa and younger age groups seeing the

greatest increases. Additionally, the ways in which people are engaging with screens is changing, with large increases being seen particularly in mobile phone use. Findings indicate a need to review existing screen time measures to establish how effectively they capture contemporary behaviour patterns and update them accordingly. It also highlights the need for policies to acknowledge that all parts of the world, and particularly lower income regions are seeing increasing rates of screen use, which may have implications for public health and well-being.

Chapter 4: The diurnal pattern and secondary activities associated with leisure time sedentary and screen-based behaviour in adults.

4.1 Introduction

The temporal trends analysis conducted in Chapter 3 identified that the daily duration of time spent in overall screen time and in specific screen-based behaviours, namely mobile phone use, online TV, and games console use, is increasing internationally. However, as demonstrated in Chapter 2, the majority of research to date has assessed daily durations of behaviours rather than exploring when these behaviours occur throughout the day. Additionally, the previous chapter demonstrated the behaviours that are being engaged in, but it would also be useful to assess what behaviours co-occur alongside different types of sedentary behaviours. Gaining an understanding of diurnal patterns and co-occurring activities extends the work in Chapter 3 by further characterising the nature of behaviour patterns. This in turn provides a more sophisticated understanding of different types of sedentary and screen-based behaviours which can be used to inform research on the health impacts of these types of behaviours and the design of behaviour change interventions. Therefore, this chapter seeks to assess the diurnal patterns and secondary activities associated with sedentary and screen-based behaviours across a 24-hour day in adults, using time use data from the UK.

4.2 Background

Time spent in sedentary behaviours has important implications for health and wellbeing and has been identified as a potentially important risk factor for chronic disease (Stamatakis *et al.*, 2019; Ferguson *et al.*, 2021). Sedentary behaviour can occur in many forms, with common activities including TV viewing, reading and driving (LeBlanc *et al.*, 2017). A TV was once the only screen-based device available to many people (Biddle *et al.*, 2017) and thus much early sedentary behaviour research measured the duration of this activity (Salmon *et al.*, 2000; Jakes *et al.*, 2003). However, the breadth and accessibility of screen-based devices, such as computers, smartphones, tablets and games consoles has increased significantly in recent years and such devices may promote prolonged sedentary time (Biddle *et al.*, 2017). Nevertheless, research has shown that not all types of sedentary behaviour have the same associations with health, which may

be influenced by whether a behaviour is mentally active or passive, amongst other things (Kikuchi *et al.*, 2014; Hallgren *et al.*, 2018, 2020; Hallgren, Dunstan and Owen, 2020). For example, a 30-minute increase in passive sedentary behaviour, such as TV viewing, was associated with increased odds of depressive symptoms cross-sectionally, whilst an increase in mentally active sedentary behaviour, such as knitting/sewing, was associated with reduced odds of depressive symptoms (Hallgren *et al.*, 2020).

A large amount of previous research has assessed the time spent in both sedentary behaviour overall and in specific sedentary activities (Chau *et al.*, 2012; Aadahl *et al.*, 2013; Prince *et al.*, 2020a), but fewer studies have explored when these activities take place during the day. One such study in older adults found that at least 30 minutes of each hour of the day was spent sedentary, with peaks occurring around 1pm and between 8pm and 10pm (Yerrakalva *et al.*, 2017). This is supported by industry collected data, which show that in adults', both TV viewing and reading appear to occur mostly in the evenings (YouGov, 2020; TV Licensing, 2022). In addition to understanding when sedentary behaviours take place during the day, it is informative to know what activities occur alongside different types of sedentary behaviour to understand behaviour patterns and co-occurring activities. 'Screen multi-tasking' involves using multiple screens simultaneously (LeBlanc *et al.*, 2017), for example, using a smartphone or tablet whilst also watching TV. In a similar vein, gaming headsets allow people to communicate whilst playing videogames, providing a social dimension to an activity typically considered to be solitary. A more nuanced understanding of the patterns and co-occurring activities associated with sedentary behaviour will support further research into the health outcomes of different types of behaviour (Bauman, Bittman and Gershuny, 2019). Additionally, understanding the diurnal pattern of sedentary and screen-based behaviours, as well as which secondary activities occur alongside different types of sedentary behaviour, can help to inform the development of behaviour change interventions. This can be accomplished by tailoring interventions to the specific times and contexts in which behaviours take place, thus providing a more precise targeting of behaviours.

Time use diaries are a useful means of capturing the sequence, duration, characteristics and context of behaviours across a 24 hour time period, which can

be used to further understanding of health outcomes (Bauman, Bittman and Gershuny, 2019). Therefore, the aim of this study was to use the United Kingdom Time Use Survey (UKTUS) to describe the diurnal pattern and secondary activities associated with sedentary and screen-based behaviours in adults.

4.3 Method

4.3.1 Sample and data collection

This study was conceived to assess behaviour patterns across the day; and therefore the pool of potential datasets was small and limited to those that had applied time-use diary methods. Data were from the 2014-2015 UKTUS (Sullivan and Gershuny, 2022), conducted on behalf of the University of Oxford's Centre for Time Use Research by NatCen and the Northern Ireland Statistics and Research Agency. The UKTUS was selected because it was the most recent time use survey available and the data could be downloaded immediately at no cost. Furthermore, the activities were coded into small units of behaviour which were relevant to the study research questions. Additionally, a robust recruitment strategy was employed which minimised sampling bias and ensured the sample was population representative. Specifically, the UKTUS used a two-stage stratified probability sampling design. In stage 1, a random sample of primary sampling units (PSUs), based on postcode sectors, was selected. A postcode sector combines a postcode area and district along with a single character e.g., SW1A 0 (Bainbridge, 2017). In stage 2, a random sample of postal addresses was drawn from each selected PSU. From 11,860 sampled households, 4,238 'household' interviews were conducted using Computer Assisted Personal Interviewing (response rate: 40.4%), in which one member of the household answered a demographic questionnaire. From these 4,238 participating households, 10,208 people aged 8+ years completed an 'individual' interview, which included modules related to education, volunteer work and leisure activities, for example.

4.3.2 Time-use diary

All participants who completed an individual interview were eligible to complete a time-use diary. Each household was randomly allocated two diary days (one weekday and one weekend day) with all members expected to complete the diaries for the same days. Each day was split into 10-minute slots, running from 4am-4am

the next day. For each time slot, participants reported their main (primary) activity and any secondary activities which occurred simultaneously. Participants responded in free text; responses were subsequently categorised into 270 sub-categories, 33 main categories and 10 domains as described previously (Morris *et al.*, 2016). An extract of the time use diary can be found in Figure 9.

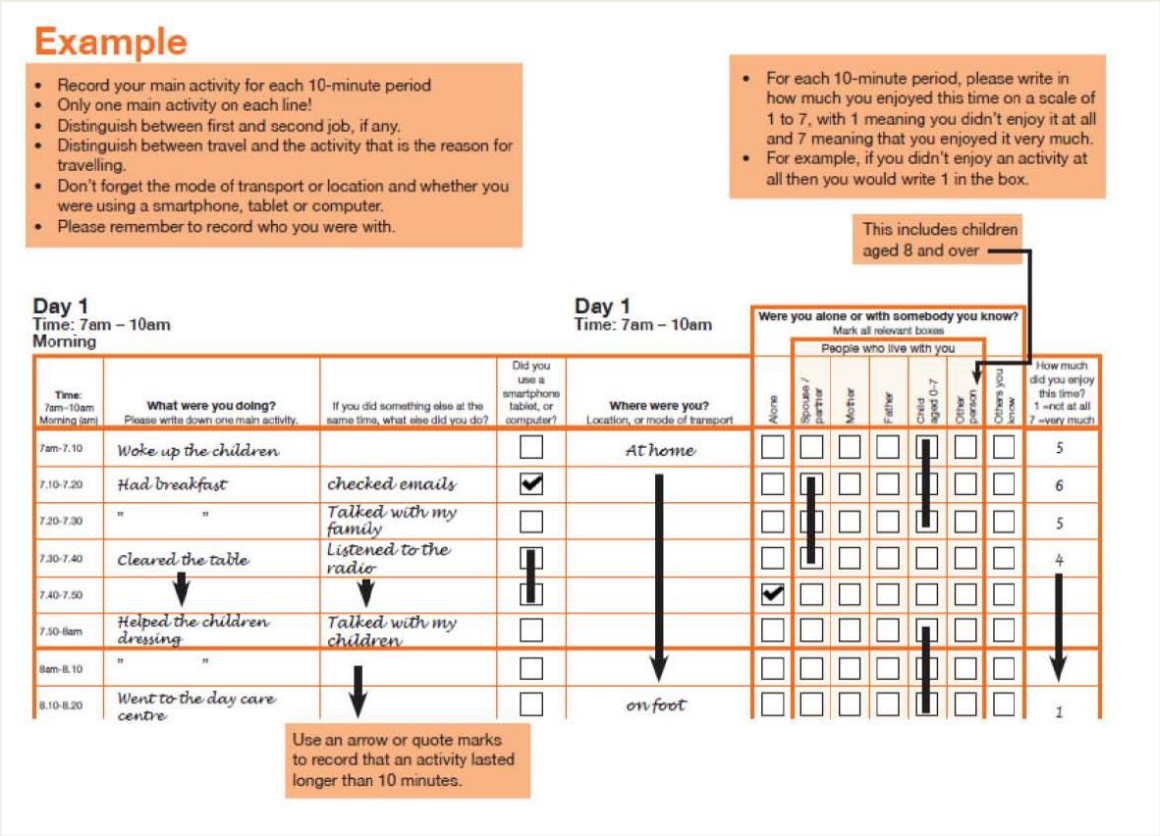


Figure 9. Example diary from the United Kingdom Time Use (Morris *et al.*, 2016).

4.3.3 Sedentary and screen-based behaviours

In terms of primary activities, the present analysis focuses on the following non-work-related screen and sedentary behaviours: 1) resting/time out; 2) reading; 3) TV, video and DVD; 4) internet use (including shopping, finance and browsing); 5) online communication; 6) gaming; and 7) other computer use. A description of the individual activities included in each category is provided in Appendix 8. Work/employment is categorised as a separate activity in the UKTUS, thus occupational sedentary time is not captured within this analysis.

For each timeslot, participants optionally reported any 'secondary' activities that were performed in parallel to the primary activity. Secondary activities were

categorised as follows: 1) personal care; 2) employment; 3) study; 4) household and family care; 5) volunteer work; 6) social life and entertainment; 7) hobbies, games, and computing and 8) mass media. Travel and sport were also collected as secondary activities but were removed from the analysis due to the low number of reported episodes. A description of the types of activities included within each secondary activity group is provided in Appendix 9.

4.3.4 Data analysis

Data management and analyses were conducted in Stata Version 16.1 (StataCorp, 2019). Quality control checks were conducted prior to analysis, with diaries being removed if they included missing data or one or more timeslots were coded as 9960 (no main activity no idea what it might be), 9970 (no main activity some idea what it might be), 9980 (illegal activity), 9990 (unspecified time use), 9991 (not applicable) or 9999 (queryable) (University of Oxford, 2016). Diaries were also removed for participants 1) aged <18 years of age, or 2) with missing data for the type of day (e.g., workday or non-workday), sex, age, or economic activity. Data are presented separately for work and non-workdays, as reported by participants at the time of completion. To describe the diurnal patterns for each of the seven primary activities, data were aggregated to summarise duration (mean minutes) for each hour of the 24h assessment period. Separately for each primary activity, we calculated the proportion of timeslots in which a co-occurring (secondary) activity was reported, and, for this subset of records, the proportion of timeslots spent in each of the secondary activity groups.

4.4 Results

Data were available for 8,278 participants, who collectively provided 16,533 days of diary data; 2,248 diary days were excluded for participants aged <18 years and a further 4,458 were excluded due to missing data. Thus, analyses were based on n=9,827 diary days (workday n=3,164; non-workday n=6,663), obtained from n=5,880 participants. From this sample (n=5,880) one diary day was provided by 1,933 participants and two diary days were provided by 3,947 participants. Participants in the analytical sample were more likely to be male (47.1% vs 45.9%) and in employment (61.2% vs 58.8%), but less likely to be aged 65 years and over (21.9% vs 23.5%) than those who were excluded.

4.4.1 Sample characteristics

Sample characteristics overall and stratified by workday and non-workday, are reported in Table 2. Overall, the majority of the sample were female (52.9%), aged 65 years and above (21.9%) and in employment (61.2%).

Table 2. Sample characteristics.

	Overall		Workday		Non-workday	
Participants (n)	n=5880		n=1898		n=3982	
Diary Days (n)	n=9827		n=3164		n=6663	
Sex (n (%))						
Female	3110	(52.9)	880	(46.4)	2230	(56.0)
Male	2770	(47.1)	1018	(53.6)	1752	(44.0)
Age (n (%))						
18-24	565	(9.6)	255	(13.4)	310	(7.8)
25-34	936	(15.9)	401	(21.1)	535	(13.4)
35-44	951	(16.2)	407	(21.4)	544	(13.7)
45-54	1171	(19.9)	455	(24.0)	716	(18.0)
55-64	968	(16.5)	290	(15.3)	678	(17.0)
65+	1289	(21.9)	90	(4.7)	1199	(30.1)
Economic activity (n (%))						
In employment	3597	(61.2)	1735	(91.4)	1862	(46.8)
Unemployed	174	(3.0)	26	(1.4)	148	(3.7)
Economically inactive	2109	(35.9)	137	(7.2)	1972	(49.5)

4.4.2 Diurnal patterns of sedentary behaviours for the overall sample

The diurnal pattern of all primary activities, stratified by work and non-workdays, is presented in Figure 10. Due to the greater duration of time spent watching TV, this behaviour is reported separately (Figure 10c). For workdays (Figure 10a), between the hours of 12am and 12pm the duration of each sedentary behaviour was less than 0.5 minutes per hour, with gaming, internet use and other computer use all remaining below 1 minute per hour for the whole day. Time spent in all studied

behaviours rose gradually from 2pm onwards to a peak between 8-10pm, but hourly duration remained less than 2 minutes in all cases.

For non-workdays (Figure 10b), between the hours of 1am and 6am, time reported in all behaviours was less than 0.5 minutes per hour. Time spent resting increased gradually from 6am to a plateau of approx. 1-2 minutes per hour between 2-9pm. Time spent reading fluctuated between 1-2 minutes per hour from 8am-8pm, before rising sharply between 9-11pm. Time spent watching TV on a workday (Figure 10c) was less than 5 minutes per hour across most of the day, peaking to >10min per hour between 7-11pm. On non-workdays the duration of TV viewing was consistently above 5 minutes per hour between 1pm and 11pm. TV viewing time peaked at 9pm on both workdays (approx. 23 minutes) and non-workdays (approx. 29 minutes).

4.4.3 Diurnal patterns of sedentary behaviours for sex

The diurnal pattern of all primary activities for males and females, stratified by work and non-workdays, is presented in Appendices 10 and 11. On workdays the time spent in each behaviour gradually increased throughout the day, peaking in the evenings at approx. 9pm for both males and females. Behaviour patterns were largely similar between sexes, although there was some indication that time spent in gaming was greater in males than females, whilst the reverse was true for online communication. On non-workdays the patterns were less consistent, although the time spent in each behaviour gradually increased from 6am onwards. Resting tended to peak slightly later for males than females, while the reverse occurred for reading. On both workdays and non-workdays, TV viewing increased throughout the day for males and females, peaking at approx. 9pm.

4.4.4 Diurnal patterns of sedentary behaviours for age

The diurnal pattern of all primary activities for individuals aged 18-44 and those aged 45 and above are presented in Appendices 12 and 13. On workdays, the duration of time spent resting, reading, and engaging in online communication increased from approx. 3pm onwards in both age groups. On non-workdays for both age groups, resting increased from 6am onwards and peaked in the afternoon, meanwhile online communication peaked at 9am and reading at 10pm. The hourly

duration of time spent watching TV increased throughout the day on workdays and non-workdays for both age groups, peaking at 9pm.

4.4.5 Secondary activities

From a total of 1,412,807 10-minute time slots, a primary screen or sedentary behaviour was reported in 230,498 (16%) instances. Of these, 62,651 (27%) timeslots included a co-occurring 'secondary' activity. The proportion of time slots in which a secondary activity was reported alongside each of the primary activities of interest is reported in Figure 11. Overall, the results show that resting was accompanied by a secondary activity in over 50% of cases. For the other primary activities, a secondary activity was reported in approx. 30% of cases or less.

The secondary activities that were reported alongside each of the primary behaviours of interest are reported in Figure 12, stratified by work and non-workdays. For all primary activities, except TV, DVD and video viewing, mass media was the most prevalent secondary activity reported. For the primary behaviour of resting, for example, almost 60% of timeslots included mass media use as the secondary activity. Online communication was accompanied by a secondary activity of employment in approx. 20% of cases. Reading was accompanied by a secondary activity of mass media or personal care in approx. 70% of time slots. The secondary activity most commonly reported alongside TV viewing was socialising, which was observed for approx. 40% of timeslots.

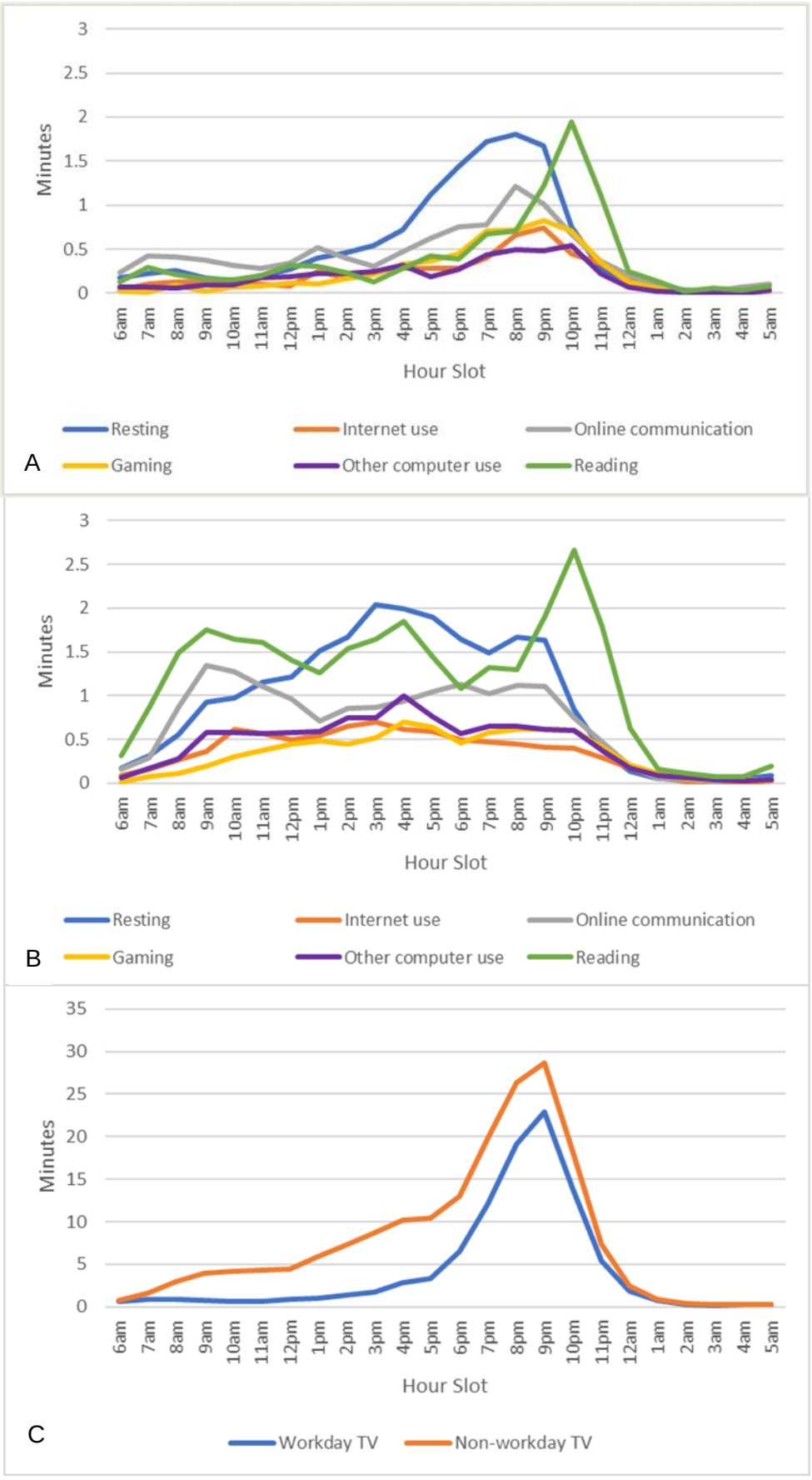


Figure 10. Diurnal patterns of primary activities for the overall sample stratified by A) workday, excluding TV viewing; B) non-workday, excluding TV viewing, C) workday and non-workday TV viewing.

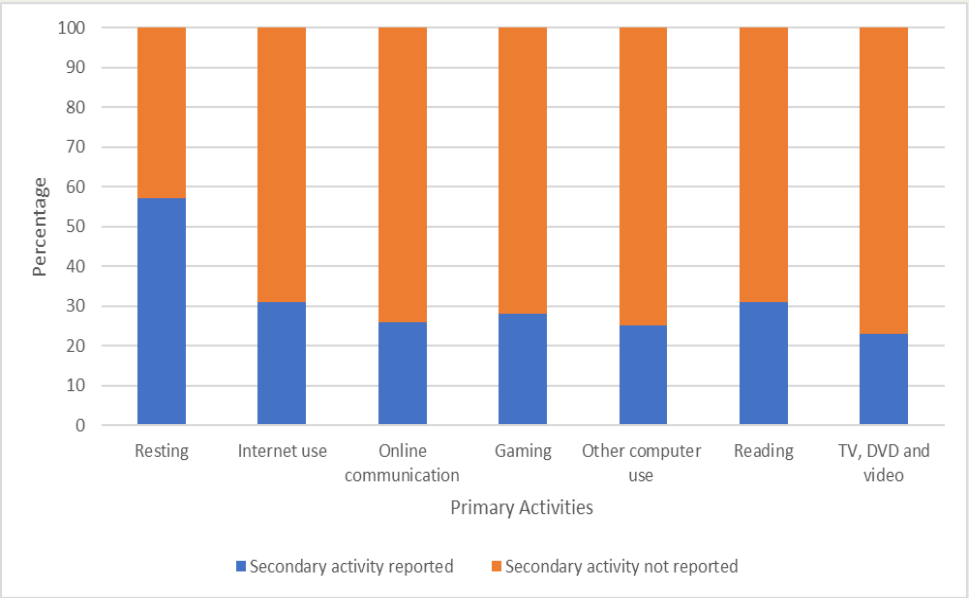


Figure 11. Proportion of time slots in which a secondary activity was reported for each primary activity.

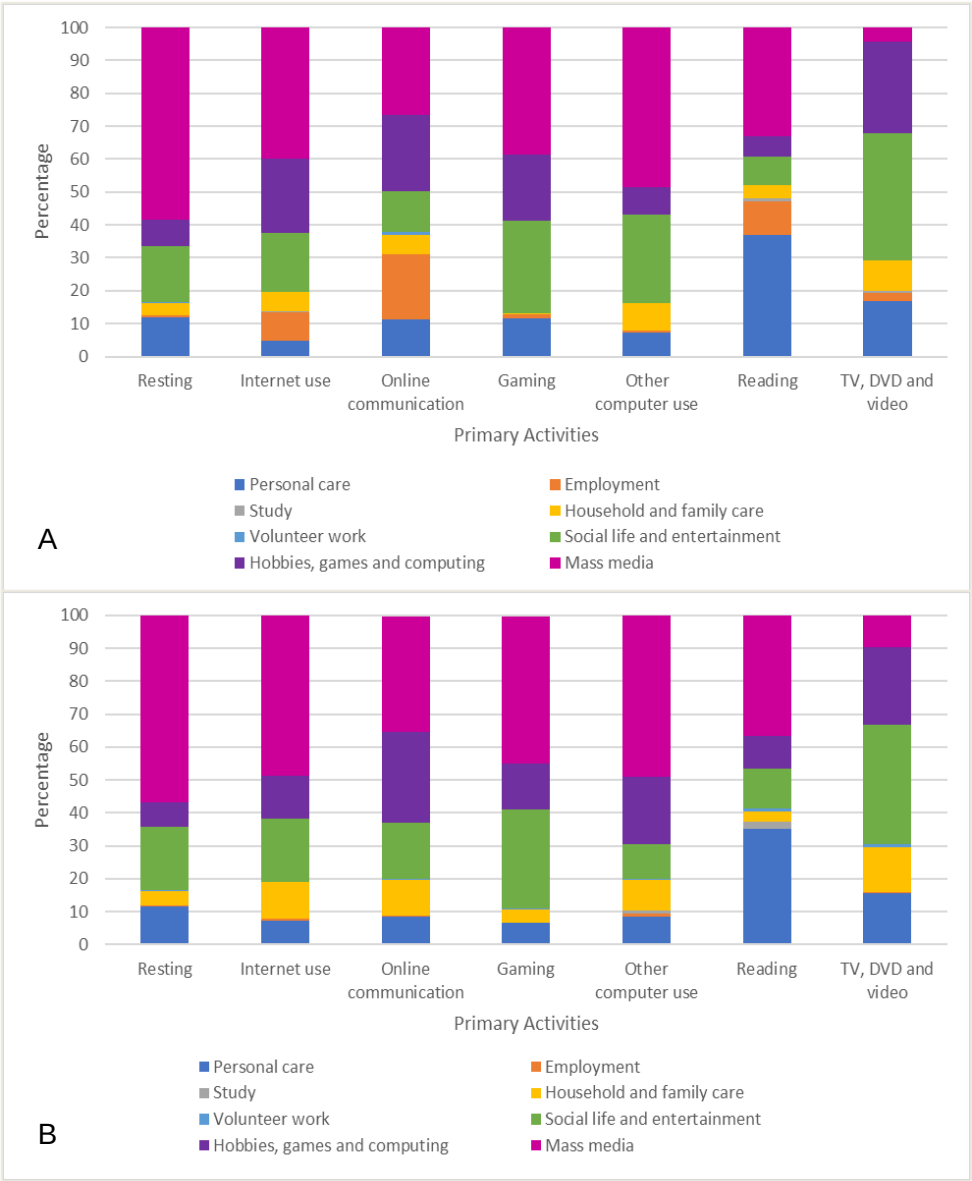


Figure 12. Proportion of 10-minute time slots spent in different types of secondary activities while engaging in each of the seven primary activities for A) workdays and B) non-workdays.

4.5 Discussion

Using data from the 2014-2015 UKTUS, this study describes the diurnal patterns of selected sedentary and screen-based behaviours and the secondary activities that co-occur alongside them. The results show that all the sedentary and screen-based behaviours studied tended to gradually increase in duration from approx. 2pm-11pm on workdays, whilst on non-workdays, behaviour durations fluctuated between 6am-11pm. However, on both types of day all sedentary and screen-based behaviours tended to peak between 8pm-10pm. Perhaps surprisingly, reporting of a secondary activity alongside a screen-based or sedentary behaviour was low; present in less than a third of all observations. Where reported, the most common secondary activity that accompanied the primary behaviours of interest was use of mass media, such as watching TV or reading.

The findings highlight that on workdays, behaviours tended to gradually increase throughout the day, peaking in the evenings. On non-workdays the pattern was less consistent with a peak in time spent resting being seen at 3pm whilst TV viewing and reading peaked in the evenings at 9pm and 10pm respectively. This is consistent with previous research in older adults which found that device-measured sedentary time tended to increase during the day, with peaks occurring at 1pm and between 8pm and 10pm (Yerrakalva *et al.*, 2017). Also based on accelerometer data, a study in Japanese adults showed that on both workdays and non-workdays, sedentary time was highest in the evenings, consistent with the findings from this study (Kurosawa *et al.*, 2020). Previous time use research has consistently shown that individuals spend a large proportion of their leisure time in sedentary activities (Chau *et al.*, 2012; Loyen *et al.*, 2019); the current study extends these findings by demonstrating when different sedentary behaviours occur during the day. These results can be used in the design of behaviour change interventions to inform more precise timings and to assist in the tailoring of interventions to the type (work/non-workday) and time of day. For example, Just-In-Time Adaptive Interventions (JITAIs) are a recent technology-based method of changing behaviour (Müller, Blandford and Yardley, 2017). This type of intervention collects contextual data such as a person's location and the time of day which enables support to be tailored to individual's and provided in real time (Müller, Blandford and Yardley, 2017; Hardeman *et al.*, 2019).

The current findings indicate possible sex differences in the time that behaviours occur during the day, though differences were small and not subject to formal statistical testing. Previous studies using device-based measures to assess sedentary time have revealed contradictory findings. One study suggested women spent more of their waking time sedentary compared to men (McVeigh *et al.*, 2016), whilst another concluded that men spent more time sedentary than women irrespective of the time of day and day of the week (Kurosawa *et al.*, 2020). The opposing findings between studies may be due to methodological differences, such as the sample characteristics (e.g. the country in which the study was conducted) and the age of the participants. Notwithstanding these points, both studies revealed sex differences in behaviour which may exist due to the different roles undertaken by men and women in society (Kurosawa *et al.*, 2020). This is supported by European Time Use data which demonstrates that women spend a larger proportion of their time undertaking household and care activities than men (Eurostat, 2022a). To date, there have been limited studies assessing the diurnal patterns of sedentary behaviours in men and women, and thus this study has extended the current knowledge in this area. These results highlight the need for interventions to be day, time, behaviour, and sex specific, such as targeting the reduction of gaming in men at approx. 9pm on workdays.

A sedentary or screen-based behaviour was accompanied by a secondary activity in less than a third of timeslots in the dataset. Previous research has shown that people often undertake more than one activity at the same time, known as multi-tasking (Eurostat, 2022a). Examples include cooking whilst listening to the radio or eating and socialising with family or friends. It is challenging to hypothesise why such a low rate of co-occurring activities was observed in this study. One possibility is that the primary sedentary activities undertaken required a level of concentration that made multi-tasking challenging. Alternatively, it could be that the respondent deemed any secondary activity insignificant if it occurred for a limited amount of time and thus, they did not report it; a required “dose” may be needed for respondents to register the action and recall it as a secondary activity. A third possibility is that participants did not opt to complete this section of the diary, given the diaries are burdensome to complete. It would be valuable to build on these findings by exploring secondary activities, possibly through qualitative methods, to gain a better understanding of what influences respondents to report a co-occurring

activity. It would also be useful to explore alternative methods of capturing multi-tasking, such as the reporting of all activities undertaken or the introduction of pre-determined behaviour combination categories (e.g. computer use and mobile phone use) that participants can choose from when completing online time use diaries (Sullivan *et al.*, 2020). Alternatively, the respondents could report their primary activity and then select an option for a screen or a non-screen-based activity as their secondary activity.

The current findings highlight that even when people report they are “resting” - and thus doing limited activity - they are often engaging in a secondary activity. The UKTUS defined resting as doing nothing, sitting and reflecting (Morris *et al.*, 2016). This illustrates the challenge of capturing multiple behaviours given respondents have reported doing nothing and yet are engaging in another activity. It also raises questions around how respondents classify primary and secondary activities. Furthermore, in over 50% of time slots where the primary activity was resting, this was accompanied by use of mass media (consisting of TV viewing, reading, and listening to radio and music). Given the differing associations of activities that are mentally active (such as reading) and passive (such as TV viewing) with health outcomes (Kikuchi *et al.*, 2014; Hallgren *et al.*, 2020; Hallgren, Dunstan and Owen, 2020), a logical extension to this work would be to examine the combined association of dual behaviours on health markers. This would require the broadening of current time use survey categories to include contemporary activities, such as mobile phone use, as well as concurrent collection of health-related outcome measures or linkage to electronic health records.

In the present study, use of mass media was the most prevalent secondary activity to be reported. This is consistent with findings from the Harmonised European Time Use Survey which highlighted that the most common secondary activities reported were listening to the radio and music, watching TV, socialising with family and visiting (includes visiting relatives and friends) and feasts (includes parties and weddings) (Eurostat, 2022a). Specific activities such as TV viewing are frequently recorded as secondary activities (Sullivan *et al.*, 2021); the UKTUS classifies TV viewing under the umbrella term of “mass media”. With the rapidity at which technology is developing, the breadth of activities and behaviours that can be categorised under this term is growing. In addition, the increasing convenience and

use of different screens and devices, has led to an increase in screen multi-tasking (Van Cauwenberge, Schaap and van Roy, 2014). Therefore, it is important that future time use surveys are able to capture the wide variety of screen behaviours that people are engaging in, to fully understand the patterns and duration of screen multi-tasking. The International Classification of Activities for Time-Use Statistics (ICATUS) includes a contextual variable on the use of an Information Communication Technology device to determine whether a device is being used in relation to the activity in question (United Nations Statistical Division, 2021). However, the classification system requires further updating to ensure mobile phone use and tablet use are captured, either as distinct categories or within the mass media grouping.

4.5.1 Implications for research, policy, and practice

The present analysis adds depth to the current understanding of sedentary and screen behaviour patterns in adults, describing its variability across the day and accompanying activities where much of previous research has reported daily duration only. The current study provides evidence that sedentary behaviours tend to peak in the evenings on both workdays and non-workdays, therefore interventions targeting screen and sedentary behaviours at specific times of the day should be considered. Additionally, a beneficial next step for developing time-specific interventions is to identify modifiable and non-modifiable correlates of different types of sedentary behaviours at specific times of the day. Based on the findings from this study, it is suggested that interventions should target reductions in behaviour in the evenings and that a degree of tailoring to specific age groups or sexes may be appropriate.

This study highlighted that it is unclear how respondents distinguish primary and secondary activities; therefore, there may be value in respondents reporting all activities they are engaging in without requiring them to designate as a primary or secondary activity. In addition, respondents could be provided with pre-determined categories which include commonly occurring behaviours that they can choose from. This is especially the case given the shift from paper-based diaries to electronic formats, and also the use of “light” diaries, which contain a reduced number of selected activities (Sullivan *et al.*, 2020). This may lessen the burden for both respondents reporting of multiple activities and researchers coding free text

responses into categories which in turn may improve the way in which tools capture co-occurring activities.

It is important that contemporary behaviours are captured within future time use surveys to provide further evidence on different types of sedentary behaviours and their co-occurring activities, which can be achieved by regularly reviewing and updating time use diary activity categories. Time use diaries provide a unique method to capture the use of various screens and behaviours simultaneously, which can be explored to examine the health effects of screen multi-tasking. Valuable avenues for future research include exploration of how particular combinations of co-occurring activities are associated with health markers and whether they should be targeted alongside primary activities within interventions.

4.5.2 Strengths and limitations

Strengths of this study include the large, diverse sample recruited for the UKTUS, and the use of granular time use data to examine diurnal behaviour patterns, which is not possible with most existing sedentary behaviour questionnaires. In addition, this is the first study to our knowledge that has assessed the secondary activities occurring alongside screen and sedentary based behaviours using time use data. Nevertheless, this study is not without its limitations. Firstly, this study used data from the UKTUS undertaken in 2014-2015, therefore the data may not be representative of contemporary behaviour patterns. This study provides useful insights into diurnal patterns and secondary activities; however, the results may not be generalisable beyond the UK adult population as we know that behaviour patterns vary between countries. Finally, this study examined diurnal patterns for select sociodemographic factors including sex and age. However, differences between males/females and younger/older age groups were not tested statistically and therefore the findings should be interpreted with caution.

4.6 Conclusion

This study is the first that we are aware of to use time use survey data to assess diurnal patterns and activities that co-occur alongside different types of sedentary behaviours. Additionally, the findings highlight the importance of treating different sedentary and screen-based behaviours separately given they can occur at different times of the day and have different co-occurring activities; both factors

should be taken into consideration when designing sedentary behaviour interventions. Further methodological developments are needed to fully understand the prevalence of secondary activities and the combined effect of primary and secondary activities on health outcomes. Finally, when updating or devising new time use diaries, it is important to consider the most appropriate method of collecting information on contemporary behaviours as well as multiple co-occurring activities.

Chapter 5: Country level correlates of self-reported sitting time in European adults.

5.1 Introduction

The temporal trends analysis conducted in Chapter 3 demonstrated between-region and socio-demographic differences in duration of time spent in screen-based behaviours. Chapter 4 aimed to further increase understanding of sedentary and screen-based behaviours patterns highlighting that behaviours occur at different times of the day and have different co-occurring activities. It was also identified in the literature review (Chapter 2) that substantial differences exist in the prevalence and duration of sedentary behaviour between countries. Therefore, the present chapter seeks to examine the extent to which country-level factors might account for these between country differences in self-reported sitting time using four waves of repeated cross-sectional data from the European Commission Eurobarometer Survey. Additionally, given the notion that health behaviours are influenced by multiple factors at different levels, as postulated in the Ecological Model, this chapter sought to explore whether the association between country level factors and sitting time vary over time and by individual factors.

5.2 Background

Adults now spend most of their waking hours engaging in sedentary activities such as TV viewing, driving a car and sitting at work (Koohsari *et al.*, 2020; Harvey *et al.*, 2022). High amounts of sedentary behaviour have been linked to an increased risk of all-cause and cardiovascular mortality, cardiovascular disease, type 2 diabetes, and metabolic syndrome (Biswas *et al.*, 2015). High quality evidence on the prevalence of sedentary behaviour can be used to measure its attributable risk in the population. Additionally, modifiable, and non-modifiable determinants can be used to inform public health policy and the development of behaviour change interventions. Consequently, there is interest in measuring sedentary behaviour prevalence and correlates through population surveillance (Loyen *et al.*, 2016).

The Ecological Model conceptualises multiple levels of influence on health behaviours, including individual, interpersonal, organisational, community, physical environmental, and policy factors (Sallis, Owen and Fisher, 2008). However, the

majority of research into the correlates of sedentary behaviour has focused on individual, social or micro-environmental influences such as age, socio-economic position and whether someone lives in an urban or rural area (Owen *et al.*, 2011; O'Donoghue *et al.*, 2016; De Craemer *et al.*, 2018). Less is known about macro-level influences on sedentary behaviour, such as GDP and population density, which operate at a regional or country-level. This is of interest because prevalence data show substantial between-country differences in sedentary behaviour (López-Valenciano *et al.*, 2020).

To date, research examining the association of macro-level factors with sedentary behaviour has produced mixed findings. Analyses comparing self-reported sitting and device-measured sedentary time between countries in South America found no association with GDP, population density or HDI (a summary measure of health, education and standard of living) (Werneck *et al.*, 2020; Ferrari *et al.*, 2022; United Nations Development Programme, 2022a). However, in an analysis of European data, population density and GDP were positively associated with self-reported sitting time (Van Cauwenberg *et al.*, 2018). These previous studies have provided useful insights into the association between country-level factors and sitting time, but the mixed findings indicate a need for further work in this area. In addition, given the differing social and environmental conditions associated with age, sex and other demographic factors, it may be hypothesised that the association of macro-level influences with sedentary behaviour will be moderated by factors at the individual level. Previous studies have assessed the moderating effect of sociodemographic factors on the associations between regional-level GDP and population density and the odds of high levels of sitting (>7.5h/day) (Van Cauwenberg *et al.*, 2018). For population density, significant interaction effects were found for adults aged 65 years and above, individuals who had 16-19 years of education or who were retired (Van Cauwenberg *et al.*, 2018). For GDP, interaction effects were observed for all sub-groups apart from women, individuals aged 65 years and above, manual workers and those who are retired (Van Cauwenberg *et al.*, 2018). The present study seeks to extend previous research by exploring whether the association between various country-level factors and sitting time is moderated by individual factors.

A barrier to examining macro-level influences on sedentary behaviour is the financial and logistical complexity of collecting harmonised data across multiple countries. To this end, the European Commission's Eurobarometer survey is a useful resource, comprising data from across the European region with harmonised assessment of participants' sitting time. Previous studies have used Eurobarometer to describe sedentary behaviour prevalence (Jelsma *et al.,* 2019; López-Valenciano *et al.*, 2020; Milton *et al.*, 2015) and socio-demographic correlates (Bennie *et al.*, 2013; Lakerveld *et al.*, 2017) but this dataset has not yet been used to examine country-level influences on sedentary behaviour. Therefore, the aims of this analysis were to 1) examine the association of country-level factors with self-reported sitting time, and 2) explore whether these associations varied over time and by individual factors.

5.3 Method

5.3.1 Data source

This study used data from four waves of the Eurobarometer Survey (European Union, 2022a): 58.2 (October-December 2002) (European Commission, 2012a), 64.3 (November-December 2005) (European Commission, 2012b), 80.2 (November-December 2013) (European Commission, 2017) and 88.4 (December 2017) (European Commission, 2022a). Recruitment was via a multi-stage, random sampling design in each wave, targeting participants aged 15 years and above in the European Union Member States (European Union, 2022b; Gesis, 2022). A total of 16,230 participants were surveyed by a trained interviewer in 2002, 29,193 in 2005, 27,919 in 2013 and 28,031 in 2017. More information on the Eurobarometer methodology can be found at https://www.gesis.org/en/eurobarometer-data-service/survey-series/standard-special-eb/sampling-and-fieldwork. The Eurobarometer survey was chosen due to the availablity of multiple waves of data, spanning a 15-year period, and collected using a standardised methodology. In addition, the Eurobarometer surveys include country-level indicators that were potentially relevant as correlates of sedentary behaviour and a large sample size suitable for the proposed effect modification analyses.

5.3.2 Outcome and exposure variables

5.3.2.1 Sitting time variable

Data on sitting time were collected using the following question: *"How much time do you spend sitting on a usual day? This may include time spent sitting at a desk, visiting friends, studying or watching television"*. In the 2002 and 2005 surveys, participants provided a free text estimate of duration. For the 2013 and 2017 surveys, participants selected from 11 categorical response options ranging from '≤60 mins' to '>8h30mins'. Responses from 2002 and 2005 were recoded into categorical variables for consistency with the 2013 and 2017 data. All four waves were then recoded to interval mid-points to create a pseudo-continuous sitting time variable that was consistent across all waves.

5.3.3 Independent variables

Data on macro-level factors were obtained for each country in each survey year (2002, 2005, 2013, 2017). Data on GDP, population density, internet use, and service sector employment were obtained from the World Bank (2022b,c,d,e). Data on HDI were obtained from the United Nations Development Programme (United Nations Development Programme, 2022b). Further details are provided below.

5.3.3.1 Gross Domestic Product (GDP)

GDP (USD, Billions) is defined as *"the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of products"*. GDP is typically interpreted as an indicator of an economy's size at a given point in time (United Kingdom Government, 2017).

5.3.3.2 Human Development Index (HDI)

HDI is a summary measure of a country's social and economic development, captured across three key dimensions: a long and healthy life (Life expectancy at birth); access to knowledge (Expected years of schooling, Mean years of schooling); and having a decent standard of living (Gross National Income per capita). Further details on the calculation of HDI are available (World Population Review, 2022). HDI is scored between 0 and 1, with higher scores indicating a higher level of human development (World Population Review, 2022).

5.3.3.3 Population density

Population density is a measure of the number of people in a given area calculated as the mid-year population per square kilometre of land area.

5.3.3.4 Internet use

Internet use was defined as the proportion (%) of the population who used the internet from any location or device in the last three months. These data were from the International Telecommunication Union (2023), obtained from the World Bank as referenced above.

5.3.3.5 Service sector employment

Service sector employment is defined as the proportion (%) of the working population engaged in any activity to produce goods or services for pay or profit in sectors such as retail, restaurants and hotels, finance, insurance, and real estate. This data was from the International Labour Organization (2023) modelled estimates database, obtained from the World Bank as referenced above.

5.3.4 Statistical analyses

Data management and statistical analyses were conducted in STATA Version 16.1 (StataCorp, 2019). Participants less than 18 years of age (n=2,718) and those with missing data for the outcome or covariates used in the analysis (n=3,910) were removed. Data for the following countries or regions: East and West Germany (Germany); Great Britain and Northern Ireland (UK); Cyprus Republic and Turkish Cypriot Community (Northern Cyprus) (Cyprus) were combined. Additionally, Turkey was removed from the analyses as this was only included for one wave of measurement (Eurobarometer 64.3; 2005).

Sample characteristics and country-level factors are summarised as n (%) or median (inter-quartile range) as appropriate. We checked for multicollinearity amongst the independent variables using the variance inflation factor, all of which were less than 10 (Marquardt, 1970). To assess the association of country-level factors with self-reported sitting time, a multi-level linear regression model was used, with participants at level 1 and country at level 2. The association of each exposure with sitting time were examined individually and then collectively in a mutually adjusted model. All models were adjusted for age (18-24, 25-34, 35-44, 45-54, 55-64 and 65 and above), sex (male/female), and occupational status

(manual worker, non-manual worker and not in employment). Standardised and unstandardised coefficients are reported for both the single exposure and mutually adjusted models. Standardised coefficients are interpreted as the average difference in the outcome for a one standard deviation change in the exposure variable. It was examined whether the association between country-level factors and sitting time was moderated by time (survey year), sex (male/female), age (18-44 years and 45 years and above) and occupation (manual worker, non-manual worker and not in employment) using a likelihood ratio test comparing models with/without an interaction term for each candidate moderator.

5.4 Results

Descriptive statistics for participants and country-level variables overall and for each survey year, are presented in Tables 3 and 4. In total, data from 93,903 participants from 28 countries were included. Most participants were female (55.1%), aged 65 years and over (23.7%) and were not in employment (48.8%).

5.4.1 Country-level associations with sitting time

The association of country-level factors with self-reported sitting time is presented in Table 5. In single exposure models, significant, positive associations with sitting time were observed for all exposures, except GDP. For example, a 1% increase in internet use was associated with a 1.1 minute [1.0,1.1] increase in sitting time. In the mutually adjusted models, HDI was positively associated with sitting time whereas GDP was negatively associated. A 1% increase in HDI was associated with a 4.9 minute [3.5, 6.2] increase in sitting time. To compare the size of association between country factors, standardised coefficients were used. The strongest association was observed for HDI, such that a 1 standard deviation increase in HDI score was associated with a 20.8 standard deviation increase in sitting time in the mutually adjusted model.

5.4.2 Effect modification by time

Associations between country-level factors and sitting time for each wave of data collection are presented in Table 6. For all exposures, likelihood ratio tests showed that associations with sitting time varied across the different survey years, but differences were small and wave-specific associations were non-significant in most

cases. For example, GDP was negatively associated, and employment positively associated with sitting time at all points of assessment; minor variations in the strength of association were observed, but all were non-significant. Positive associations with sitting time were seen for internet use across all survey years; however, these were small and non-significant in all years apart from 2013. Interaction coefficients for time are available in Appendix 10.

5.4.3 Effect modification by person-level factors

Associations between country-level factors and sitting time, stratified by person-level factors, are presented in Tables 7 (sex), 8 (age group) and 9 (occupation). For all exposures, likelihood ratio tests showed that associations with sitting time varied by sex. HDI was positively associated, and GDP negatively associated with sitting time in both sexes, but associations were stronger in men than women in both cases. Interaction coefficients for sex are available in Appendix 11.

Likelihood ratio tests showed that associations between sitting time and GDP, internet use and service sector employment varied by age. The association between GDP and sitting time was small, negative, and significant in both age groups but stronger in the older age category. For employment and sitting time the associations were in opposing directions but were small and non-significant in both cases. Finally, the association between internet use and sitting time was negative for those aged 18-44 years, whereas no association was found for individuals aged 45 years and above. Interaction coefficients for age are available in Appendix 12.

For all exposures, likelihood ratio tests showed that associations with sitting time varied by occupation. A significant positive association was observed between HDI and sitting time for all occupation groups with the strongest association in those not in employment, although, the differences between groups were small. A significant negative association for GDP and sitting time was seen for all occupation groups, with the strongest association in those in non-manual occupations. For all remaining exposures, differences were observed between occupation groups, but confidence intervals for subgroup specific associations overlapped zero in all cases. Interaction coefficients for occupation are available in Appendix 13.

Table 3. Participant characteristics for the total sample and stratified by survey year.
Values are n(%) unless otherwise stated.

	Total	**2002**	**2005**	**2013**	**2017**
	n=93,903	n=14,692	n=25,803	n=26,617	n=26,791
Number of countries (n)	28	15	28	28	28
Sex (female)	51,751 (55.1)	7,910 (53.8)	14,573 (56.5)	14,555 (54.7)	14,713 (54.9)
Age					
18-24	8,441 (9.0)	1,780 (12.1)	2,619 (10.2)	2,231 (8.4)	1,811 (6.8)
25-34	14,323 (15.3)	2,682 (18.3)	4,238 (16.4)	3,852 (14.5)	3,551 (13.3)
35-44	16,348 (17.4)	2,866 (19.5)	4,768 (18.5)	4,455 (16.7)	4,259 (15.9)
45-54	16,189 (17.2)	2,451 (16.7)	4,390 (17.0)	4,786 (18.0)	4,562 (17.0)
55-64	16,308 (17.4)	2,163 (14.7)	4,333 (16.8)	4,887 (18.4)	4,925 (18.4)
65+	22,294 (23.7)	2,750 (18.7)	5,455 (21.1)	6,406 (24.1)	7,683 (28.7)
Occupation groups					
Non-manual worker	28,265 (30.1)	4,261 (29.0)	7,811 (30.3)	7,838 (29.5)	8,355 (31.2)
Manual worker	19,843 (21.1)	3,519 (24.0)	5,374 (20.8)	5,368 (20.2)	5,582 (20.8)
Not in employment	45,795 (48.8)	6,912 (47.1)	12,168 (48.9)	13,411 (50.4)	12,854 (48.0)

Table 4. Country-level characteristics for the total sample and stratified by survey year. Values are median and inter-quartile range.

	Total	**2002**	**2005**	**2013**	**2017**
	n=93,903	n=14,692	n=25,803	n=26,617	n=26,791
GDP (billion US$)	238.8 (95.2, 831.8)	266.8 (153.8, 1494.3)	211.8 (45.8, 392.2)	238.8 (58.9, 876.9)	255.0 (59.2, 831.8)
HDI (%)	88.1 (84.5, 90.7)	88.1 (85.0, 88.8)	85.3 (81.3, 89.7)	88.2 (84.5, 92.1)	89.6 (85.9, 92.9)
Population Density (people/km^2)	1.1 (0.7, 2.0)	1.3 (0.8, 2.4)	1.1 (0.8, 1.3)	1.1 (0.7, 2.0)	1.1 (0.7, 2.1)
Internet Use (%)	69.9 (48.8, 81.6)	46.3 (28.0, 61.3)	46 (35.0, 68.7)	75.2 (66.7, 84.2)	81.0 (76.0, 87.9)
Employment in Services (%)	68.1 (62.7, 75.3)	67.3 (65.2, 73.3)	65.1 (56.7, 72.6)	69.5 (63.2, 76.9)	71.2 (63.4, 78.1)

Table 5. Single exposure and mutually adjusted models assessing country-level factors and sitting time.

	Single Exposure			**Mutually Adjusted Models**		
	Unstandardised Coefficient	95%CI	Standardised Coefficient	Unstandardised Coefficient	95%CI	Standardised Coefficient
GDP (billion US$)[¥]	0.000060	[-0.00088, 0.0010]	0.1	-0.016	[-0.020, -0.012]*	-15.4
HDI (%)	3.8	[3.6, 4.1]*	16.5	4.9	[3.5, 6.2]*	20.8
Population Density (people/km^2)	0.6	[0.1, 1.1]*	1.1	-0.5	[-4.1, 3.2]	-0.8
Internet Use (%)[¥]	1.1	[1.0, 1.1]*	23.2	-0.2	[-0.3, 0.016]	-3.3
Employment in Services (%)	1.6	[1.5, 1.8]*	14.5	-0.2	[-0.8, 0.4]	-1.8

*p<0.05, [¥]Reported to two significant figures, 95%CI = 95% confidence intervals

Table 6. The association of country-level factors with sitting time, stratified by year of assessment.

	2002	**2005**	**2013**	**2017**	**P for Interaction**
	Coefficient [95% CI]	Coefficient [95% CI]	Coefficient [95% CI]	Coefficient [95% CI]	
GDP[¥]	-0.0042 [-0.021, 0.012]	-0.01 [-0.03, 0.0068]	-0.0046 [-0.015, 0.0063]	-0.0043 [-0.016, 0.0071]	<0.001
HDI	2.4 [-5.1, 9.9]	2.9 [-2.2, 8.0]	-0.3 [-5.3, 4.6]	2.0 [-2.7, 6.7]	<0.001
Population Density	0.2 [-9.5, 9.9]	-3.5 [-8.9, 1.9]	-2.7 [-6.8, 1.4]	-0.9 [-4.6, 2.8]	<0.001
Internet Use	0.9 [-0.1, 2.0]	0.3 [-0.7, 1.3]	1.5 [0.1, 3.0]*	0.6 [-1.2, 2.4]	<0.001
Employment in Services	0.2 [-2.6, 3.0]	1.0 [-1.2, 3.2]	0.2 [-1.3, 1.7]	0.1 [-1.5, 1.6]	<0.001

[¥]GDP is reported to two significant figures, *p<0.05

Table 7. The association of country-level factors with siting time, stratified by sex.

	Women	**Men**	**P for Interaction**
	Coefficient [95% CI]	Coefficient [95% CI]	
GDP[¥]	-0.015 [-0.020, -0.0094]*	-0.016 [-0.021, -0.0098]*	<0.001
HDI	3.9 [2.1, 5.7]*	6.2 [4.3, 8.1]*	<0.001
Population Density	-0.2 [-4.1, 3.8]	-2.0 [-5.9, 1.9]	<0.001
Internet Use[¥]	-0.2 [-0.4, 0.034]	-0.1 [-0.4, 0.1]	<0.005
Employment in Services	0.1 [-0.7, 0.9]	-0.3 [-1.1, 0.5]	<0.001

[¥]Reported to two significant figures, *p<0.05

Table 8. The association of country-level factors with siting time, stratified by age group.

	18-44 years	**45+ years**	**P for Interaction**
	Coefficient [95% CI]	Coefficient [95% CI]	
GDP[¥]	-0.0087 [-0.015, -0.0026]*	-0.022 [-0.027, -0.017]*	<0.001
HDI	4.9 [2.9, 6.8]*	5.1 [3.4, 6.9]*	0.196
Population Density	0.2 [-3.7, 4.0]	-2.7 [-6.9, 1.4]	0.404
Internet Use	-0.3 [-0.6, -0.1]*	-0.041 [-0.3, 0.2]	0.029
Employment in Services	-0.1 [-0.9, 0.8]	0.1 [-0.7, 0.9]	<0.001

[¥]Reported to two significant figures, *p<0.05

Table 9. The association of country-level factors with siting time, stratified by occupation.

	Non-manual Worker	**Manual Worker**	**Not in Employment**	**P for Interaction**
	Coefficient [95% CI]	Coefficient [95% CI]	Coefficient [95% CI]	
GDP[¥]	-0.012 [-0.018, -0.0047]*	-0.017 [-0.024, -0.011]*	-0.019 [-0.024, -0.013]*	<0.001
HDI	3.6 [1.5, 5.7]*	4.4 [2.2, 6.6]*	6.8 [5.9, 8.7]*	<0.001
Population Density	0.3 [-3.3, 3.9]	-2.6 [-6.3, 1.1]	-1.5 [-5.8, 2.7]	<0.001
Internet Use	-0.1 [-0.4, 0.2]	-0.01 [-0.4, 0.2]	-0.024 [-0.3, 0.2]	<0.001
Employment in Services[¥]	0.2 [-0.8, 1.2]	0.033 [-0.9, 1.0]	-0.7 [-1.6, 0.076]	<0.001

[¥]Reported to two significant figures, *p<0.05

5.5 Discussion

Using four waves of Eurobarometer data, with a sample exceeding 90,000 participants, the present study examined the associations of country-level factors with self-reported sitting time and assessed whether these associations varied over time and by individual-level factors. In mutually adjusted models, GDP was negatively associated, whilst HDI was positively associated with sitting time. Effect modification analyses indicated that the association between country-level factors and sitting time varied over time and by select demographic factors, but differences were typically small in magnitude.

After adjustment for selected sociodemographic factors and other exposures of interest, a negative association between GDP and self-reported sitting time was observed. A recent systematic review reported mixed findings for the association between economic growth and sedentary behaviour, but this was based on just four published papers, two of which were conducted in adolescents (Yang *et al.*, 2023). Among the studies conducted in adults, one found no association between GDP and sitting time in a sample of South American adults (Werneck *et al.* 2020), whereas a previous analysis using Eurobarometer data reported a significant positive association between GDP and the odds of sitting >7.5h/day (Van Cauwenberg *et al.*, 2018). One explanation for the mixed findings observed on this topic is the different measures of economic growth and sedentary behaviour that have been used between studies. This includes use of regional versus country level markers of GDP, as well as sitting time versus TV viewing time outcomes (Van Cauwenberg *et al.*, 2018; Werneck *et al.*, 2020) which limit comparability between studies. Economic growth, as reflected by GDP, is one factor typically accompanied by related changes in social and built environment, such as increased car ownership, developments in technology and a shift in occupation from manual jobs to sedentary, desk-based jobs (Van Cauwenberg *et al.*, 2018; Yang *et al.*, 2023). As such, a negative association between GDP and sitting time is somewhat unexpected. Nonetheless, this association was small, therefore highlighting that GDP which could be considered as a more distal factor, has a limited impact on sitting time at the individual level.

In adjusted analyses, no association was observed between the proportion of the population using the internet and sitting time. We are aware of no previous studies

that have examined the association of population-level internet use with sitting time. However, the results are contrary to recent research which found a positive association between DESI score and sitting time (Moreno-Llamas, García-Mayor and De la Cruz-Sánchez, 2020). The DESI is a summary measure of indicators related to digital performance and includes broadband connectivity and integration of technology into businesses (Moreno-Llamas, García-Mayor and De la Cruz-Sánchez, 2020; European Commission, 2022b). It is possible that the more restricted focus on internet use as an exposure used in the present study was too narrow to serve as an independent correlate of sitting time at the individual level. Internet use is now increasingly ubiquitous with 90% of individuals aged 16-74 in the European Union using the internet at least once a week and 89% using the internet at least weekly (Eurostat, 2022b). A lack of heterogeneity limits the usefulness of internet use as a standalone exposure for studies concerned with understanding influences on sedentary behaviour. Instead, taking internet use into consideration as part of a wider measure of digitalisation, may be useful in attempting to understand how internet use and access to particular digital services impacts individual level sedentary behaviour.

Interestingly, HDI and self-reported sitting time were positively related within the present study. This contradicts previous research conducted in South America, which found no association between HDI and self-reported sitting time and/or device measured sedentary time (Werneck *et al.*, 2020; Ferrari *et al.*, 2022). The reasons for the differing findings between the present study and those conducted in South America are unclear but may be attributable to differences in study location and/or the measurement/operationalisation of sedentary behaviour. It is perhaps surprising that the associations between GDP and HDI were in opposing directions given these are both broad markers of economic growth. It could be hypothesised that as HDI is a summary measure of a range of factors related to broader societal aspects, it may be more useful in explaining differences in sitting time compared to the size of a country's economy. Overall, HDI is a valuable summary measure consisting of three different dimensions, which may be more directly relevant to factors such as health and education which are experienced at the individual level. However, it is currently unclear which of the individual components are most strongly associated with sitting time. Future research should seek to disentangle these measures to further understand their unique associations with sitting time,

with the goal of identifying which factors in isolation or combination could be targeted through upstream intervention programmes.

In the effect modification analyses it was observed that the association between HDI and sitting time differed according to participant's occupation. Specifically, the association was stronger in those not in employment compared to non-manual workers. Whilst it is widely acknowledged that factors from different levels of the Ecological Model will likely interact to influence both physical activity and sedentary behaviour, few studies have examined this to date (Sallis, Owen and Fisher, 2008; O'Donoghue *et al.*, 2016). The findings indicate that the influence of HDI on sitting is not equal for all sub-groups. Specifically, those not in employment may be more detrimentally affected by changes that accompany social/economic development than those working in non-manual occupations. Overall, these findings reveal which groups may be more likely to accumulate higher sitting time as HDI increases which can be used for the development of upstream policy measures.

5.5.1 Implications for research, policy, and practice

A key concept of the Ecological Model is the notion that interventions that seek to modify factors at multiple levels will potentially be more effective in changing behaviour than those focussed only on a single domain (Sallis, Owen and Fisher, 2008). Therefore, examining the effect of macro-level influences can help to identify factors that underlie these between-country differences which in turn can help to inform policy and/or interventions to reduce sedentary behaviour. Of the constructs examined in this analysis, the most robust associations with sitting time were observed for HDI. From a development perspective, there is a case for implementing mitigation measures to minimise the reduction in physical activity and increase in sedentary behaviour that accompanies the Epidemiological Transition (Katzmarzyk and Mason, 2009). Interactions were seen between individual factors and sitting time, which is consistent with the Ecological Model. Results from the effect modification analysis highlight that social and economic development may be most detrimental on sitting time for those who are not in employment. Upstream policy measures that limit the impact social and economic development have on this sub-group may be appropriate. One suggestion is a health and wellbeing support system for those not in employment that aims to maintain and/or enhance physical and mental health (including the limiting of sedentary time), which could

be set up at the national level to provide those not in employment with structure that can assist with breaking up sitting time.

5.5.2 Strengths and limitations

The current study addressed novel research questions that have received little attention to date in the sedentary behaviour literature. The analyses exploited key strengths of the Eurobarometer dataset, including its longitudinal nature, harmonised assessment of sitting time and large-multi-country sample. In addition, the interaction between country-level and individual-level factors as correlates of sitting time were assessed, which is valuable for informing the targeting and content of policies and interventions aimed at changing behaviour. The following limitations are acknowledged. The sitting time outcome was self-reported and thus may be susceptible to response bias, though psychometric testing of the International Physical Activity Questionnaire (IPAQ) (which is the assessment tool used within Eurobarometer) has shown very good reliability and criterion validity that is similar to other questionnaires (Craig *et al.*, 2003). In addition, respondents had to choose from a set of pre-defined categories in the 2013 and 2017 surveys and thus it was not possible to define the specific sitting time duration of participants. However, pseudo-continuous categories were created for all four waves to ensure consistency across survey years. Also, the service sector employment data were based on modelled estimates. Nevertheless, these estimates provide a complete set of data that is internationally comparable (International Labour Organization, 2023). A further limitation of this study is that the earliest wave of data was collected over 20 years ago and thus it may not represent contemporary behaviour patterns. The most recent wave of Eurobarometer data was collected between April-May 2022 and published in September 2022 (European Union, 2022c) after the completion of the current study. Therefore, this analysis could be updated with the inclusion of data from the most recent sweep of the survey. Finally, the overall sample was relatively old and had low employment levels, which may have influenced the results and generalisability to other populations.

5.6 Conclusion

In a large and geographically diverse analysis of Eurobarometer data, small, but temporally consistent, associations for GDP and HDI with self-reported sitting time

were observed. Specifically, GDP was negatively associated and HDI positively associated with self-reported sitting time. It was also observed that the association of these factors with sitting time differed across socio-demographic subgroups; evidence that may be valuable in the targeting and development of intervention content. These preliminary data indicate that upstream policy measures may need to target specific sub-groups to reduce the impact of social and economic development.

Chapter 6: A review of sedentary behaviour assessment in national surveillance systems.

6.1 Introduction

Chapter 3 examined temporal trends in the duration of screen-based behaviours internationally, shining a light on population changes in the types of behaviours being engaged in. Specifically, the analysis revealed a reduction in time spent in traditional behaviours such as TV viewing and computer use and an increase in mobile phone use, games console use and online TV viewing. The findings also highlighted the specific regions and sub-groups with the greatest increases in overall screen time, namely the Middle East and Africa, Latin America, and younger age groups. The final study, presented in this chapter, describes the characteristics of questionnaires used for national surveillance of sedentary behaviour and seeks to identify which types of behaviours are being measured in national surveillance systems.

6.2 Background

During the last two decades, there has been a considerable increase in research assessing sedentary behaviour and its potential links with health (Stamatakis *et al.*, 2019). Sedentary behaviour defined as *"any waking behaviour characterised by an energy expenditure ≤1.5 METs while in a sitting or reclining posture"*, (Tremblay, 2012, p540.) has been identified as a risk factor for all-cause mortality as well as various chronic diseases including cardiovascular disease, cancer, and type 2 diabetes (Biswas *et al.*, 2015; Dempsey *et al.*, 2020)', . In addition, time spent in a variety of sedentary behaviours, particularly screen-based activities, appears to be increasing (Chau *et al.*, 2012; Van Der Ploeg *et al.*, 2013; Yang *et al.*, 2019; Harvey *et al.*, 2022). As a result, various authorities have released public health guidelines on sedentary behaviour. For example, the WHO recommend that adults should limit the amount of time they spend being sedentary (World Health Organization, 2020a), whilst national guidelines in Canada advise limiting daily sedentary time to 8 hours or less and not exceeding 3 hours of recreational screen time (The Canadian Society for Exercise Physiology, 2021). To assess compliance with public health guidelines, assessment of sedentary behaviour should be incorporated into population surveillance systems.

A surveillance system can be defined as "*a systematic collection, analysis and interpretation of the health-related data needed for the planning, implementation, and evaluation of public health practice*" Centers for Disease Control (1986, cited in Thacker and Berkelman, 1988, p.1). Population surveillance supports evidence informed decision making in public health by monitoring how many people are meeting public health guidelines, identifying risk factors associated with health and disease, and informing public health policies and programmes (Bauman *et al.*, 2006; Fulton *et al.*, 2016; Troiano, Stamatakis and Bull, 2020). Many tools exist for the assessment of sedentary behaviour, but not all are suitable for use within population surveillance (Atkin *et al.*, 2012). Whilst device-based measurement is becoming increasingly widespread in epidemiological research more broadly, it is often considered too time or resource intensive to be used for population surveillance and fails to capture the different domains and types of sedentary behaviour that people undertake (LeBlanc *et al.*, 2017). Comparatively, self-report tools have been found to have low to moderate validity, typically underestimating total sedentary time compared to device-based measurement (Bakker *et al.*, 2020; Prince *et al.*, 2020b). Nevertheless, their relatively low cost and burden mean that use of self-report measures is likely to continue in surveillance systems for the foreseeable future (Troiano, Stamatakis and Bull, 2020).

Emerging evidence suggests that the nature of our sedentary behaviour patterns is changing. One recent analysis, covering the period 2012 to 2019, reported an increase in time spent using a mobile phone, games consoles and watching online TV, along with a decline in traditional (terrestrial) TV viewing and PC, laptop and tablet use (Harvey *et al.*, 2022). Other studies have reported a similar trend in the changing make-up of sedentary behaviours over time (Van Der Ploeg *et al.*, 2013; Prince, *et al.*, 2020a). Against this backdrop, it is vital that surveys used for population surveillance adequately capture contemporary behaviour patterns (Prince *et al.*, 2017b). This is necessary to ensure that prevalence estimates are accurate, but also because different modes of sedentary behaviour may have different associations with health (Prince *et al.*, 2017b). For example, TV viewing has been linked with depressive symptoms and reduced cognitive function, whereas internet use and reading have been associated with reduced depressive symptoms and higher cognitive function (Hamer and Stamatakis, 2014). Therefore, the overall purpose of this review was to identify what types of sedentary behaviour

are being captured in surveillance systems and how these behaviours are being measured. The specific aims were to: 1) describe the characteristics of questionnaires used for national surveillance of sedentary behaviour in adults; and 2) identify the types of sedentary behaviours being measured in these questionnaires.

6.3 Method

The methods and findings from surveillance systems are not typically published in the peer-reviewed literature. As such, rather than conducting a conventional search of scientific databases, the Global Observatory for Physical Activity (GoPA!) country cards (Global Observatory for Physical Activity, 2021) were used to locate potentially relevant sources of information for this review. The GoPA! country cards, currently available for 217 countries, are a summary of country level data on a variety of physical activity and sedentary behaviour metrics, including population surveillance (Ramirez Varela *et al.*, 2018; Global Observatory for Physical Activity, 2020). The cards are populated using a standardised methodology and all content is approved by a designated 'country contact' prior to publication (Varela *et al.*, 2017). Whilst most surveillance systems included on the country cards meet the definition provided above, some are more aptly described as epidemiological (cross-sectional/cohort) studies. Nonetheless, such studies may offer similar insights as conventional surveillance, and given that their inclusion is subject to approval by a designated country contact, it was opted that such studies were retained within this review.

6.3.1 Inclusion and exclusion criteria

Surveillance systems were included if they 1) measured duration of sedentary behaviour in the adult population and 2) used a nationally representative sample which was determined by examining the sample section of relevant reports or websites. Surveillance systems that used a non-national (i.e., local, or regional) sample were only included when a surveillance system using a nationally representative sample could not be obtained; in such cases, the most recent surveillance system using a non-national sample was included.

No limits were set on how many surveillance systems could be included for a given country. If multiple surveillance systems were reported for a country, the most

recent available wave for each one that met the criteria was selected. Surveillance systems were excluded if the questionnaires could not be obtained in their entirety. Additionally, questionnaires were excluded if they were designed specifically for use within children or if they only included questions on device ownership, screen/technology access or frequency of use. For this review, the 2017 Eurobarometer Survey was only included once as the questions remained unchanged across each country in which it was used. Similarly, the WHO STEPwise approach to surveillance (STEPS) was included once where no adaptations to the survey were made. However, STEPS allows flexibility for countries to make adaptations; therefore where surveys differed to the original STEPS, these were considered separately (World Health Organization, 2020b).

6.3.2 Locating sources

Data were extracted from the second set of GoPA! country cards, published in 2020 (Global Observatory for Physical Activity, 2020). All sources of data listed under the following sections of the country card were considered for inclusion: 'Physical Activity Prevalence', 'Surveys and instruments used to assess physical activity', and 'Sedentary Behaviour (sitting time)'. Surveillance systems were assessed by one member of the research team (DH) to identify when the data collection took place. Once the relevant surveillance system(s) had been identified for each country, we sought to obtain the questionnaires to determine whether a question was included on the duration of sedentary behaviour. Questionnaires written in languages other than English were translated using the Google Translate app. We followed a pre-defined process to locate the questionnaires, as follows:

Firstly, an internet search using the Google search engine was conducted. The reference for many of the sources listed under the 'physical activity prevalence' heading on the country cards was Guthold *et al.* (2018) which described global and regional trends in insufficient physical activity using a pooled analysis from 358 population-based surveys. In these cases, we used the supplementary file of Guthold *et al.* (2018) to identify the original data sources and used Google searches to obtain the questionnaire(s). If a questionnaire was not obtained through Google searches, a bespoke email was sent to the country contact(s) requesting a copy of the missing questionnaire(s). If a response was not received within 10 days, a follow-up email was sent. If a response was not received within 10 days of this

follow-up, no further attempts were made to obtain this information. Figure 13. is an adapted PRISMA flow diagram (Page *et al.*, 2021) which depicts the process that was followed for surveillance system selection.

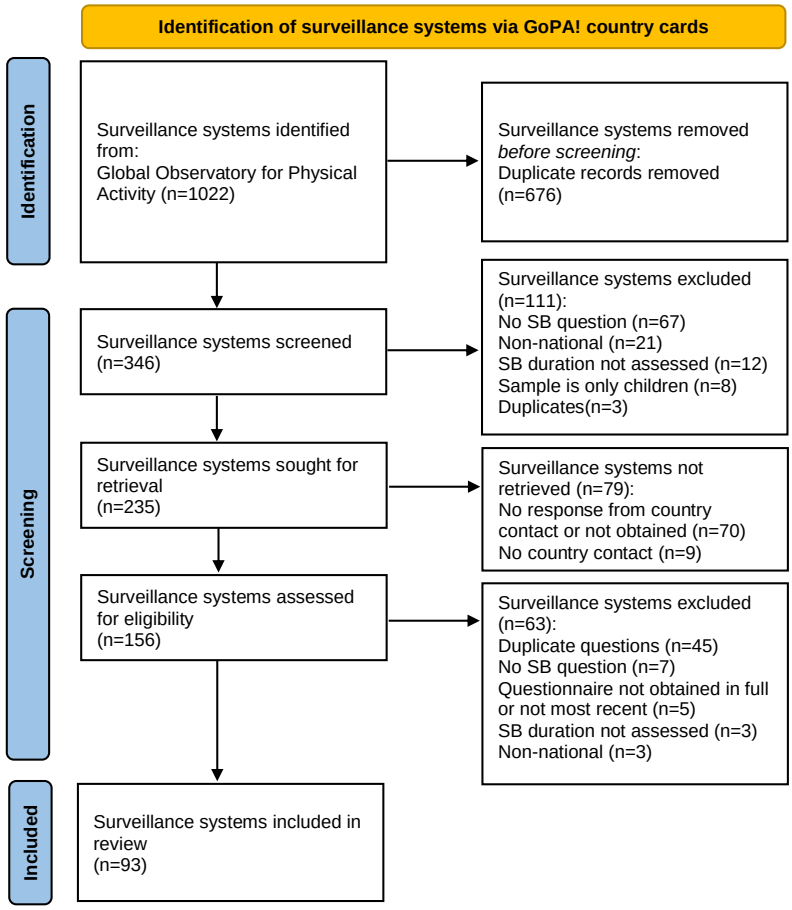


Figure 13. Adapted PRISMA flow diagram for depicting the process of surveillance systems selection.

6.3.3 Data extraction

Information pertaining to each of the included surveillance systems, such as year of measurement and sampling characteristics, were recorded in a Microsoft Excel spreadsheet. Verbatim text for the sedentary behaviour questions were also extracted which included any pre-amble and response options.

6.3.4 Data synthesis

Data synthesis comprised two parts. To describe the characteristics of the included questionnaires, the Taxonomy of Self-reported Sedentary Behaviour Tools (TASST) was used. To record the behaviours captured within each questionnaire, the Sedentary Behaviour International Taxonomy (SIT) was used. TASST and SIT

are described in more detail below. To ensure accuracy when mapping the questionnaires, two members of the research team (DH and AA) separately mapped approximately 10% of the surveys for both frameworks. The results were compared and any discrepancies were discussed and cross checked with the coding for the original frameworks and Rivière *et al.* (2018) for the SIT. Through this process clear practices were established for the remaining surveys which were mapped by DH.

6.3.4.1 Questionnaire characteristics

Questionnaire characteristics were mapped using a modified version of the TASST, as depicted in Figure 14. (Dall *et al.*, 2017). The TASST describes the characteristics of self-report sedentary behaviour measurement tools, captured in four domains: type of assessment, recall period, temporal unit, and assessment period. *Type of assessment* refers to how the outcome of time spent in sedentary behaviour is produced from the instrument and can be either a single or composite item. Composite measures comprise two or more items assessing behaviours or domains. A new sub-category of 'behaviours and domains' (1.2.2.3, Figure 14) was added to capture questionnaires that measured both behaviours and domains, which was not included in the original taxonomy. *Recall period* is the time frame over which respondents were asked to consider their sedentary behaviour, for example, a previous day or previous week. *Temporal unit* is the time within the recall period that an individual reports their sedentary behaviour; this can be a single day, a week or longer. Finally, the *period of assessment* refers to whether there are any parameters set on the temporal unit, for example, periods within the day (e.g., before/after work) or distinguishing week/weekend days.

If there were multiple questions measuring sedentary behaviour in a questionnaire that had a degree of similarity in question style, theme, and/or response options, then these were included collectively and reviewed as one. For example, a questionnaire that included separate questions on duration of TV viewing and computer use on a weekday was mapped once onto the taxonomy. Where questions were stylistically and/or thematically different they were included as distinct items and mapped separately.

6.3.4.2 Sedentary behaviour characteristics

Characteristics of the behaviours that were assessed in each questionnaire were mapped using the SIT (Chastin, Schwarz and Skelton, 2013). The SIT consists of nine facets (purpose, environment, type, posture, social, time, state, associated behaviours, and measure) two of which were relevant to the current review. The *purpose* facet (Figure 15) was used to describe the contexts in which the sedentary behaviours took place, whilst the *type* facet (Figure 16) was used to describe the types of sedentary behaviours that were assessed. The “other” category shown in Figures 15 and 16 was used in cases where the purpose or type of behaviour did not fit into one of the pre-determined categories. Each facet on the SIT also includes an ‘undetermined’ category. Although not shown on Figures 15 and 16, this category was used if the purpose or type of sedentary behaviour could not be determined from the questionnaire.

The questionnaires were mapped according to the purpose(s) and type(s) of sedentary behaviour that they assessed. The *purpose* facet was used in its original format. A small number of amendments were made to the *type* facet, as shown in Figure 16. The non-screen category of ‘phoning’ was changed to ‘phone calls’ to provide clarity on phone use, given phones can now be used for a variety of activities including watching videos and browsing the internet (Barkley, Lepp and Salehi-Esfahani, 2016). Additionally, ‘driving’ was revised to include driving and using public transport to capture questions that included a measure of sitting on public transport. For screen behaviours, the ‘small devices’ category was replaced with two new categories of 1) iPad/Tablet/E-reader, and 2) smartphone, as recent research has shown differences in patterns of phone and tablet use, with smartphone use increasing and tablet use decreasing (Harvey *et al.*, 2022).

Consistent with Rivière *et al.* (2018) the examples that were given for a sedentary behaviour facet or categories included in a facet (e.g., work or TV) in each questionnaire were recorded. These were mapped separately from the main question. When mapping the questionnaires onto the taxonomy, “free time” was included under the purpose of ‘leisure’. Many questionnaires included the example of “sitting at a desk”; in these instances, sitting at a desk was classified under the work purpose when work was mentioned within the question and under the education purpose if school or studying was mentioned within the question. If

neither work nor education were mentioned, the example of sitting at a desk was placed under the “undetermined” category.

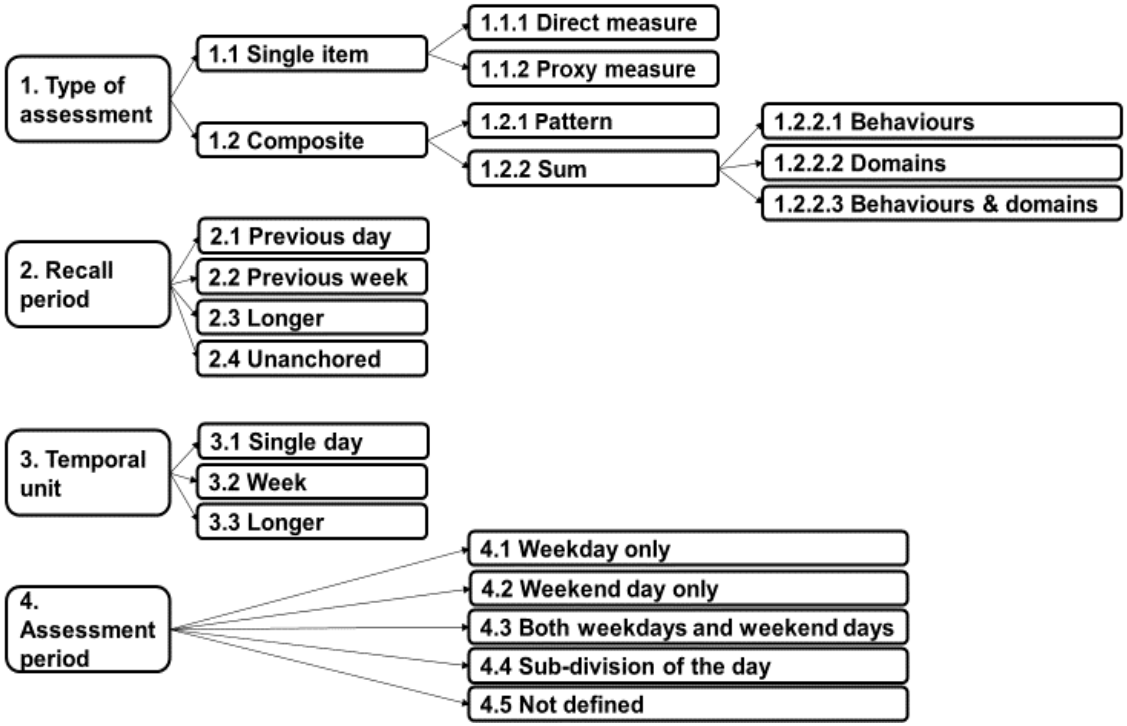


Figure 14. Modified Taxonomy of Self-reported Sedentary Behaviour Tools (TASST).

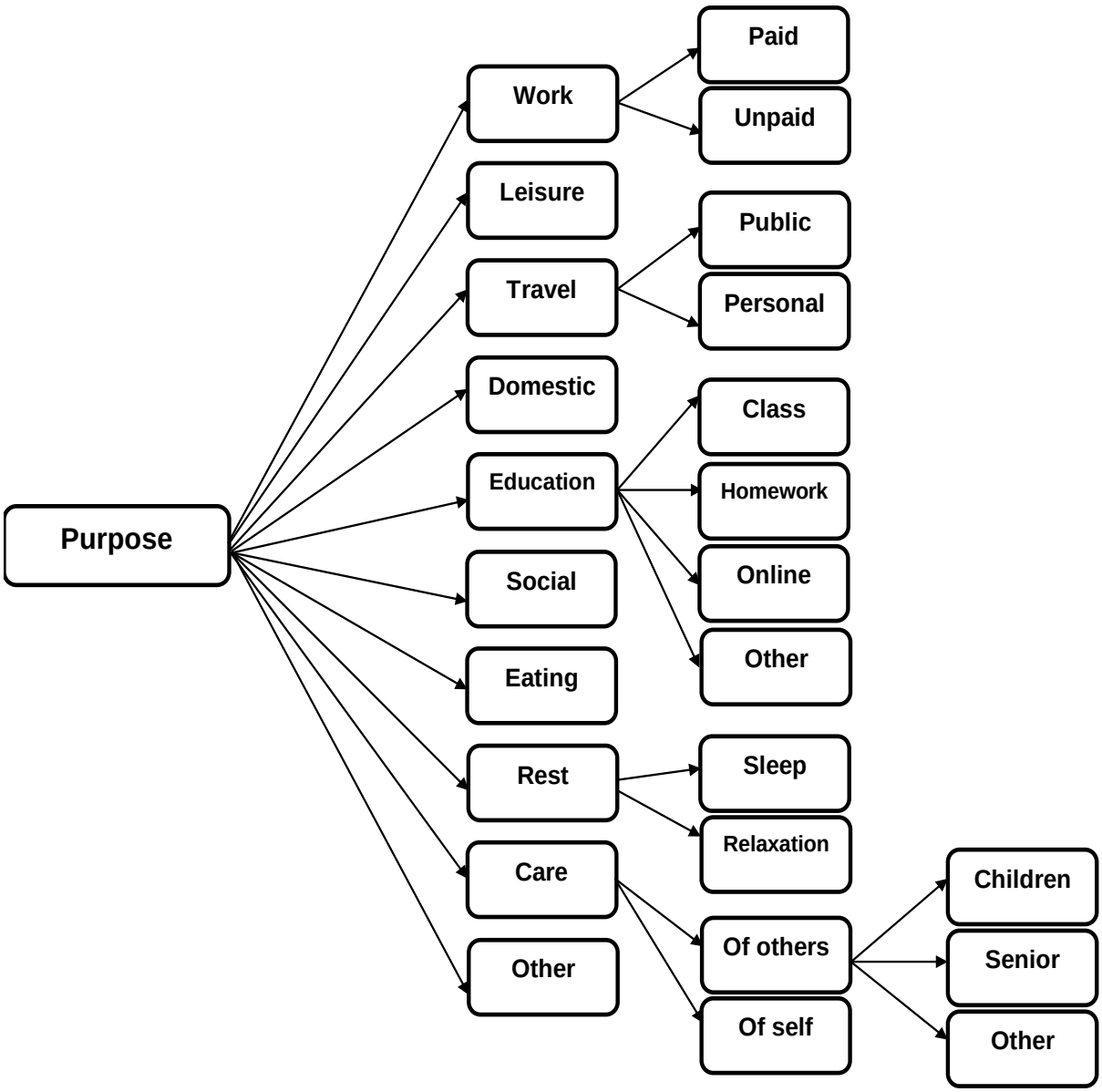


Figure 15. Purpose facet from the Sedentary Behaviour International Taxonomy (SIT).

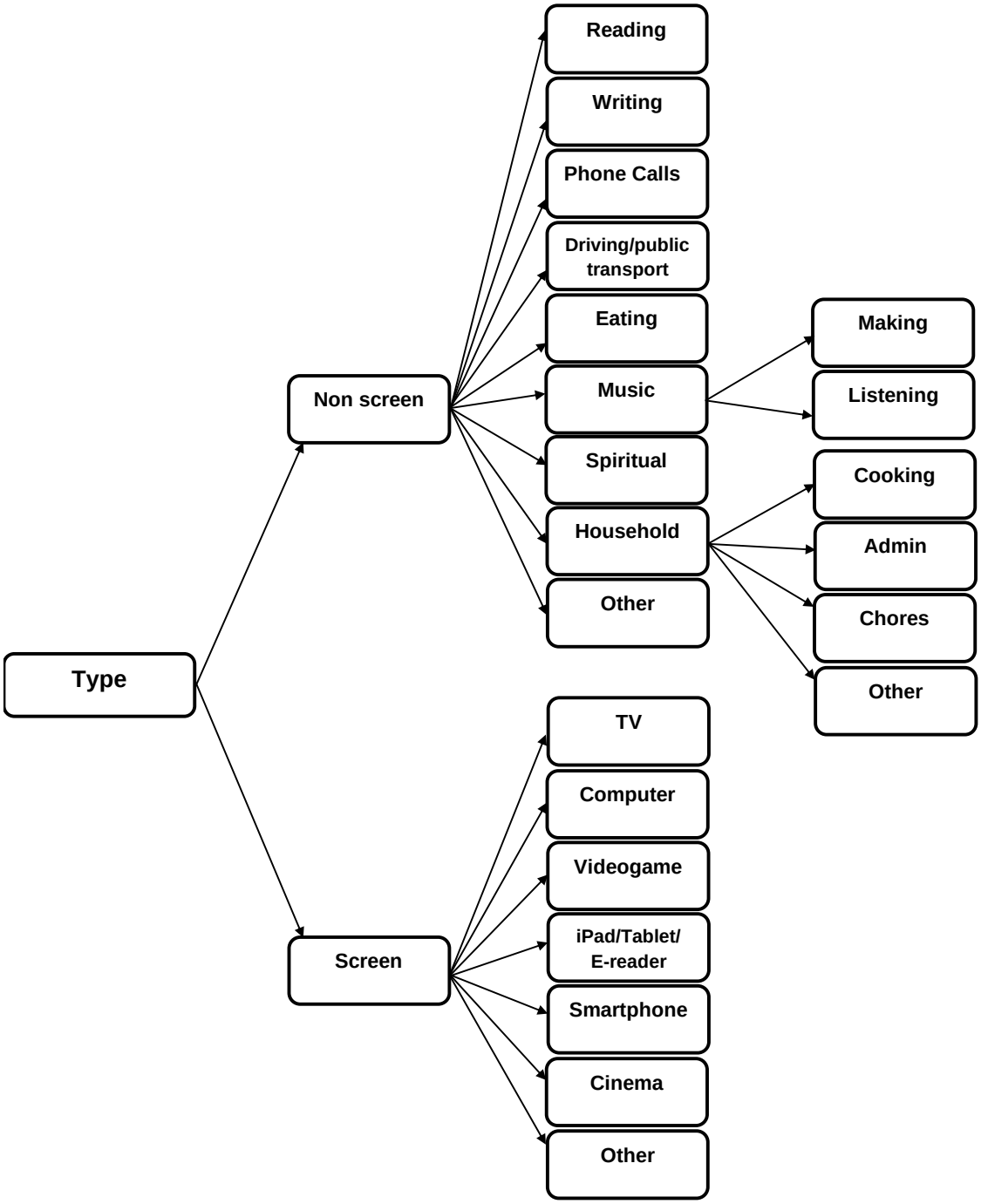


Figure 16. Adapted ‘type’ facet from the Sedentary Behaviour International Taxonomy (SIT).

6.4 Results

6.4.1 Overview

From 346 surveillance systems screened for eligibility, 93 questionnaires were located from 135 countries. Characteristics of the questionnaires in relation to

global region and The World Bank income classification are presented in Table 10. Over a third of the questionnaire units (n=33, 35%) used the WHO STEPS survey (World Health Organization, 2020b). Just under a third of countries (n=30, 32%) used the 2017 Eurobarometer survey (Gesis, 2017), with at least one national survey being included in addition to Eurobarometer in half of these countries (n=15).

Table 10. Global region and The World Bank income classifications for countries with included questionnaires.

Global Region	**n**	**(%)**
Africa	31	(23)
Eastern Mediterranean	11	(8)
Europe	42	(31)
Southeast Asia	9	(7)
The Americas and The Caribbean	19	(14)
Western Pacific	23	(17)
Income classification		
Low income	15	(11)
Lower middle-income	34	(25)
Upper middle-income	31	(23)
High income	55	(41)

6.4.2 Questionnaire characteristics

Of the 93 questionnaires that were included in the review, nine contained multiple items on sedentary behaviour that could not be categorised in their entirety in the TASST due to variability in the question characteristics. These nine questionnaires were subsequently split into 20 question items and mapped separately. Hereafter, the term ‘questionnaire units’ is used to refer collectively to complete questionnaires *and* these 20 questionnaire items. A total of 104 questionnaire units were mapped onto the TASST, comprising 84 complete questionnaires and 20 question items.

Characteristics of the 104 questionnaire units that were mapped onto the TASST are summarised in Table 11. Most questionnaire units (n=83, 80%) were single item direct measures of sitting time. Proxy single-item measures of sedentary behaviour were based on TV viewing (n=2, 1%), travel (n=2, 1%) and computer use (n=1, 1%). A composite assessment was used in 21 questionnaire units, of which 17 used

a composite measure of a sum of behaviours and four used a sum of behaviours and domains (e.g., at home watching TV).

Most questionnaire units used an unanchored recall period (n=65, 63%), meaning respondents were asked about a general period of time, such as a typical day rather than specifying a particular period of time. Almost all questionnaire units used a temporal unit of a single day (n=100, 96%) with the remaining requesting a weekly estimate (n=4, 4%). For the assessment period, almost three quarters of questionnaire units (n=76, 73%) were classified as “not defined” meaning they did not specify any parameters on the temporal unit. Fourteen questionnaire units (13%) specified weekdays only, 12 (12%) specified both weekdays and weekend days, and two (2%) stated a subdivision of the day with both questionnaire units stating before 6pm and after 6pm on a weekday and weekend.

Table 11. Questionnaire characteristics mapped onto the Taxonomy of Self-reported Sedentary Behaviour Tools (TASST); (n=104).

Taxonomy item		**n**	**(%)**
1	**Type of assessment**		
1.1	*Single item*	*83*	(80)
1.1.1	Direct measure	78	
1.1.2	Proxy measure	5	
1.2	*Composite item*	*21*	(20)
1.2.1	Pattern	0	
1.2.2	Sum	21	
1.2.2.1	Behaviours	17	
1.2.2.2	Domains	0	
1.2.2.3	Behaviours and domains	4	
2	**Recall period**		
2.1	Previous day	2	(2)
2.2	Previous week	31	(30)
2.3	Longer	6	(6)
2.4	Unanchored	65	(63)
3	**Temporal unit**		
3.1	Day	100	(96)
3.2	Week	4	(4)
3.3	Longer	0	(0)
4	**Assessment period**		
4.1	Weekdays only	14	(13)
4.2	Weekend days only	0	(0)
4.3	Both weekdays and weekend days	12	(12)
4.4	Subdivision of the day	2	(2)
4.5	Not defined	76	(73)

6.4.3 Sedentary behaviour characteristics

The behavioural characteristics of the 93 included questionnaires were mapped onto the SIT as shown in Table 12. Firstly, the questionnaires were mapped according to the purpose(s) and type(s) of sedentary behaviour that they assessed. The examples of sedentary behaviour that were used within the questions were then mapped.

6.4.3.1 Purpose

Most questionnaires measured more than one purpose, with the categories of work (n=60, 65%) and domestic (n=48, 52%) being captured most frequently. Fewer questionnaires assessed the purposes of leisure (n=21, 23%) and education (n=10, 11%), with 11 having an undetermined purpose. The purpose categories of work (n=63, 68%), travel (n=49, 53%), and social (n=47, 51%) were included most frequently within the examples.

6.4.3.2 Type

Most questionnaires captured total sitting time (n=77, 83%) while 26 (28%) questionnaires captured any form of screen/non-screen-based sedentary behaviours. For non-screen behaviours, questionnaires referred to reading (n=3, 3%) and driving/using public transport (n=3, 3%) most frequently. For the screen-based behaviours, TV (n=21, 23%) and computer use (n=15, 16%) were the behaviours captured most frequently. Fewer questionnaires captured iPad/tablet/E-Reader (n=7, 8%), smartphone (n=5, 5%) and videogame use (n=4, 4%).

With regards to the example behaviours provided with the questionnaires, the non-screen examples were mostly classified as reading (n=63, 68%), driving/using public transport (n=49, 53%) and “other”. The most common behaviour categorised as ‘other’ was playing cards. The screen behaviour most frequently given as an example was TV viewing, which was included in 67 questionnaires. The screen behaviours of PC use (n=21, 23%), playing video games (n=12, 13%), using an iPad/Tablet/E-Reader (n=7, 8%) or smartphone (n=5, 5%) were included less frequently.

Table 12. Frequency of sedentary behaviour characteristics mapped onto the Sedentary Behaviour International Taxonomy (SIT); (n=93).

Facet	Category	Measured (n)	Examples (n)
Purpose			
	Work	60	63
	Leisure	21	1
	Travel	44	49
	Domestic	48	12
	Education	10	18
	Social	36	47
	Eating	0	2
	Rest	0	2
	Care	0	0
	Other	0	1
	Undetermined	11	8
	Total sitting	77	-
Type			
Non screen			
	Reading	3	63
	Writing	0	1
	Phone calls	0	0
	Driving/using public transport	3	49
	Eating	0	2
	Music	1	4
	Spiritual	0	0
	Household	0	0
	Other	0	39
Screen			
	TV	21	67
	PC	15	21
	Videogame	4	12
	iPad/Tablet/E-reader	7	5
	Smartphone	5	5
	Cinema	0	1
	Other	0	1
	Undetermined	1	-

6.5 Discussion

Using 93 questionnaires from 135 countries, the characteristics of sedentary behaviour assessment in national surveillance systems are described. Based on classification using TASST, it was found that most systems used a single item direct measure of total sitting time, with some using a single item proxy measure or a composite measure, but this was less common. In addition, through the use of the SIT, it was found that most questionnaires referred to multiple purposes, with work and domestic being the most frequently captured. TV viewing and computer use were the most frequently captured types of sedentary behaviours.

A single item direct measure of total sitting time was the most frequently used question type identified in this review. Single-item questions are generally preferred in surveillance systems because they take up relatively little space within the survey, and have low participant burden (Scholes *et al.*, 2016; Prince *et al.*, 2019; Mielke *et al.*, 2020; Marconcin *et al.*, 2021). However, single item measures of sitting time do not provide information on the type and domain of behaviours; this is important because there is evidence that specific types of sedentary behaviour are uniquely associated with morbidity and mortality, sometimes more strongly than overall sitting time (Rezende *et al.*, 2014; Ekelund *et al.*, 2016; Rivière *et al.*, 2018; Mielke *et al.*, 2020). In addition, many single item measures provide less accurate estimates of sedentary time than composite questionnaires comprising multiple items (Prince *et al.*, 2018; Mielke *et al.*, 2020). Whilst most of the questions included in this review asked the respondent to report their duration of sitting/lying down, there were some subtle differences in language. For example, some questions referred to sitting only whilst others referred to resting or reclining (further details are provided in Appendix 14). The impact of these differences in phrasing on reported duration and subsequent prevalence estimates is unclear, but they may impact the validity of between country comparisons.

A key function of population surveillance of sedentary behaviour is to monitor compliance with national guidelines (Troiano, Stamatakis and Bull, 2020). The predominant assessment of total sitting time is consistent with most public health guidelines, which typically recommend that sedentary behaviour (in general) be limited (without specifying an upper limit), though a small number of countries, such as Canada have produced quantified and behaviour specific recommendations

(The Canadian Society for Exercise Physiology, 2021). In such cases, surveillance instruments may need to be amended to ascertain population compliance with these guidelines. In the context of physical activity surveillance, a recent review in older adults found that from 38 surveys, only five included a question asking about muscle strengthening activities and none asked about balance and coordination activities, both of which are key components of public health guidelines (Milton *et al.*, 2018). It is imperative that population surveillance systems include appropriate questions that measure all aspects of both physical activity and sedentary behaviour guidelines to generate accurate prevalence estimates.

Historically, sedentary behaviour research has had a strong focus on time spent TV viewing and its association with health and well-being (Biddle *et al.*, 2017). It was found that relatively few surveillance systems (only 19%) captured time in specific behaviours, but those that did predominantly assessed time spent watching TV or using a computer. This is consistent with findings by Rivière *et al.* (2018) in their review of sedentary behaviour questionnaires. Periodically, surveillance tools may need to be updated to ensure they adequately capture contemporary behaviour patterns. For example, secular data indicate that time spent watching traditional (terrestrial) TV has declined in recent years, whilst time spent using a mobile phone and watching online TV has increased (Harvey *et al.*, 2022). A key challenge to this process will be ensuring 'backwards compatibility' in questionnaire content to ensure that updated questionnaires are sufficiently consistent with older versions, such that data on temporal trends is accurate, whilst also capturing newer types of behaviour. This will likely require piloting and validity testing of new questionnaires prior to them being rolled out.

In addition to mapping the behaviours explicitly measured in the questionnaires, any accompanying examples used in the question pre-amble or main text were also captured. The types of sedentary behaviours most commonly provided as examples in the questionnaires were reading, driving/using public transport, playing cards, and watching TV. Example behaviours provided in questionnaires are important because they serve as prompts for respondents and may influence the estimates that an individual provides. In the context of physical activity measurement, Cusatis and Garbarski (2018) reported that priming participants to think about specific activity domains, either separately or collectively, significantly

impacted upon subsequent estimates of weekly physical activity duration. Furthermore, research assessing understanding of physical activity questionnaires indicates that many respondents believe the list of activities provided as examples are too long and they were unsure whether the activities provided were an exhaustive list or merely examples (Altschuler *et al.*, 2009). These findings suggest that the number and type of behaviours provided as examples may impact participant responses, but this is an under-researched area, particularly with regard to sedentary behaviour. We suggest the number and types of behaviours included as examples should be carefully considered when updating or developing new tools for population surveillance of sedentary behaviour to ensure they reflect current behaviour patterns.

The following strengths and limitations of this review are acknowledged. A strength is the location of data sources using the most recent GoPA! country cards, which provide an overview of physical activity and sedentary behaviour surveillance systems used globally. In addition, rigorously developed classification tools (TASST and SIT) were used to describe and categorise questionnaire characteristics, facilitating synthesis and comparisons between surveillance systems. A limitation is the potential for a degree of subjectivity in the application of the frameworks used to guide the synthesis. We were unable to locate all the questionnaires used in the most recent national surveillance systems listed on the country cards and some of the surveillance systems included within this study may have been updated or changed since this work was completed. In addition, although the GoPA! country cards provide an overview of global surveillance systems it is acknowledged that some potentially relevant sources may be missing from the country cards and hence from this review. Lastly, the focus was on describing the characteristics of sedentary behaviour surveillance questionnaires. As such the method of sample recruitment, obtained sample sizes and the validity and reliability of the questions used were not considered, but it is acknowledged that these are important considerations for obtaining representative prevalence estimates. The psychometric properties of self-report methods to assess sedentary behaviour has recently been reviewed elsewhere (Bakker *et al.*, 2020).

6.6 Conclusion

From the present review of sedentary behaviour assessment in population surveillance, it was found that most countries are using a single item direct measure of sitting time to estimate their country level prevalence, and these tools are largely consistent with public health guidelines. To ensure that surveillance systems are able to adequately capture contemporary behaviour patterns, questions assessing the duration of multiple behaviours are necessary, particularly for activities that are becoming increasingly prevalent, such as mobile phone and games console use. Additionally, the example behaviours provided, and the types of behaviours being measured, should be periodically reviewed in response to evidence on contemporary behaviour patterns in the population and the release of updated public health guidelines to ensure they remain relevant.

Chapter 7: General discussion

7.1 Overview

This thesis has presented four distinct but interlinked studies using diverse data sources to characterise sedentary and screen-based behaviours in adults. The findings produced from this thesis can be used to inform surveillance, the development of tools to measure sedentary behaviour and the design of behaviour change interventions. This chapter summarises the main findings from each of the four studies before discussing the overall thesis in relation to wider literature. Finally, methodological, and personal reflections are presented, before directions for future research are considered and concluding statements are made.

7.2 Summary of main findings

7.2.1 Study 1 - International trends in screen-based behaviours from 2012 to 2019.

It has been acknowledged that adults are accumulating a considerable amount of time in screen-based behaviours, including watching TV, playing computer and videogames or using a smartphone or tablet (LeBlanc *et al.*, 2017). However, there is limited evidence on the temporal changes in type and duration of screen device use. Additionally, some researchers have questioned whether current academic research accurately reflects contemporary behaviour patterns (LeBlanc *et al.*, 2017). Using industry data from the global market research company GWI, this study was devised to address these gaps in knowledge.

This analysis revealed that screen time increased globally by approx. 2 hours/day between 2012 and 2019, with the greatest increases being observed in Latin America and the Middle East and Africa. Additionally, this study provided important evidence on the temporal trends in specific types of screen behaviours. Mobile phone use, online TV viewing and games console use were found to have increased across the eight-year period. Conversely, PC, laptop and tablet use and traditional TV viewing decreased in duration across the same time span. Younger adults aged 16-24 and 25-34 years spent the highest amounts of time engaging in all behaviours apart from traditional TV viewing. This suggests that behaviour change interventions may need to target specific demographic groups such as

younger adults, and behaviours that are most prevalent within these groups to have the greatest potential to benefit health. These findings give an up-to-date picture of contemporary behaviour patterns globally.

7.2.2 Study 2 - The diurnal pattern and secondary activities associated with sedentary and screen-based behaviour in adults.

Using data from the UKTUS, this study described the diurnal patterns and secondary activities associated with sedentary and screen-based behaviours in adults. Time spent in all behaviours studied increased gradually from 2pm on workdays, but the patterns were less consistent on non-workdays. Each of the included sedentary behaviours peaked between 8pm and 10pm on both workdays and non-workdays. This study provided important insights into diurnal patterns, addressing gaps in knowledge around when, during the day, different types of sedentary and screen-based behaviours occur. The findings indicate that intervention content should be tailored towards demographic factors (sex and age), specific behaviours and the type of day, as well as targeting evenings on both workdays and non-workdays.

A novel aspect of this study was the examination of secondary activities that co-occur alongside different types of sedentary behaviour. Secondary activities were reported in just over a quarter of timeslots. Use of mass media, which included TV viewing, reading, and listening to radio and music, was the most prevalent secondary activity reported. Capturing contemporary behaviours and their co-occurring activities in future time use research is needed to explore how different behaviour combinations may be associated with health outcomes. Information on multi-tasking can also be used to inform the design of time- and activity-specific behaviour change interventions and to assist with the development of tools to capture multiple behaviours. To achieve this, the current coding system used to categorise participant's time-use diary entries (University of Oxford, 2016) will need to be expanded to capture contemporary behaviours, including mobile phone use and allow online TV viewing to be distinguished from traditional TV viewing.

7.2.3 Study 3 - Country-level correlates of self-reported sitting time in European adults.

Building on the observation that substantial between-country differences exist in sedentary behaviour, as identified in Study 1, the third study examined country level correlates of sitting time using data from the multi-country Eurobarometer survey. The analysis showed that GDP was negatively associated, and HDI positively associated, with self-reported sitting time. These findings addressed gaps in knowledge surrounding macro-level influences on sedentary behaviour. The results from this study suggest that country-level factors influence individual sitting time, but these associations are typically small. Given that human development is positively associated with sitting time, which may be detrimental to health, further research is needed to identify modifiable factors that may underlie this association, which in turn can be used to inform behaviour change interventions.

A second aim of this study was to explore whether the associations between country level factors and sitting time varied over time and by individual factors. For all exposures, the associations with sitting time varied by sex and occupation, whilst the associations between sitting time and GDP, internet use and service sector employment varied by age. These findings can be used to identify population sub-groups that may benefit from targeted interventions. Based on the study findings, HDI was the most strongly associated with self-reported sitting time. Effect modification analyses revealed that the associations between HDI and sitting time were strongest in men, individuals aged 45 and above and those not in employment (relevant to their respective reference groups) and therefore these groups should be targeted within upstream interventions.

7.2.4 Study 4 - A review of sedentary behaviour assessment in national surveillance systems.

Study 4 described the characteristics of questionnaires used to measure sedentary behaviour in national surveillance systems and identified the types of sedentary behaviours being measured by these tools. This review revealed that most questionnaires used a single item direct measure of sitting time. Critically, this study highlighted that few surveillance systems captured time spent in specific behaviours and those that did tended to focus on TV viewing and computer use. This was also the case for any example behaviours included in question pre-amble or introductory text. This demonstrates that despite the apparent decline in time spent watching TV

and using a computer, as shown in Study 1, these behaviours are still the most frequently measured in surveillance. These findings combined suggest that surveillance systems may not be capturing the full breadth of behaviours that are engaged in within society and may need to be updated to better reflect contemporary behaviour patterns. The behaviours considered in Study 1 (traditional TV viewing, PC/laptop/tablet use, online TV viewing, games console use and mobile phone use) should be measured within surveillance systems to gain an understanding of the time spent in individual behaviours. Alternatively, if due to time and space constraints multiple questions cannot be included, a single item question that can provide an estimate of total sedentary time is recommended.

7.3 General discussion of thesis findings

In this section the results of the thesis are discussed in the context of wider literature on measurement, surveillance, the design of behaviour change interventions and future challenges for classifying types of sedentary behaviours.

7.3.1 Measurement and surveillance

7.3.3.1 Measurement

A common theme identified in this thesis was the need for tools used to measure sedentary behaviour to be updated and/or developed. Screens are an integral part of daily life, but there is evidence that their use is changing from larger screens such as TVs to smaller, portable screens such as smartphones and tablets (LeBlanc *et al.*, 2017; Stamatakis *et al.*, 2019). Findings from Study 1 lend further support to this observation, highlighting the changing screen-use landscape. This poses methodological challenges for researchers in being able to measure uptake and usage of new screen devices and ascertain the impact of these different behaviours on health. To address the challenges associated with the measurement of different types and domains of sedentary behaviour, a new 18-item instrument was developed and tested by Vizcaino *et al.* (2019) to quantify different types of screen use including TV, TV-connected devices, laptop/computer, smartphone and tablet use. This tool has demonstrated utility in quantifying the use of different types of sedentary behaviours which in turn can be used to assess the association between different types of sedentary behaviours and health outcomes amongst other things. As new tools are developed, they can also be used to provide better

insight into contemporary behaviour patterns. Currently, there is a lack of primary evidence which has examined the associations between contemporary behaviours such as smartphone use and health outcomes (Saunders *et al.*, 2020). Therefore, it would be valuable to introduce questions assessing contemporary behaviours into new or ongoing prospective cohort studies.

Findings from this thesis highlighted the increasing use of portable screen devices, which poses a measurement challenge for establishing the posture that accompanies device usage, which may have implications for associations with health. For example, TV viewing has traditionally been regarded as an activity undertaken in a seated position, however, content can now be viewed on a smartphone or tablet in a lying, seated or standing position or even whilst being physically active on a treadmill. Recent research has demonstrated that up to 75% of mobile device use occurs whilst lying or sitting, with the remaining 25% of time occurring in a standing or stepping posture (Alzhrani *et al.*, 2022). Additionally, it is important to consider that behaviours can be undertaken in a variety of postures, which may change during the period of use. One possible route to capturing this complexity in screen-based behaviours is to use self-report and device-based measures in combination to provide both contextual and postural information. The use of Ecological Momentary Assessments, which are a type of self-report measure in which people report their activities in real-time (Prince *et al.*, 2020a), alongside inclinometers to ascertain postural information (Atkin *et al.*, 2012) are recommended. Many cohort studies are now using device-based measures to assess total sitting and sedentary time (Pulsford *et al.*, 2023). A key example is the SurPASS project which has been devised for the surveillance of physical activity, sedentary behaviour, and sleep (Crowley *et al.*, 2022). This system uses a thigh worn accelerometer to measure the frequency and intensity of movement (Byrom *et al.*, 2016) alongside a smartphone app which respondents can use to report their work and sleep time (Crowley *et al.*, 2022).

7.3.3.2 Surveillance

This thesis has highlighted the challenges associated with the surveillance of sedentary behaviour. It is recommended that population surveillance uses the same questions across surveys to enable trends to be established over time (Dall *et al.*, 2017; Prince *et al.*, 2017b). The use of consistent questions also allows

comparisons to be made across countries and sub-groups, as highlighted in studies 1 and 3 of this thesis. In 2019 it was reported that the four home nations of the UK (England, Wales, Scotland, and Northern Ireland) used different surveys and questions to assess sedentary behaviour and thus cross-country comparisons could not be made (Strain *et al.*, 2020). One suggestion was to use a harmonised measure by selecting one of the four home countries' questionnaires, which would assist with the monitoring of trends using existing data (Strain *et al.*, 2020).

It is important to consider that the monitoring of behaviours can be influenced by various factors including new technologies (Prince *et al.*, 2017b) and guideline changes (Troiano, Stamatakis and Bull, 2020). This can inevitably lead to issues with measuring trends, as well as problems with survey space and time constraints. A single question assessing sedentary behaviour could be included in surveys, which would address issues around space constraints (Strain *et al.*, 2020). However, one question alone would not be able to provide contextual information on different types and domains of sedentary behaviours. Based on the findings from Study 4, when a single question has been used, these have typically assessed total sitting time. As an alternative, a short, flexible surveillance module assessing different types and domains of sedentary behaviour was developed in Canada, which ordered questions based on their associated risks with health (Prince *et al.*, 2019). The flexible nature of this module meant that if only one or two questions could be included in the survey, the types of behaviours with the greatest evidence base for detrimental associations with health would be incorporated (Prince *et al.*, 2019). This module provides a practical way of dealing with the varying time and space issues in surveillance systems.

7.3.3.3 The future of measurement, surveillance, and technology

Self-report questionnaires are often used to measure sedentary behaviour and screen time (Biddle *et al.*, 2017; Reeves, Robinson and Ram, 2020). However, technological advancements are increasingly allowing for more sophisticated ways of capturing sedentary behaviour and screen time. One innovative system for the surveillance of physical activity, sedentary behaviour and sleep has been developed through the SurPASS project. The system uses a combination of four elements: 1) thigh worn accelerometry with Bluetooth connectivity; 2) a smartphone app for users to read instructions on device use and to record work and sleep time;

3) automatic uploading, analysis, storage and feedback to individuals that complies with data privacy regulations; and 4) a web application for administrative tasks (Crowley *et al.*, 2022). This system and its associated protocol provides a valuable starting place for the development of modern surveillance tools to measure movement behaviours (Crowley *et al.*, 2022). Additionally, Nielsen, an industry leader in measuring audience behaviour, devised the platform Neilsen ONE, allowing cross-media measurement to capture what, where, and how audiences are watching and using screen media (Nielsen, 2023). Given the platform can be used across different types of media, this could present a useful way of measuring and providing more contextual information on screen use.

The Human Screenome Project has been devised to capture screen media use through a series of screenshots capturing what people are doing on their smartphones at specified intervals (Reeves, Robinson and Ram, 2020). This software collects screenshots when the smartphone is on and extracts text and images which can be analysed to produce a more complete picture of people's interaction and use of smartphones (Brinberg *et al.*, 2021). Currently, this project only uses smartphone data, however, there is potential for other screens to be observed in the future, thus providing a unique way of capturing screen media use (Brinberg *et al.*, 2021). Notwithstanding the benefits of this project, the issue of privacy should not be ignored. Screenshots can reveal personal and private information of both participants and third parties (Brinberg *et al.*, 2021; Reeves *et al.*, 2021; Yee *et al.*, 2023). Despite use of encryption, limiting the number of screenshots viewed by members of the research team, and following data storage and access procedures to ensure security of the data collected, many people chose not to participate due to reservations around privacy (Reeves, Robinson and Ram, 2020; Brinberg *et al.*, 2021; Reeves *et al.*, 2021). A further limitation is that the software used for collecting the screenshots is not freely available and requires substantial time and computer programming knowledge to set up, which many researchers and/or their institutions may lack (Brinberg *et al.*, 2021; Yee *et al.*, 2023). Additionally, large numbers of screenshots are collected which takes a significant amount of time to process and inhibits the collection of data from large numbers of participants. Finally, the Screen Life Capture study (Yee *et al.*, 2023) highlighted the potential challenges that researchers face if screenshots suggest

harm or criminal activity; in such cases there may be a legal obligation to report their findings.

7.3.2 Design of behaviour change interventions

This thesis has provided insights that can be used to inform the timing of behaviour change interventions. Findings from Study 2 highlighted that there may be value in targeting sedentary and screen-based behaviour reduction interventions in the evening, specifically between 8pm and 10pm, when usage typically peaks. However, to date there is a lack of research assessing the effectiveness of screen reduction interventions targeting specific times of the day. JITAIs are a contemporary method of changing behaviour which utilise technology to provide support to individuals when and where they need it (Müller, Blandford and Yardley, 2017; Hardeman *et al.*, 2019). Information such as the location, time of day, and number of prompts given, can be collected via a smartphone (Müller, Blandford and Yardley, 2017). Support for individuals is provided in real-time and tailored based on the information collected by the screen device, which then triggers the support (Hardeman *et al.*, 2019). Thus far, evidence on the effects of JITAIs in reducing sedentary behaviour is mixed, which may be because this type of intervention is in its infancy (Hardeman *et al.*, 2019). Nevertheless, one JITAI aimed to break up periods of sedentary behaviour in obese adults through walking breaks (Thomas and Bond, 2015). A greater number of prompts was associated with greater adherence to changing behaviour; specifically, encouraging individuals to walk for 3 minutes after 30 minutes of continuous sedentary behaviour resulted in the greatest number of walking breaks (Thomas and Bond, 2015). Findings from this thesis highlighted that behaviours occur at different times of the day, therefore JITAIs may have the greatest success in reducing time spent in different types of sedentary behaviour in the evening. Further exploration of contextual factors such as people's location and who they are with in the evenings are also needed to inform the delivery of evening targeted interventions.

Findings from Study 2 highlight the potential need for tailoring interventions to specific demographic groups and behaviours. Prior to Study 2 being conducted, there was a lack of research assessing diurnal patterns of screen and non-screen-based behaviours in different population sub-groups. Study findings revealed that, for example, on workdays, males tend to engage in more gaming and females

typically engage in more online communication. These results are supported by previous research which revealed that males engaged in more videogame play and leisure screen time, whilst females took part in more leisure time reading (Prince *et al.*, 2020c). A first step to targeting behaviours in specific population groups would be to use both quantitative and qualitative methods to gain an understanding of what behaviours individuals feel they could reduce and why (Arundell *et al.*, 2019), which can be used to inform the design of behaviour change strategies.

Historically, epidemiological studies of sedentary behaviour have tended to focus on individual, highly prevalent behaviours such as TV viewing (Hu, 2003; Jakes *et al.*, 2003), whilst Study 4 highlighted that in surveillance total sitting time is often the preferred metric. However, to progress knowledge on this topic, there is value in disaggregating sedentary behaviour into smaller behavioural units and focussing on a broader range of behaviours. This will enable a more precise understanding of behaviour patterns and associations of individual behaviours with health indicators, both of which are informative for public health policy and intervention design. However, this approach also poses important challenges. It may not be possible to establish associations between behaviours of very low duration and health markers due to insufficient dose or heterogeneity of the exposure. Designing and evaluating behaviour change interventions aimed at very small units of behaviour may also be methodologically challenging and lack participant buy in. Moreover, as highlighted in Study 2, behaviours often co-occur, and multiple behaviours can be engaged in at one time. Identifying the relationships between these individual units of behaviour and health outcomes and targeting these within interventions is challenging given it can be difficult to measure behaviours in isolation. Improving the ways in which we measure these behaviours will contribute to addressing these limitations (Perez *et al.*, 2023). As evidence accumulates on behaviour-specific associations with health indicators, there may be scope to reaggregate certain groups of behaviours with clear (shared) links to health to provide more substantive targets of intervention.

7.3.3 Future challenges for classifying types of sedentary behaviours

This thesis has highlighted the potential challenges in classifying sedentary and screen behaviours in a rapidly evolving technology landscape. One emerging challenge is keeping up with the plethora of screen devices available in

society. Findings from Study 1 indicate a transition across time from using more traditional fixed devices, such as TVs, to using portable screen devices such as mobile phones, which can be used for a variety of purposes (e.g. talking to friends/family, internet browsing, playing video games) and need not necessarily be used whilst sitting. This poses the question as to whether we should classify sedentary activities by the device that is used or the behaviour that is engaged in. It may be easier for interventions to target device use (i.e. a reduction in mobile phone use) rather than the reduction of specific behaviours engaged in on a given device (i.e. reading on a mobile phone). In comparison, classifying sedentary activities by the behaviour provides a more nuanced understanding of different activities. However, it should be acknowledged that the landscape will inevitably change, with some devices and behaviours emerging and others disappearing. Introduced in Study 4, the SIT provides a multi-faceted classification system for sedentary behaviours, developed through an expert consensus process (Chastin, Schwarz and Skelton, 2013). Considered here, the SIT provides a useful tool for capturing the multi-dimensional nature of sedentary behaviour, though it is now over 10 years old. Such a tool can serve as a guide to identifying gaps in evidence as it relates to different dimensions of sedentary behaviour and associations with health.

Research in the last decade has identified that sedentary behaviours requiring different levels of mental engagement, categorised as mentally passive (i.e., TV viewing) and mentally active (i.e., reading or using a computer), may be differentially associated with health (Kikuchi *et al.*, 2014; Hallgren et al., 2018;2020). These differing associations suggest it may not necessarily be the device or behaviour per se that drives an association with health outcomes, but rather whether the activity is mentally stimulating or not. Studies thus far have highlighted that passive sedentary behaviours are associated with negative health outcomes, such as worse cognitive performance, whereas mentally active sedentary behaviours are associated with more favourable outcomes such as a decreased risk of depression onset (Kikuchi *et al.*, 2014; Hallgren *et al.*, 2018; Ringin *et al.*, 2023). However, research to date has assessed a limited range of predominantly mental-health related markers, with less attention paid to physical health. Moreover, the majority of studies in this area have been cross-sectional and thus the issue of reverse causality cannot be ignored (Kikuchi *et al.*, 2014); it is unclear whether the

nature of the behaviour (i.e. active or passive) influences health or whether a person's health influences their decision to choose a certain activity. Finally, there is currently no consensus on which activities should be classified as mentally active and passive (Ringin *et al.*, 2023). Therefore, it is suggested that experts should be consulted via a Delphi process to establish a consensus definition for active/passive behaviours and consider whether this dimension should be added to the existing SIT classification tool (Chastin, Schwarz and Skelton, 2013). Future studies should use this categorisation of behaviours to identify correlates of mentally active and passive sedentary behaviours and to assess the associations of these behaviour categories with health outcomes.

7.4 Implications for research, policy, and practice

Implications of the work presented in this thesis for measurement (section 7.3.1), surveillance (section 7.3.1) and the design of behaviour change interventions (section 7.3.2) have been considered in previous sections. Here, specific implications are considered in relation to research, policy, and practice.

Further development and testing of sedentary behaviour measurement tools. The psychometric properties of commonly used sedentary behaviour questionnaires have recently been reviewed (Bakker *et al.*, 2020). However, newer instruments, such as those developed to measure different types of behaviours and/or behaviour categories i.e. mentally active or passive (Prince *et al.*, 2019; Vizcaino *et al.*, 2019; Qi *et al.*, 2023) have thus far been subject to limited psychometric testing. The Edinburgh Framework has been proposed for establishing the validity and reliability of a sedentary behaviour measure (Kelly, Fitzsimons and Baker, 2016). When considering validity, the framework highlights the importance of determining the most appropriate gold standard measure as these will differ depending on the aspect of sedentary behaviour in question (Kelly, Fitzsimons and Baker, 2016). Therefore, the use of direct observation or inclinometers (which are widely considered as the gold standard measures) may not always be appropriate. Additionally, if participants are going to be classified into categories (e.g. high or low levels of screen use), this should be incorporated into the validation (Kelly, Fitzsimons and Baker, 2016). A second consideration is that future validation studies should be conducted on samples representativeness of the

wider population. To date, the psychometric properties of tools have often been tested on small sample sizes with participants from specific population groups such as students or groups of workers (Vizcaino *et al.*, 2019; Qi *et al.*, 2023). This introduces a bias as the sample are not representative of the general population or the groups of people the questionnaire is intended for (Hagströmer *et al.*, 2012). Given the tools highlighted above have the potential to measure screen use and different types of behaviours in the general population, studies should consider using nationally representative samples that cover both sexes and a range of age groups.

Tools used to measure different types of sedentary behaviour should be periodically reviewed to ensure they meet the current needs of society. The need to accurately capture time spent in a breadth of sedentary behaviours has been discussed previously. However, it is vital that self-report measures are able to keep up with the evolution of technology and capture contemporary behaviours both now and over time (Prince *et al.*, 2019). Many questionnaires currently in use to assess screen-based behaviours or overall screen time tend to only measure TV viewing time and/or leisure time computer use (Vizcaino *et al.*, 2019) despite the emergence of a much more complex sedentary behaviour landscape. One suggestion for addressing this greater complexity is to use generic questions for each type of sedentary behaviour with detailed examples provided alongside that can be updated as and when necessary (Prince *et al.*, 2017b). Currently, there is no guidance on whether existing questionnaires should undergo periodic reviews and how often this should take place. Therefore, the research community should acknowledge the need for and implement regular reviewing and updating of questionnaires to ensure they are still able to adequately capture current sedentary behaviour patterns.

The influence example behaviours have on respondents estimates of sedentary behaviour should be explored. Previous research has revealed the influence that question placement has on respondents' reporting of sedentary behaviour (Prince *et al.*, 2019). For example, when a total sitting time question was placed after domain specific questions on screen time, reading and transport, participants only recalled sitting time outside of these other domains (Prince *et al.*, 2019). However, example behaviours have received little attention to date, despite

their potential influence on sedentary behaviour estimates. Qualitative methods have demonstrated utility in gaining feedback on example behaviours (Prince *et al.*, 2019) and should be considered as a method for understanding the behaviours that participants feel are most appropriate for inclusion in questionnaires. This can be further extended by conducting research that assesses the duration estimates of sedentary behaviour when the same groups of people receive variations in example behaviours, such as no examples, traditional behaviours and contemporary behaviours to assess whether there are differences between the estimates reported.

Greater inclusion of sedentary behaviour measurement in surveillance. Findings from Study 4 highlighted that many countries do not measure sedentary behaviour in their national surveillance systems. STEPs is a standardised survey devised by WHO that can be used for the collection and analysis of data on a variety of non-communicable diseases (World Health Organization, 2017). It is currently the recommended tool for many low- and middle-income countries as it allows flexibility for differences in each individual country's needs (World Health Organization, 2003). However, at present sedentary behaviour is not a "core" item within STEPs; rather it is an optional item that countries can include (World Health Organization, 2017). One potential starting point would be to ensure sedentary behaviour is a mandatory element within STEPs, which would enable cross country comparisons in prevalence and duration estimates and allow trends to be monitored both within and between countries.

Device-based and self-report measures should be used together in surveillance. Questionnaires are widely used for surveillance due to their relatively low participant and administrative burden, but are prone to reporting bias (Stamatakis *et al.*, 2019). In comparison, devices have greater validity than self-report measures and allow a more accurate measure of daily physical activity as well as sitting and sedentary time (Troiano, Stamatakis and Bull, 2020). However, device-based measures do not capture the contextual information needed to identify the types of behaviours that people are doing (Prince *et al.*, 2019; Prince *et al.*, 2020a). Given their relative strengths, it would be beneficial to use both questionnaires and devices simultaneously. To date, the incorporation of device-based measurement into surveillance systems has only occurred in a small number

of high-income countries, likely due to the high costs and administrative burden associated with their use at large scale (Troiano, Stamatakis and Bull, 2020). The SurPASS system utilises a thigh worn accelerometer to measure physical activity, sedentary behaviour and sleep and a smartphone app to provide instructions and report work and sleep time (Crowley *et al.*, 2022). SurPASS provides a new approach for the integration of devices into surveillance of sedentary behaviour. However, it would be useful if the project could be extended to enable participants to report their specific sedentary activities alongside their work and sleep time to get a more nuanced understanding of sedentary behaviour.

In practice, interventions should be employed that focus on the times of the day and locations in which sedentary behaviour and/or screen time occurs. In the context of this thesis, the observation that time spent in most screen and sedentary behaviours peaked during the evening (Study 2) suggests that the home environment is likely to be a key setting for the delivery of behaviour change interventions. A recent systematic review revealed the effectiveness of environmental interventions in reducing sitting time, as measured by device-based and self-report measures (Peachey *et al.*, 2020). However, it should be acknowledged that each of the studies which employed environmental interventions were all based in the workplace. Nevertheless, some features may be useful in other settings, such as the use of environmental restructuring (Morton *et al.*, 2022). One suggestion is to use screen-based prompts that encourage people to move (Peachey *et al.*, 2020; Morton *et al.*, 2022), which could be a viable method for interrupting sedentary behaviour in the home. Given the plethora of studies on workplace interventions, a useful starting point may be to consider which strategies are most feasible to transfer from the workplace into the home setting.

The usefulness of industry/academic partnerships has been highlighted and should be utilised to reduce sedentary behaviour and build the evidence base on the links with health. Wearable technology such as fitness trackers, accompanied by smartphone apps, have become increasingly popular for monitoring health behaviours with large amounts of data collected (Evenson, Goto and Furberg, 2015). Specific features of wearable devices such as skin and environment temperature and heart rate can provide useful information on health related factors (Evenson, Goto and Furberg, 2015). Therefore, developing

relationships with technology companies that own these devices is required to fully utilise their features and inform new ones that can increase understanding of the links between sedentary behaviour and health. Additionally, there is evidence to suggest wearable technology can be used to reduce sedentary behaviour (Stephenson *et al.*, 2017; O'keeffe, Scheid and West, 2020). Therefore, given the advantages of understanding the settings in which people are sedentary, it would be beneficial to utilise GPS features for targeting interventions to a specific environment (Evenson, Goto and Furberg, 2015). Furthermore, given the ubiquity of these devices and potential for continued use, working with companies to design features that may help to reduce sedentary behaviour long-term is worthwhile.

7.5 Methodological reflections

7.5.1 Industry data

Study 1 used data from GWI, who collected data on a range of screen-based behaviours. This thesis highlighted that the range of screen-based behaviours collected by GWI is greater than what is collected within academic research. Companies such as Google, Facebook and Apple now routinely monitor and collect large amounts of data assessing people's digital lives (Reeves, Robinson and Ram, 2020). Therefore, industry-academic collaborations have the potential to advance research and benefit society (King and Persily, 2020). Building stronger links with market research companies such as GWI, technology companies such as Apple, and those collecting audience insights such as Neilsen and Ofcom, would be particularly beneficial for public health research specifically for screen time and screen-based behaviours.

One issue that was encountered when using data from GWI was that it was aggregated data comprising the number of participants selecting each response option to each question, rather than person-level data, which limited what data management and analyses could be undertaken. For example, data could not be inspected for errors and statistical hypothesis testing could not be conducted. Companies can be tentative about sharing their data due to fears of data leaks or findings that may negatively affect the business (Reeves, Robinson and Ram, 2020). In the case of screen behaviours if data show that screen time is detrimental for health it is possible that technology companies would not want their data used

in this way. It is therefore imperative that the aims and motivations of any research are outlined to the company at the outset, which occurred when undertaking this thesis. In line with the suggestion by King and Persily (2020), it would be beneficial to set up a data sharing programme between technology companies and academics to enable the secure sharing of data whilst maintaining individuals' privacy.

The Social Science One programme was created at Harvard University to combat issues around companies giving researchers full access to their data and to be able to publish without prior approval by the company (King and Persily, 2020). The model is structured so there is one independent group of academics who are allowed access to the data and to publish without company approval. A second group, consisting of senior academics, are granted full access to the data and any other relevant company information but are prevented from publishing. This group serve as a trusted third party to both the company and the academics working on the project. The proposed model could be implemented in other institutions; however, this does detract from the individual researchers forming a personal relationship with the company themselves which I found particularly beneficial in my research. Overall, the model proposed by King and Persily (2020) provides a structured approach to forming industry-academic partnerships, ensuring the research and companies are protected, and could be a model that is adopted in other academic institutions.

Despite the strengths of The Social Science One programme, a limitation is that academics who act as a trusted third party are prevented from publishing material using the industry data (King and Persily, 2020). This is vital to ensuring the data are at the required standard for academic use, but nevertheless, it may be a factor that deters academics from being part of similar projects in the future. Furthermore, a large amount of time and effort is required to gain an understanding of the data that companies have available and to build relationships with these organisations. One ethical issue that should be considered is that a data sharing programme, as suggested by King and Persily (2020), would need to adhere to data protection regulations and laws set out in individual countries. Additionally, there may be issues around data sharing if participants have consented to company use but not third-party use. Finally, a data sharing programme may also be costly to set up and

require specialist computing knowledge which may limit the institutions that can implement this to those with expertise and resources.

7.5.2 Time use diary data

In Study 2, diurnal patterns and secondary activities associated with sedentary and screen-based behaviours were explored using data from the UKTUS. This dataset provided a more complete picture of sedentary and screen-based behaviours across a 24-hour period compared to self-report questionnaires, allowing diurnal patterns to be studied. Additionally, due to the granular nature of the data collected, secondary activities could be explored, which are not routinely collected in sedentary behaviour questionnaires.

Participants in the UKTUS recorded their activities as free text responses, which were categorised into pre-determined categories by a team of specialised coders (Morris *et al.*, 2016). The activity classification categories employed by time use surveys have typically been based on a conceptual model that classified four "kinds of time": 1) necessary time; 2) contracted time; 3) committed time; and 4) free time (As, 1978). A limitation of the UKTUS dataset is that the classification system is outdated. For example, the categories included under mass media in the UKTUS are limited to reading, TV and video, and radio and music, and do not include the use of tablets or smartphones. This highlights the need for future time use surveys in the UK to update their activity categories to include more contemporary behaviours. This in turn can provide a more up to date picture of the sedentary behaviour landscape across a 24-hour period. In 2016, the ICATUS was developed to improve the consistency and comparability of time use statistics (United Nations Statistical Division, 2021). This classification system suggested the inclusion of a contextual variable on the use of technology while undertaking certain activities, until diaries are able to distinguish between internet use and non-internet use for an activity (United Nations Statistical Division, 2021). Overall, the system devised by ICATUS may provide a more up to date classification system for categorising activities provided by respondents in the UKTUS.

7.5.3 Personal reflections

During the course of undertaking this thesis, I have learnt a lot about myself and the research process. My master's supervisor told me a PhD has "peaks and

troughs," she was right - resilience, patience and hard work are key. This PhD has enabled me to use a variety of data sources and methods which has challenged me in writing four very different studies. In turn this has developed my synthesising, data analysis and writing skills. I am grateful to have been able to shape my PhD, deviating from the original proposal and running with ideas, whilst being supported by my supervisory team. I am thankful for the opportunity to present my research both internally and externally and for having the chance to go through the peer-review and publishing process. This process has developed both my research and interpersonal skills, which I can transfer into a future career. The PhD has taught me what I enjoy and what I do not enjoy, as well as making me more aware of my strengths and weaknesses.

7.6 Thesis limitations

The aim of this thesis was to advance understanding of contemporary patterns in different types of sedentary and screen-based behaviours. Therefore, self-report methods were used in each of the studies as they can distinguish different types of behaviours. However, it has been acknowledged in other sections of this thesis that self-report measures tend to underestimate the duration of sedentary behaviour, with device-based methods typically providing more accurate estimates (Prince *et al.*, 2020b). A second limitation is that psychometric testing has not been conducted on all the tools used within this thesis. A further limitation is that none of the studies within this thesis used samples that were representative of the population as the samples tended to include a large proportion of older adults. Therefore, the findings may be more generalisable to older individuals rather than the overall population.

Given the focus of this thesis was to assess contemporary behaviours, a limitation is the age of the data, which ranged from 2002-2019 across the four studies. However, as noted throughout, each study used the most recent data available. Finally, this thesis was undertaken during the COVID-19 pandemic and although the data used were not collected during this period, the impact of the pandemic on the sedentary behaviour landscape cannot be ignored. Systematic review evidence highlighted an increase in sedentary behaviour from before to during the COVID-19 lockdown, which appears robust across population groups and measurement methods (Stockwell *et al.*, 2021). The collection of long-term data in the post-COVID period will be required to ascertain whether such changes have been maintained

or whether behaviour patterns returned to pre-pandemic levels. Key findings and implications from this thesis are unlikely to be substantively affected by COVID-19 related measures, particularly with regard to recommendations for research and surveillance.

7.7 Conclusion

This thesis aimed to characterise sedentary and screen-based behaviours in adults through four interlinked studies. Overall, the findings demonstrated that mobile phone use and online TV viewing are prevalent screen-based behaviours, highlighting the population shift from traditional behaviours such as TV viewing and computer use. This thesis suggests that behaviour change interventions should be time and behaviour specific and may benefit from targeting two behaviours simultaneously. Additionally, the cross-level interactions between country and individual level influences of sedentary behaviour suggest multi-level interventions may also be appropriate for reducing sitting time. Finally, the plethora of devices and associated behaviours that can be engaged in are likely to continue evolving, which poses potential challenges for measuring behaviours, screen devices, and postures during use. The work presented in this thesis has highlighted the rapidly evolving technological landscape whilst bringing to the forefront sedentary and screen-based behaviour patterns, correlates, and measures. This thesis has also acknowledged the challenges that are faced in the future, providing directions for how future research will need to evolve to better capture sedentary and screen-based behaviours.

Appendices

Appendix 1. List of countries in each of the global regions.

Asia Pacific	**Europe**	**Latin America**	**Middle East and Africa**	**North America**
China	Austria	Argentina	Egypt	Canada
Hong Kong	Belgium	Brazil	*Ghana	United States of America
India	Denmark	Colombia	Israel	
Indonesia	France	Mexico	*Kenya	
Japan	Germany		*Morocco	
Malaysia	Ireland		*Nigeria	
New Zealand	Italy		Saudi Arabia	
Philippines	Netherlands		South Africa	
Singapore	Poland		United Arab Emirates	
South Korea	Portugal			
Taiwan	Romania			
Thailand	Russia			
Vietnam	Spain			
	Sweden			
	Switzerland			
	Turkey			
	United Kingdom			

*Only tracking time spent on Mobile and Social Media

Appendix 2. International temporal trends in duration (hr:min) of screen-based behaviours from 2012-2019 (Values are mean (standard deviation); presented graphically in Figure 1).

	2012	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Personal Computer/Laptop/Tablet	4:19 (3:00)	4:27 (2:57)	4:16 (2:57)	3:57 (2:55)	3:54 (2:57)	3:40 (2:58)	3:27 (2:57)	3:24 (2:56)
Mobile	1:18 (2:02)	1:37 (2:16)	2:02 (2:34)	2:21 (2:43)	2:36 (2:47)	3:05 (2:57)	3:18 (2:59)	3:22 (2:56)
Traditional Television	2:15 (2:10)	2:12 (2:07)	2:08 (2:07)	2:05 (2:05)	2:04 (2:07)	1:58 (2:04)	1:55 (2:03)	1:57 (2:07)
Online Television	0:43 (1:24)	0:45 (1:23)	0:49 (1:31)	0:51 (1:33)	0:58 (1:39)	1:06 (1:45)	1:10 (1:49)	1:20 (1:57)
Games Console	0:43 (1:28)	0:46 (1:30)	0:48 (1:35)	0:49 (1:36)	0:53 (1:42)	0:56 (1:48)	1:00 (1:51)	1:09 (2:00)

Appendix 3. Duration (hr:min) of time spent online via personal computer/laptop/tablet from 2012-2019 (Values are mean (standard deviation); presented graphically in Figure 2.

	2012	2013	2014	2015	2016	2017	2018	2019
Region*								
AP	4:16 (3:01)	4:19 (2:55)	4:07 (2:54)	3:42 (2:50)	3:38 (2:52)	3:24 (2:54)	3:09 (2:51)	3:04 (2:47)
Europe	3:59 (2:53)	4:09 (2:52)	4:03 (2:53)	3:57 (2:51)	3:54 (2:52)	3:42 (2:50)	3:31 (2:50)	3:30 (2:52)
LA	4:49 (3:07)	5:14 (3:06)	5:05 (3:06)	4:59 (3:07)	4:55 (3:09)	4:43 (3:08)	4:22 (3:08)	4:21 (3:26)
MEA	4:39 (3:06)	4:48 (3:09)	4:30 (3:12)	4:33 (3:14)	4:21 (3:16)	4:24 (3:16)	4:07 (3:15)	3:57 (3:12)
NA	4:39 (3:00)	4:53 (3:13)	4:39 (3:03)	4:13 (3:01)	4:19 (3:04)	4:04 (3:06)	4:00 (3:08)	4:00 (3:09)
Age								
16-24	4:31 (3:05)	4:33 (2:59)	4:20 (3:00)	3:50 (2:56)	3:53 (3:01)	3:50 (3:05)	3:31 (3:03)	3:28 (2:58)
25-34	4:34 (3:04)	4:44 (3:01)	4:28 (3:02)	4:11 (3:01)	4:03 (3:02)	3:51 (3:05)	3:37 (3:04)	3:34 (3:03)
35-44	4:10 (2:57)	4:16 (2:54)	4:12 (2:56)	3:54 (2:52)	3:52 (2:56)	3:28 (2:54)	3:21 (2:52)	3:18 (2:54)
45-54	4:00 (2:54)	4:11 (2:53)	4:02 (2:50)	3:54 (2:50)	3:50 (2:50)	3:28 (2:48)	3:19 (2:47)	3:18 (2:47)
55-64	3:42 (2:43)	3:57 (2:47)	3:50 (2:41)	3:37 (2:40)	3:38 (2:44)	3:19 (2:38)	3:13 (2:39)	3:10 (2:38)
Education[Ŧ]								
School to 16	3:55 (3:03)	4:01 (3:02)	3:49 (2:58)	3:16 (2:40)	3:21 (2:47)	3:12 (2:59)	2:47 (2:50)	2:34 (2:41)
School to 18	4:03 (2:57)	4:09 (2:57)	3:56 (2:56)	3:40 (2:51)	3:33 (2:54)	3:21 (2:56)	3:03 (2:51)	2:54(2:47)
Trade school/college	4:19 (3:05)	4:30 (2:58)	4:17 (2:57)	4:00 (2:56)	3:54 (2:57)	3:42 (2:59)	3:42 (3:02)	3:39 (3:02)
UG Degree	4:24 (2:58)	4:31 (2:55)	4:23 (2:56)	4:07 (2:55)	4:05 (2:56)	3:57 (2:59)	3:46 (2:56)	3:43 (2:57)
PG Degree	4:45 (3:03)	4:51 (3:02)	4:45 (3:02)	4:28 (3:06)	4:32 (3:04)	4:16 (3:04)	4:05 (3:03)	3:58 (3:04)
Sex								
Male	4:21 (3:02)	4:25 (2:57)	4:16 (2:57)	3:58 (2:55)	3:57 (2:40)	3:43 (2:59)	3:31 (2:58)	3:21 (2:55)
Female	4:17 (2:58)	4:28 (2:58)	4:16 (2:57)	3:55 (2:55)	3:50 (2:57)	3:36 (2:59)	3:20 (2:56)	3:14 (2:55)

* AP = Asia Pacific, LA = Latin America, MEA = Middle East and Africa, NA = North America,

Ŧ UG Degree = Undergraduate Degree, PG Degree = Postgraduate Degree

Appendix 4. Duration (hr:min) of time spent online via a mobile phone from 2012-2019 (Values are mean (standard deviation); presented graphically in Figure 3.

	2012	2013	2014	2015	2016	2017	2018	2019
Region*								
AP	1:29 (2:01)	1:45 (2:09)	2:12 (2:27)	2:30 (2:36)	2:48 (2:41)	3:17 (2:53)	3:26 (2:53)	3:22 (2:49)
Europe	0:51 (1:43)	1:06 (1:57)	1:19 (2:10)	1:34 (2:20)	1:45 (2:24)	2:07 (2:36)	2:21 (2:40)	2:39 (2:46)
LA	1:30 (2:32)	2:00 (2:53)	2:52 (3:25)	3:43 (3:36)	3:55 (3:32)	4:10 (3:27)	4:28 (3:21)	4:37 (3:17)
MEA	1:58 (2:45)	2:22 (2:57)	3:00 (3:13)	3:22 (3:18)	3:27 (3:17)	3:40 (3:13)	4:00 (3:18)	4:18 (3:11)
NA	1:01 (1:52)	1:28 (2:24)	1:46 (2:33)	1:52 (2:35)	2:00 (2:36)	2:18 (2:39)	2:28 (2:45)	2:36 (2:46)
Age								
16-24	1:55 (2:22)	2:17 (2:34)	2:51 (2:52)	3:10 (2:59)	3:24 (2:59)	4:01 (3:09)	4:13 (3:09)	4:08 (3:04)
25-34	1:33 (2:09)	1:52 (2:18)	2:22 (2:37)	2:45 (2:46)	3:05 (2:50)	3:29 (2:58)	3:40 (2:59)	3:42 (2:57)
35-44	1:00 (1:45)	1:19 (2:00)	1:40 (2:17)	1:59 (2:28)	2:20 (2:36)	2:42 (2:40)	2:55 (2:44)	3:06 (2:44)
45-54	0:35 (1:18)	0:49 (1:38)	1:01 (1:49)	1:16 (2:05)	1:31 (2:11)	1:58 (2:22)	2:12 (2:28)	2:31 (2:37)
55-64	0:21 (1:01)	0:31 (1:21)	0:39 (1:31)	0:44 (1:33)	0:57 (1:44)	1:15 (1:57)	1:33 (2:11)	1:46 (2:16)
Education[Ŧ]								
School to 16	1:13 (2:18)	1:28 (2:23)	2:03 (2:40)	2:15 (2:30)	2:20 (2:44)	2:55 (3:05)	3:12 (3:01)	2:59 (2:49)
School to 18	1:08 (2:02)	1:27 (2:15)	1:54 (2:34)	2:18 (2:47)	2:27 (2:44)	3:01 (2:57)	3:16 (2:58)	3:21 (2:55)
Trade school/college	1:15 (2:03)	1:39 (2:16)	2:04 (2:34)	2:19 (2:43)	2:37 (2:46)	3:11 (2:47)	3:23 (3:03)	3:31 (3:00)
UG Degree	1:24 (1:59)	1:41 (2:13)	2:04 (2:31)	2:22 (2:42)	2:40 (2:48)	3:05 (2:56)	3:18 (2:57)	3:27 (2:56)
PG Degree	1:17 (2:02)	1:43 (2:23)	2:07 (2:40)	2:25 (2:50)	2:51 (2:56)	3:01 (2:56)	3:10 (2:53)	3:14 (2:54)
Sex								
Male	1:21 (2:03)	1:36 (2:12)	2:00 (2:29)	2:16 (2:38)	2:31 (2:42)	2:56 (2:51)	3:10 (2:51)	3:14 (2:51)
Female	1:14 (2:00)	1:39 (2:20)	2:06(2:39)	2:43 (2:50)	2:42 (2:53)	3:15 (3:03)	3:26 (3:04)	3:32 (3:02)

* AP = Asia Pacific, LA = Latin America, MEA = Middle East and Africa, NA = North America

Ŧ UG Degree = Undergraduate Degree, PG Degree = Postgraduate Degree

Appendix 5. Duration (hr:min) of time spent watching traditional television from 2012-2019 (Values are mean (standard deviation); presented graphically in Figure 4.

	2012	2013	2014	2015	2016	2017	2018	2019
Region*								
AP	1:44 (1:47)	1:40 (1:39)	1:38 (1:42)	1:36 (1:39)	1:39 (1:44)	1:39 (1:48)	1:36 (1:46)	1:39 (1:52)
Europe	2:36 (2:09)	2:33 (2:08)	2:33 (2:12)	2:28 (2:09)	2:24 (2:09)	2:19 (2:07)	2:16 2:09)	2:18 (2:12)
LA	2:45 (2:14)	2:41 (2:17)	2:36 (2:18)	2:33 (2:19)	2:28 (2:18)	2:22 (2:18)	2:17 (2:13)	2:22 (2:19)
MEA	2:22 (2:10)	2:12 (2:06)	2:09 (2:03)	2:04 (2:06)	1:58 (2:06)	1:58 (2:09)	1:56 (2:08)	1:55 (2:10)
NA	3:28 (2:49)	3:30 (3:01)	3:19 (2:44)	3:12 (2:44)	3:10 (2:45)	2:51 (2:39)	2:51 (2:41)	2:49 (2:42)
Age								
16-24	1:44 (2:02)	1:42 (1:56)	1:41 (1:57)	1:37 (1:51)	1:37 (1:54)	1:36 (1:57)	1:30 (1:53)	1:30 (1:56)
25-34	2:10 (2:04)	2:04 (1:58)	1:58 (1:59)	1:55 1:58)	1:55 (2:00)	1:51 (2:00)	1:50 (2:02)	1:53 (2:05)
35-44	2:21 (2:08)	2:18 (2:03)	2:13 (2:04)	2:10 (2:03)	2:12 (2:07)	2:00 (2:02)	2:00 (2:00)	2:03 2:05)
45-54	2:40 (2:14)	2:45 (2:19)	2:40 (2:17)	2:36 (2:15)	2:34 (2:15)	2:19 (2:08)	2:17 (2:14)	2:22 (2:15)
55-64	3:16 (2:29)	3:12 (2:27)	3:09 (2:26)	3:03 (2:24)	2:55 (2:23)	2:43 (2:16)	2:43 (2:16)	2:40 (2:16)
Education[Ŧ]								
School to 16	2:55 (2:38)	2:51 (2:33)	2:30 (2:27)	2:23[¥] (2:21)[¥]	2:15 (2:14)	2:12 (2:17)	2:06 (2:15)	2:00 (2:06)
School to 18	2:32 (2:20)	2:30 (2:20)	2:22 (2:18)	2:12 (2:11)	2:10 (2:13)	2:03 (2:10)	1:57 (2:05)	2:01 (2:11)
Trade school/college	2:20 (2:15)	2:13 (2:12)	2:08 (2:12)	2:12 (2:15)	2:03 (2:08)	1:56 (2:05)	1:57 (2:07)	2:01 (2:12)
UG Degree	2:01 (1:58)	1:59 (1:54)	2:00 (1:56)	1:58 (1:55)	1:59 (2:00)	1:51 (1:54)	1:48 (1:53)	1:48 (1:56)
PG Degree	2:09 (2:07)	2:05 (1:59)	2:03 (1:59)	2:06 (2:02)	2:07 (1:59)	1:58 (1:57)	1:55 (1:59)	1:52 (2:00)
Sex								
Male	2:03 (2:02)	2:00 (1:58)	1:58 (1:59)	1:55 (1:57)	1:56 (2:00)	1:48 (1:56)	1:48 (1:57)	1:48 (2:00)
Female	2:30 (2:18)	2:27 (2:16)	2:21 (2:15)	2:16 (2:12)	2:15 (2:14)	2:10 (2:12)	2:04 (2:09)	2:07 (2:14)

* AP = Asia Pacific, LA = Latin America, MEA = Middle East and Africa, NA = North America

Ŧ UG Degree = Undergraduate Degree, PG Degree = Postgraduate Degree

¥ Midpoint used due to anomalous data.

Appendix 6. Duration (hr:min) of time spent watching online television from 2012-2019 (Values are mean (standard deviation); presented graphically in Figure 5.

	2012	2013	2014	2015	2016	2017	2018	2019
Region*								
AP	0:52 (1:26)	0:50 (1:20)	0:54 (1:29)	0:55 (1:30)	1:02 (1:37)	1:13 (1:46)	1:16 (1:48)	1:28 (1:56)
Europe	0:28 (1:09)	0:33 (1:15)	0:34 (1:19)	0:37 (1:21)	0:40 (1:24)	0:42 (1:25)	0:46 (1:29)	0:54 (1:38)
LA	0:34 (1:19)	0:39(1:26)	0:42 (1:32)	0:49 (1:40)	0:52 (1:41)	0:59 (1:45)	1:02 (1:50)	1:13 (1:58)
MEA	0:28 (1:16)	0:35 (1:26)	0:40 (1:34)	0:44 (1:39)	0:54 (1:51)	1:04 (1:59)	1:13 (2:03)	1:19 (2:08)
NA	0:39 (1:32)	0:47 (1:39)	0:55 (1:48)	1:00 (1:55)	1:10 (2:01)	1:09 (1:57)	1:18 (2:08)	1:24 (2:13)
Age								
16-24	0:58 (1:35)	0:58 (1:34)	1:02 (1:42)	1:03 (1:43)	1:07 (1:47)	1:17 (1:56)	1:18 (1:57)	1:24 (2:02)
25-34	0:53 (1:32)	0:53 (1:27)	0:58 (1:36)	1:03 (1:41)	1:10 (1:46)	1:16(1:50)	1:22 (1:55)	1:33 (2:03)
35-44	0:36 (1:15)	0:38 (1:15)	0:42 (1:23)	0:45 (1:25)	0:56 (1:38)	1:04 (1:41)	1:09 (1:45)	1:22 (1:54)
45-54	0:24 (0:59)	0:27 (1:04)	0:28 (1:07)	0:31 (1:12)	0:37 1:19)	0:46 (1:28)	0:53(1:31)	1:06 (1:47)
55-64	0:15 (0:48)	0:18 (0:54)	0:19 (0:59)	0:22 (0:59)	0:27 (1:05)	0:31 (1:11)	0:39 (1:23)	0:46 (1:28)
Education[Ŧ]								
School to 16	0:42 (1:35)	0:44 (1:39)	0:56 (1:45)	0:57 (1:31)	0:54 (1:40)	1:01 (1:49)	1:22 (2:02)	1:28 (1:57)
School to 18	0:35 (1:23)	0:37 (1:19)	0:44 (1:31)	0:47 (1:32)	0:55 (1:40)	1:07 (1:50)	1:13 (1:51)	1:28 (2:03)
Trade school/college	0:43 (1:22)	0:47 (1:25)	0:52 (1:34)	0:51 (1:34)	0:59 (1:38)	1:09 (1:45)	1:07 (1:47)	1:14 (1:53)
UG Degree	0:46 (1:20)	0:47 (1:21)	0:49 (1:25)	0:52 (1:31)	0:57 (1:38)	0:59 (1:37)	1:03 (1:41)	1:09 (1:46)
PG Degree	0:48 (1:35)	0:48 (1:28)	0:49 (1:34)	0:56 (1:45)	1:03 (1:43)	1:09 (1:47)	1:17 (1:55)	1:25 (2:02)
Sex								
Male	0:45 (1:23)	0:45 (1:14)	0:49 (1:30)	0:51 (1:33)	0:57 (1:37)	1:03 (1:42)	1:09 (1:48)	1:18 (1:54)
Female	0:42 (1:24)	0:45 (1:24)	0:49 (1:31)	0:51 (1:34)	0:58 (1:41)	1:08 (1:48)	1:11 (1:50)	1:22 (1:59)

* AP = Asia Pacific, LA = Latin America, MEA = Middle East and Africa, NA = North America

Ŧ UG Degree = Undergraduate Degree, PG Degree = Postgraduate Degree

Appendix 7. Duration (hr:min) of time spent playing on a games console from 2012-2019 (Values are mean (standard deviation); presented graphically in Figure 6.

	2012	2013	2014	2015	2016	2017	2018	2019
Region*								
AP	0:43 (1:24)	0:43 (1:21)	0:47 (1:29)	0:48 (1:30)	0:52 (1:38)	1:00 (1:50)	1:04 (1:53)	1:18 (2:04)
Europe	0:35 (2:21)	0:40 (1:27)	0:37 (1:26)	0:38 (1:25)	0:40 (1:29)	0:39 (1:29)	0:39 (1:29)	0:43 (1:35)
LA	0:58 (1:42)	1:02 (1:49)	1:02 (1:49)	1:04 (1:53)	1:00 (1:48)	1:01 (1:51)	1:01 (1:50)	1:07 (1:57)
MEA	0:45 (1:32)	0:56 (1:48)	0:55 (1:49)	1:00 (1:56)	1:01 (1:58)	1:04 (2:05)	1:06 (2:02)	1:09 (2:03)
NA	0:49 (1:41)	0:56 (1:49)	0:59 (1:55)	0:58 (1:56)	1:08 (2:05)	0:58 (1:57)	1:05 (2:08)	1:06 (2:11)
Age								
16-24	1:03 (1:51)	1:02 (1:47)	1:06 (1:53)	1:04 (1:48)	1:08 (1:55)	1:16 (2:07)	1:15 (2:05)	1:19 (2:07)
25-34	0:50 (1:29)	0:54 (1:35)	0:57 (1:40)	0:59 (1:44)	1:04 (1:50)	1:05 (1:54)	1:10 (1:59)	1:24 (2:11)
35-44	0:34 (1:13)	0:39 (1:18)	0:40 (1:23)	0:43 (1:28)	0:48 (1:36)	0:51 (1:40)	0:56 (1:45)	1:09 (1:57)
45-54	0:25 (1:03)	0:26 (1:06)	0:24 (1:03)	0:26 (1:09)	0:28 (1:12)	0:32 (1:22)	0:38 (1:28)	0:48 (1:44)
55-64	0:14 (0:46)	0:15 (0:50)	0:15 (0:57)	0:15 (0:49)	0:18 (0:57)	0:17 (0:56)	0:24 (1:11)	0:28 (1:16)
Education[ŦŦ]								
School to 16	0:54 (1:52)	0:55 (1:49)	1:01 (1:57)	0:54 (1:37)	0:52 (1:45)	0:55 (1:53)	1:12 (2:08)	1:16 (2:03)
School to 18	0:40 (1:25)	0:49 (1:37)	0:49 (1:40)	0:48 (1:38)	0:55 (1:45)	1:02 (1:56)	1:04 (1:56)	1:19 (2:08)
Trade school/college	0:42 (1:28)	0:43 (1:27)	0:46 (1:35)	0:45 (1:33)	0:48 (1:36)	0:54 (1:45)	0:53 (1:45)	1:02 (1:56)
UG Degree	0:44 (1:25)	0:46 (1:26)	0:48 (1:28)	0:49 (1:33)	0:52 (1:41)	0:52 (1:41)	0:54 (1:43)	0:58 (1:46)
PG Degree	0:46 (1:29)	0:48 (1:34)	0:49 (1:38)	0:55 (1:49)	1:02 (1:51)	0:57 (1:48)	1:05 (2:00)	1:10 (2:05)
Sex								
Male	0:51 (1:36)	0:54 (1:38)	0:56 (1:43)	0:57 (1:43)	1:01 (1:48)	1:04 (1:56)	1:09 (2:00)	1:18 (2:06)
Female	0:35 (1:16)	0:37 (1:18)	0:39 (1:23)	0:39 (1:25)	0:43 (1:33)	0:47 (1:39)	0:49 (1:40)	1:00 (1:53)

* AP = Asia Pacific, LA = Latin America, MEA = Middle East and Africa, NA = North America

[ŦŦ] UG Degree = Undergraduate Degree, PG Degree = Postgraduate Degree

Appendix 8. Variables included for each of the primary activity categories.

Resting/time out	Resting- Time out (5310)
Reading	Reading newspapers in a library (5245) Unspecified reading (8100) Reading periodicals (8110) Reading books (8120) Other specified reading (8190)
TV, video and DVD	Unspecified TV video or DVD watching (8210) Watching a film on TV (8211) Watching sport on TV (8212) Other specified TV watching (8219) Unspecified video watching (8220) Watching a film on video (8221) Watching sport on video (8222) Other specified video watching (8229)
Internet use (shopping, finance and browsing)	Unspecified household management using the internet (3720) Shopping for and ordering unspecified goods and services via the internet (3721) Shopping for and ordering food via the internet (3722) Shopping for and ordering goods and services related to accommodation via the internet (3724) Shopping for and ordering mass media via the internet (3725) Shopping for and ordering entertainment via the internet (3726) Banking and bill paying via the internet (3727) Other specified household management using the internet (3729) Using internet in the library (5243) Using computers in the library other than internet use (5244) Information searching on the internet (7231)
Communication	Unspecified communication by computer (7240) Communication on the internet (7241) Other specified communication by computing (7249) Skype or other video call (7251) Telephone conversation (5140)

Gaming	Computer games (7330)
Oher computer use	Computing – programming (7220) Unspecified information by computing (7230) Other specified information by computing (7239) Unspecified other computing (7250) Other specified computing (7259)

Appendix 9. Variables included for each of the secondary activity categories.

Personal Care	Unspecified personal care (0) Sleep (110) In bed not asleep (111) Sick in bed (120) Eating (210) Unspecified other personal care (300) Wash and dress (310) Other specified personal care (390)
Employment	Unspecified employment (1000) Unspecified main job (1100) Working time in main job (1110) Coffee and other breaks in main job (1120) Working time in second job (1210) Coffee and other breaks in second job (1220) Unspecified activities related to employment (1300) Lunch break (1310) Other specified activities related to employment (1390) Activities related to job seeking (1391) Other specified activities related to employment (1399)
Study	Unspecified study school or university (2000) Unspecified activities related to school or university (2100) Classes and lectures (2110) Homework (2120) Other specified activities related to school or university (2190) Free time study (2210)
Household and Family Care	Unspecified household and family care (3000) Unspecified food management (3100) Food preparation and baking (3110) Dish washing (3130) Preserving (3140) Other specified food management (3190) Unspecified household upkeep (3200) Cleaning dwelling (3210) Cleaning yard (3220) Heating and water (3230) Arranging household goods and materials (3240) Disposal of waste (3250)

	Other or unspecified household upkeep (3290 Unspecified making and care for textiles (3300) Laundry (3310) Ironing (3320) Handicraft and producing textiles (3330) Other specified making and care for textiles (3390) Gardening (3410) Tending domestic animals (3420) Caring for pets (3430) Walking the dog (3440) Other specified gardening and pet care (3490) Unspecified construction and repairs (3500) House construction and renovation (3510) Repairs of dwelling (3520) Making repairing and maintaining equipment (3530) Woodcraft metalcraft sculpture and pottery (3531) Other specified making repairing and maintaining equipment (3539) Vehicle maintenance (3540) Other specified construction and repairs (3590) Unspecified shopping and services (3600) Unspecified shopping (3610) Shopping mainly for food (3611) Shopping mainly for clothing (3612) Shopping mainly related to accommodation (3613) Shopping or browsing at car boot sales or antique fairs (3614) Window shopping or other shopping as leisure (3615) Other specified shopping (3619) Commercial and administrative services (3620) Personal services (3630) Other specified shopping and services (3690) Household management not using the internet (3710) Shopping for and ordering clothing via the internet (3713) Unspecified household management using the internet (3720) Shopping for and ordering unspecified goods and services via the internet (3721) Shopping for and ordering food via the internet (3722) Shopping for and ordering goods and services related to accommodation via the internet (3724) Shopping for and ordering mass media via the internet (3725) Shopping for and ordering entertainment via the internet (3726)

	Banking and bill paying via the internet (3727) Other specified household management using the internet (3729) Unspecified childcare (3800) Unspecified physical care & supervision of a child (3810) Feeding the child (3811) Other and unspecified physical care & supervision of a child (3819) Teaching the child (3820) Reading playing and talking with child (3830) Accompanying child (3840) Other or unspecified childcare (3890) Unspecified help to a non-dependent e.g. injured adult household member (3910) Physical care of a non-dependent e.g. injured adult household member (3911) Accompanying a non-dependent adult household member e.g. to hospital (3914) Other specified help to a non-dependent adult household member (3919) Unspecified help to a dependent adult household member (3920) Physical care of a dependent adult household member e.g. Alzheimic parent (3921) Accompanying a dependent adult household member e.g. Alzheimic (3924) Other specified help to a dependent adult household member (3929)
Volunteer Work and Meeting	Unspecified volunteer work and meetings (4000) Unspecified organisational work (4100) Work for an organisation (4110) Volunteer work through an organisation (4120) Other specified organisational work (4190) Unspecified informal help to other households (4200) Food management as help to other households (4210) Household upkeep as help to other households (4220) Gardening and pet care as help to other households (4230) Construction and repairs as help to other households (4240) Shopping and services as help to other households (4250) Help to other households in employment and farming (4260) Unspecified childcare as help to other households (4270) Physical care and supervision of child as help to other household (4271) Teaching non-coresident child (4272) Reading playing & talking to non-coresident child (4273) Accompanying non-coresident child (4274)

	Physical care and supervision of own child as help to other household (4275) Reading playing & talking to own non-coresident child (4277) Accompanying own non-coresident child (4278) Other specified childcare as help to other household (4279) Unspecified help to an adult of another household (4280) Physical care and supervision of an adult as help to another household (4281) Accompanying an adult as help to another household (4282) Other specified help to an adult member of another household (4283) Other specified informal help to another household (4289) Other specified informal help (4290) Unspecified participatory activities (4300) Meetings (4310) Religious activities (4320) Other specified participatory activities (4390)
Social Life and Entertainment	Unspecified social life and entertainment (5000) Unspecified social life (5100) Socialising with family (5110) Visiting and receiving visitors (5120) Celebrations (5130) Telephone conversation (5140) Other specified social life (5190) Unspecified entertainment and culture (5200) Cinema (5210) Unspecified theatre or concerts (5220) Plays musicals or pantomimes (5221) Opera operetta or light opera (5222) Concerts or other performances of classical music (5223) Live music other than classical concerts, opera, and musicals (5224) Dance performances (5225) Other specified theatre or concerts (5229) Art exhibitions and museums (5230) Unspecified library (5240) Borrowing books records audiotapes videotapes CDs VDs etc. from a library (5241) Reference to books and other library materials within a library (5242) Using internet in the library (5243) Using computers in the library other than internet use (5244) Reading newspapers in a library (5245)

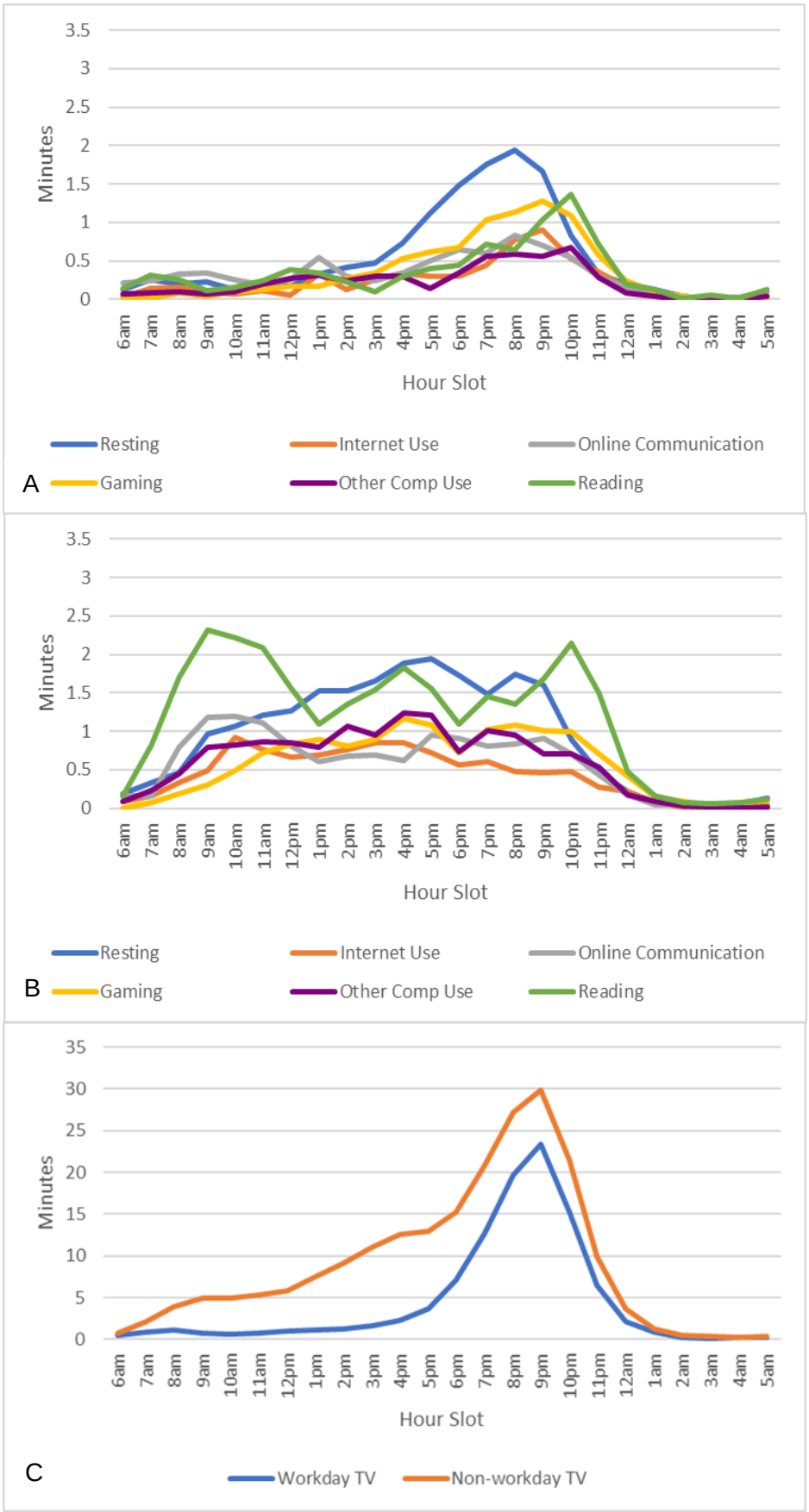
	Other specified library activities (5249) Sports events (5250) Other specified entertainment and culture (5290) Visiting a historical site (5291) Visiting a wildlife site (5292) Visiting a botanical site (5293) Visiting a leisure park (5294) Visiting an urban park playground designated play area (5295) Other or unspecified entertainment or culture (5299) Resting - Time out (5310)
Sports and Outdoor Activities	Unspecified sports and outdoor activities (6000) Unspecified physical exercise (6100) Walking and hiking (6110) Taking a walk or hike that lasts at least miles or 1 hour (6111) Other walk or hike (6119) Jogging and running (6120) Biking skiing and skating (6130) Biking (6131) Skiing or skating (6132) Unspecified ball games (6140) Indoor pairs or doubles games (6141) Indoor team games (6142) Outdoor pairs or doubles games (6143) Outdoor team games (6144) Other specified ball games (6149) Gymnastics (6150) Fitness (6160) Unspecified water sports (6170) Swimming (6171) Other specified water sports (6179) Other specified physical exercise (6190) Unspecified productive exercise (6200) Hunting and fishing (6210) Picking berries mushroom and herbs (6220) Other specified productive exercise (6290) Unspecified sports related activities (6310) Activities related to sports (6311) Activities related to productive exercise (6312)
Hobbies, games and computing	Unspecified hobbies games and computing (7000) Unspecified arts (7100)

	Unspecified visual arts (7110) Painting drawing or other graphic arts (7111) Making videos taking photographs or related photographic activities (7112) Other specified visual arts (7119) Unspecified performing arts (7120) Singing or other musical activities (7121) Other specified performing arts (7129) Literary arts (7130) Other specified arts (7140) Unspecified hobbies (7150) Collecting (7160) Correspondence (7170) Other specified or unspecified arts and hobbies (7190) Computing – programming (7220) Unspecified information by computing (7230) Information searching on the internet (7231) Other specified information by computing (7239) Unspecified communication by computer (7240) Communication on the internet (7241) Other specified communication by computing (7249) Unspecified other computing (7250) Skype or other video call (7251) Other specified computing (7259) Unspecified games (7300) Solo games and play (7310) Unspecified games and play with others (7320) Billiards pool snooker or petanque (7321) Chess and bridge (7322) Other specified parlour games and play (7329) Computer games (7330) Gambling (7340) Other specified games (7390)
Mass media	Unspecified mass media (8000) Unspecified reading (8100) Reading periodicals (8110) Reading books (8120) Other specified reading (8190) Unspecified TV video or DVD watching (8210) Watching a film on TV (8211) Watching sport on TV (8212)

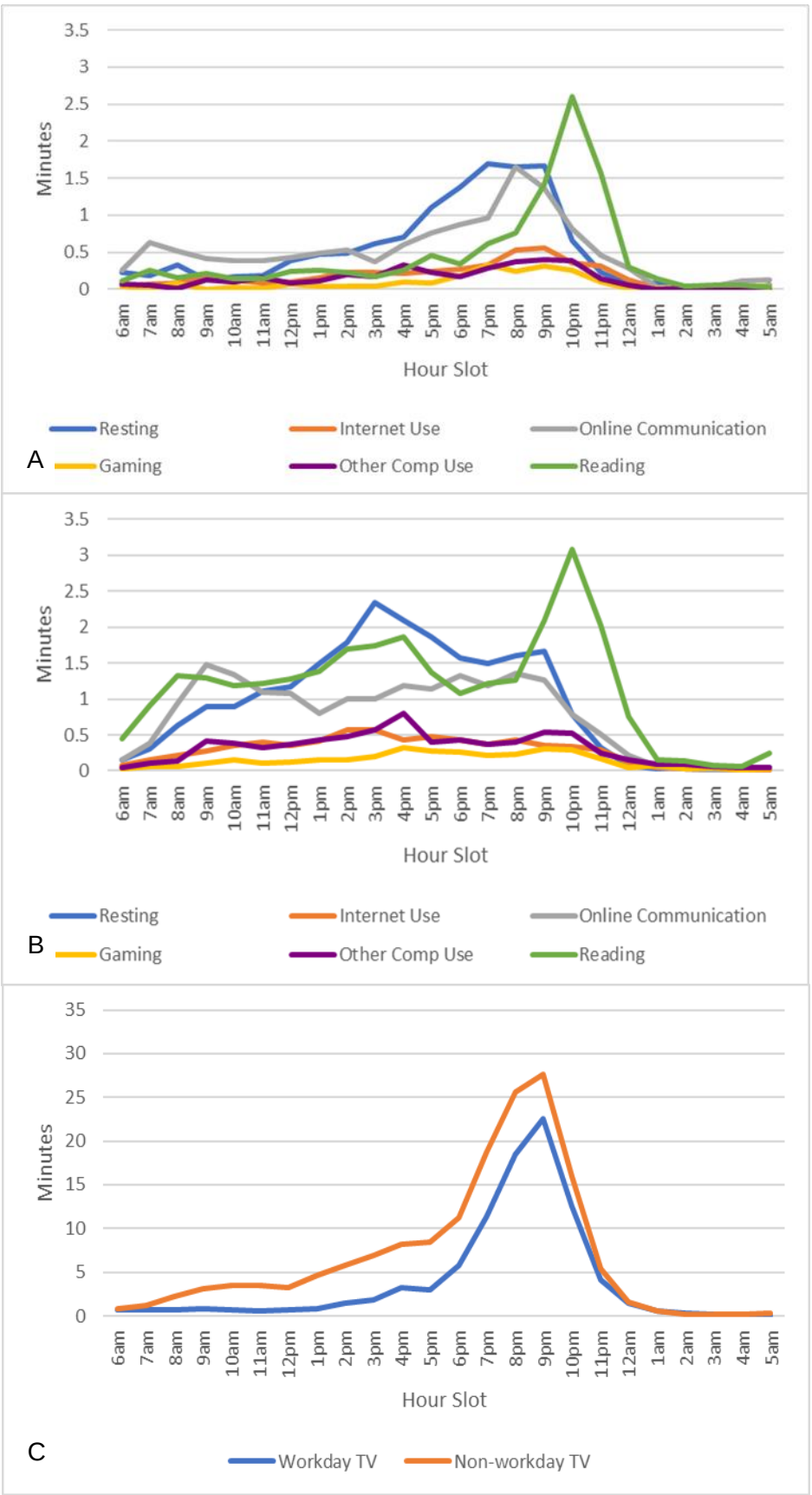
	Other specified TV watching (8219) Unspecified video watching (8220) Watching a film on video (8221) Watching sport on video (8222) Other specified video watching (8229) Unspecified listening to radio and music (8300) Unspecified radio listening (8310) Listening to music on the radio (8311) Listening to sport on the radio (8312) Other specified radio listening (8319) Listening to recordings (8320)
Travel	Travel related to unspecified time use (9000) Travel related to personal business (9010) Travel to/from work (9100) Travel in the course of work (9110) Travel to work from home and back only (9120) Travel to work from a place other than home (9130) Travel related to education (9210) Travel escorting to/ from education (9230) Travel related to household care (9310) Travel related to shopping (9360) Travel related to services (9370) Travel escorting a child other than education (9380) Travel escorting an adult other than education (9390) Travel related to organisational work (9400) Travel related to voluntary work and meetings (9410) Travel related to informal help to other households (9420) Travel related to religious activities (9430) Travel related to participatory activities other than religious activities (9440) Travel to visit friends/relatives in their homes not respondents household (9500) Travel related to other social activities (9510) Travel related to entertainment and culture (9520) Travel related to other leisure (9600) Travel related to physical exercise (9610) Travel related to hunting & fishing (9620) Travel related to productive exercise other than hunting & fishing (9630) Travel related to gambling (9710) Travel related to hobbies other than gambling (9720)

	Travel related to changing locality (9800) Travel to holiday base (9810) Travel for day trip/just walk (9820) Other specified travel (9890)

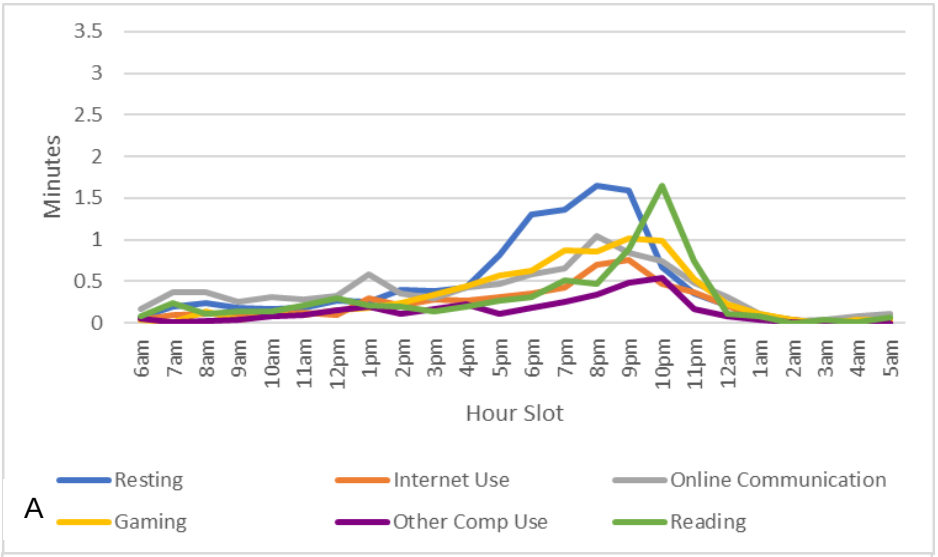
Appendix 10. Diurnal patterns of primary activities for males stratified by A) workday, excluding TV viewing; B) non-workday, excluding TV viewing, C) workday and non-workday TV viewing.



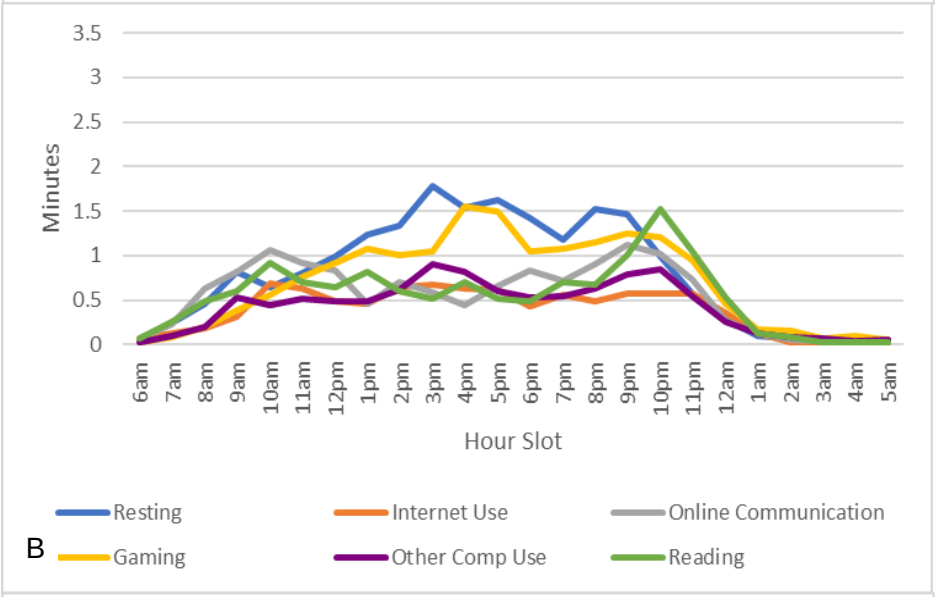
Appendix 11. Diurnal patterns of primary activities for females stratified by A) workday, excluding TV viewing; B) non-workday, excluding TV viewing, C) workday and non-workday TV viewing.



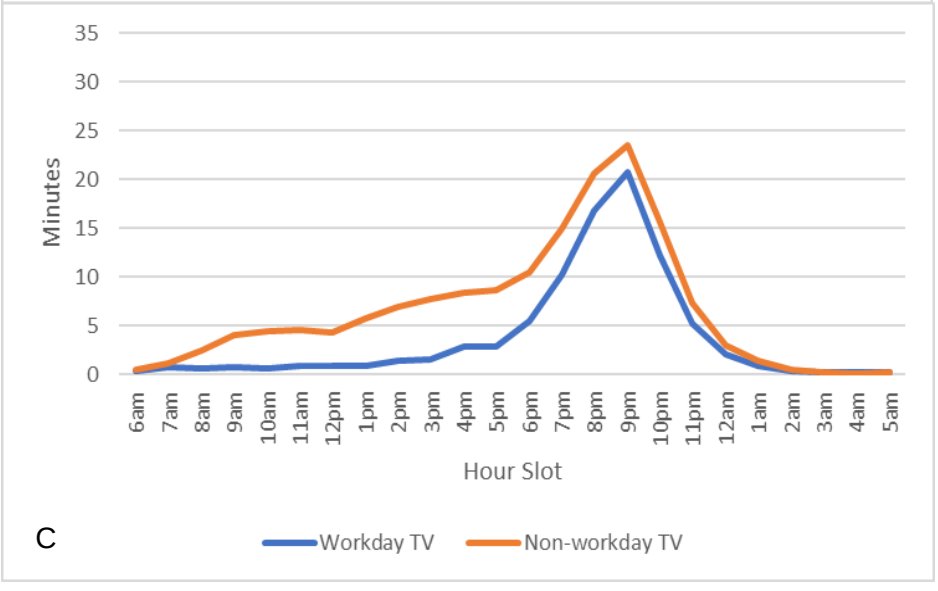
Appendix 12. Diurnal patterns of primary activities for individuals aged 18-44 stratified by A) workday, excluding TV viewing; B) non-workday, excluding TV viewing, C) workday and non-workday TV viewing.



A

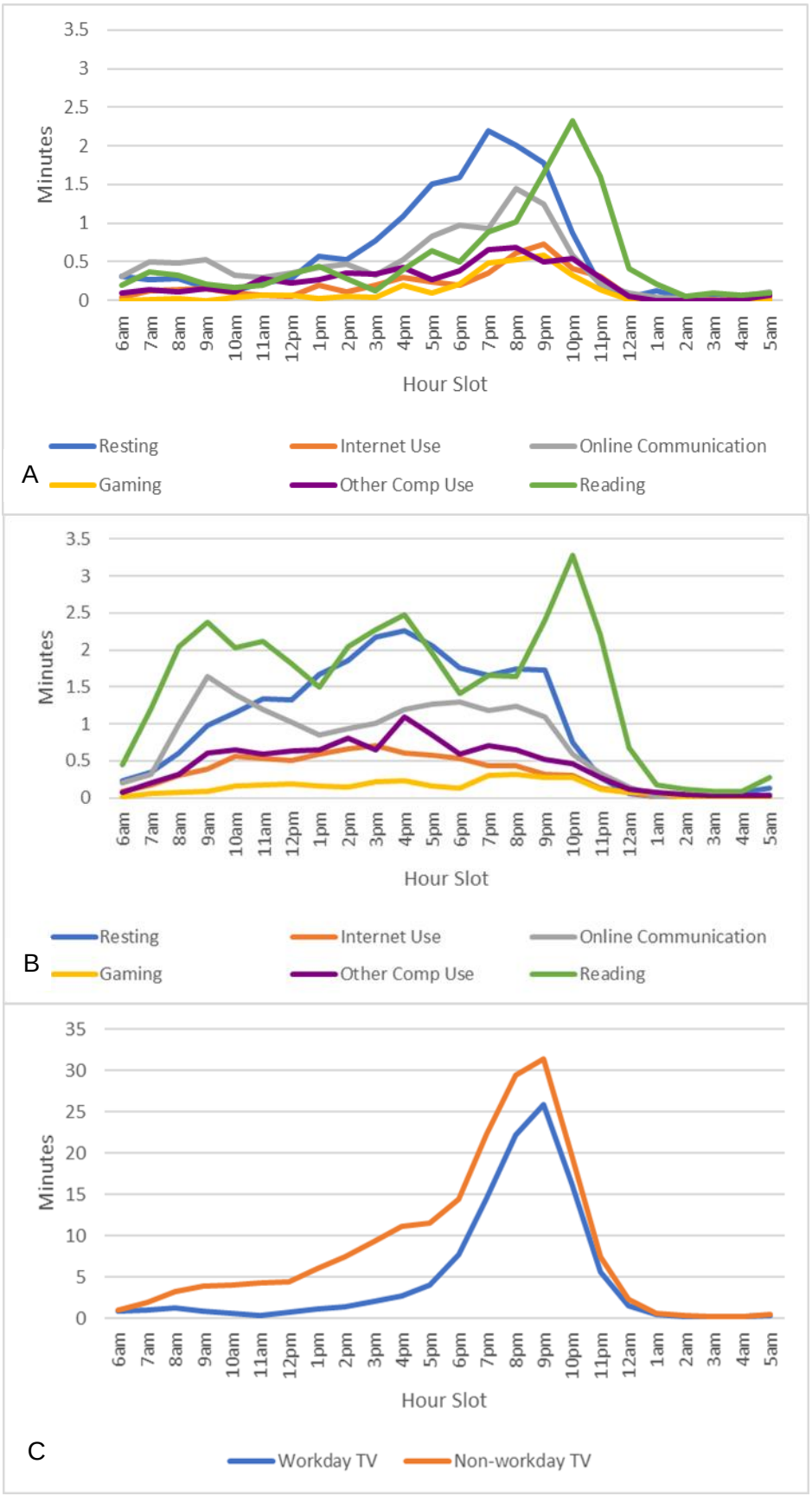


B



C

Appendix 13. Diurnal patterns of primary activities for individuals aged 45 and above stratified by A) workday, excluding TV viewing; B) non-workday, excluding TV viewing, C) workday and non-workday TV viewing.



Appendix 14. Interaction coefficients for country level factors and variation across time. Reference category: 2002.

	2005	**2013**	**2017**
	Coefficient [95% CI]	Coefficient [95% CI]	Coefficient [95% CI]
GDP[¥]	0.0016 [-0.0041, 0.0073]	0.0036 [-0.0037, 0.012]	0.0042 [-0.0029, 0.011]
HDI	0.3 [-0.7, 1.4]	-1.2 [-2.3, -0.1]*	-1.5 [-2.7, -0.3]*
Employment in Services	1.0 [0.5, 1.5]*	0.9 [0.4, 1.4]*	0.8 [0.2, 1.3]*
Using Internet[¥]	-0.019 [-0.2, 0.2]	0.1 [-0.2, 0.3]	-0.3 [-0.6, -0.1]*
Population Density	6.2 [3.9, 8.6]*	5.8 [3.4, 8.1]*	8.2 [5.8, 10.5]*

[¥] Reported to two significant figures.
*p <0.05

Appendix 15. Interaction coefficients for country level factors and gender. Reference category: males.

	Female
	Coefficient [95% CI]
GDP[¥]	-0.0036 [-0.0054, -0.0017]*
HDI	-1.4 [-1.9, -1.0]*
Employment in Services	-0.7 [-0.9, -0.5]*
Using Internet[¥]	-0.1 [-0.2, -0.049]*
Population Density	-3.1 [-4.1, -2.1]*

[¥] Reported to two significant figures.
*p <0.05

Appendix 16. Interaction coefficients for country level factors and age. Reference category: 18–44-year-olds.

	45+
	Coefficient [95% CI]
GDP[¥]	0.0033 [0.0014, 0.0052]*
HDI	0.3 [-0.1, 0.7]
Employment in Services	0.4 [0.2, 0.6]*
Using Internet[¥]	0.1 [0.0094, 0.2]*
Population Density	0.4 [-0.6, 1.5]

[¥] Reported to two significant figures.
*p <0.05

Appendix 17. Interaction coefficients for country level factors and occupation. Reference category: non-manual worker.

	Manual worker	**Not in employment**
	Coefficient [95% CI]	Coefficient [95% CI]
GDP[¥]	-0.0033 [-0.0059, -0.00071]*	0.0019 [-0.00021, 0.0040]
HDI	-0.41 [-1.0, 0.2]	1.1 [0.6, 1.6]*
Population Density	-4.2 [-5.7, -2.6]*	-2.6 [-3.7, -1.5]*
Employment in Services	-0.5 [-0.8, -0.2]*	0.4 [0.2, 0.6]*
Using Internet[¥]	0.0013 [-0.1, 0.1]	0.1 [0.017, 0.2]*

[¥] Reported to two significant figures.
*p <0.05

Appendix 18. Included questionnaires and associated information.

Country	Region	World Bank Income Classification	Questionnaire	Year(s) of data collection	Non-national	Questions Included (with response options)
Algeria	AFRO-Middle East&North Africa	Lower middle income	STEPS (1)	2003	Non-national	The next questions are about sitting or lying down, think of the last 7 days, time spent at work, at home, during your leisure time including time spent sitting on a chair at the desk, visiting friends, watching TV not including the time spent sleeping. During the last 7 days, how much time do you spend sitting or resting for a typical day? Hours and minutes Minutes only
American Samoa	WPRO-East Asia&Pacific	Upper middle income	STEPS (2)	2004		The following question is about sitting or reclining. Think back over the past 7 days, to time spent at work, at home, in leisure, including time spent sitting at a desk, visiting friends, reading, or watching television, but do not include time spent sleeping. Over the past 7 days, how much time did you spend sitting or reclining on a typical

						day? Hours and minutes Minutes only
Argentina	PAHO-Latin America and Caribbean	Upper middle income	Encuesta Nacional de Factores de Riesgo/National Risk Factor Survey	2018		How much time per day do you usually spend sitting, for example at home, at work or in class. Hours and minutes. NS/NC
Armenia	EURO-Europe and Central Asia	Upper middle income	STEPS (3)	2016		The following question is about sitting or reclining at work, at home, getting to and from places, or with friends including time spent sitting at a desk, sitting with friends, traveling in car, bus, train, reading, playing cards or watching television, but do not include time spent sleeping.[INSERT EXAMPLES] (USE SHOWCARD) How much time do you usually spend sitting or reclining on a typical day? Ask the participant to consider total time spent sitting at work, in an office, reading, watching television, using a computer, doing hand craft like knitting, resting etc. The participant should not include time spent

						sleeping. Hours and minutes
Austria	EURO-Europe and Central Asia	High income	Austrian Health Interview Survey	2019		The next question is about the time you spend sitting or resting, at work, at home, moving around or with friends, for example, sitting at your desk, sitting with friends, driving a car, bus, train, playing cards or watch tv. The time you spend sleeping should be excluded. How much total time do you spend sitting or resting on a typical day? Hours and minutes per day
Austria	EURO-Europe and Central Asia	High income	Federal Ministry of Sport	2017		How much time do you spend on a normal day sitting or resting, e.g. at your desk while watching TV or at the computer, in the car, bus or train or when sitting with friends? (does not mean sleeping) Hours and minutes

Austria	EURO-Europe and Central Asia	High income	Special Eurobarometer 472 - Wave 88.4	2017		How much time do you spend s itting on a usual day This may include time spent at a desk, visiting friends, studying or wat ching television. 1 hour or less, 1 hour to 1 hour and 30 minutes, 1 hour 31 minutes to 2 hours 30 minutes, 2 hours 31 minutes to 3 hours 30 minutes, 3 hours 31 minutes to 4 hours 30 minutes, 4 hours 31 minutes to 5 hours 30 minutes, 5 hours 31 minutes to 6 hours 30 minutes, 6 hours 31 minutes to 7 hours 30 minutes, 7 hours 31 minutes to 8 hours 30 minutes, More than 8 hours and 30 minutes, Don't know
Bangladesh	SEARO-South Asia	Lower middle income	STEPS (4)	2009-2010		The following question is about sitting or reclining at work, at home, getting to and from places, or with friends including time spent sitting at a desk, sitting with friends, traveling in car, bus train, reading, playing cards or watching television, but do not include time spent sleeping. How much time do you usually spend sitting or reclining on a

						typical day? Hours and minutes
Barbados	PAHO-Latin America and Caribbean	High income	STEPS (4)	2007		See Bangladesh
Barbados	PAHO-Latin America and Caribbean	High income	Health of the Nation Survey	2015		1) On average over the last 4 weeks, can you tell me how much TV you watch per day during the following times: i. On a weekday before 6pm (none, less than 1 hour a day, 1 to 2 hours a day, 2 to 3 hours a day, 3 to 4 hours a day, more than 4 hours a day) ii. On a weekday after 6pm (same response options as above) ii. On a weekend before 6pm (same response options as above) iv. On a weekend after 6pm

						(same response options as above) 2) On average over the last 4 weeks, can you tell me how much you used your computer at home, but not at work, during the following times: (e.g. internet, email, PlayStation, Xbox, Gameboy, etc.) i. On a weekday before 6pm (none, less than 1 hour a day, 1 to 2 hours a day, 2 to 3 hours a day, 3 to 4 hours a day, more than 4 hours a day) ii. On a weekday after 6pm (same response options as above) ii. On a weekend before 6pm (same response options as above) iv. On a weekend after 6pm (same response options as above)
Belarus	EURO-Europe and Central Asia	Upper middle income	STEPS (5)	2016-2017		The next question is about sitting or reclining at work, at home, when moving from place to place, including time spent sitting at a table, sitting with friends, while traveling in a car, bus, train while reading, playing cards or watching television, but excluding sleep. [INSERT EXAMPLES] (USE ANSWER CARDS) How much time do you usually spend sitting or reclining on a

						typical day? Hours and minutes
Belgium	EURO-Europe and Central Asia	High income	Special Eurobarometer 472 - Wave 88.4	2017		See Austria
Benin	AFRO-Sub-Saharan Africa	Lower middle income	STEPS (6)	2015		The next question concerns the time spent in a sitting or lying position, at work, at home, on the go, visiting friends, and includes time spent sitting at a desk, traveling in a car, bus, train, reading, playing cards or watching TV but does not include time spent to sleep. (SHOW CARDS) How much time do you spend sitting or lying down? Hours and minutes

Bhutan	SEARO-South Asia	Lower middle income	STEPS (7)	2014		The following question is about sitting or reclining at work, at home, getting to and from places, or with friends including time spent sitting at a desk, sitting with friends, traveling in bus, reading, playing cards or watching television, but do not include time spent sleeping. (Use showcard) How much time do you usually spend sitting or reclining on a typical day? Hours and minutes
Bolivia	PAHO-Latin America and Caribbean	Lower middle income	Encuesta Nacional de Demografia y Salud (ENDSA)	2008		How many hours do you spend sitting daily? (Record the number of hours if less than 10 circle the code 10 yes 10 hours or more) Number of hours 10 Hours or more
Botswana	AFRO-Sub-Saharan Africa	Upper middle income	STEPS (4)	2014		See Bangladesh

Brazil	PAHO-Latin America and Caribbean	Upper middle income	PNS Pesquisa Nacional de Saúde (National Health Survey)	2013		On average how many hours a day do you usually watch television? (read the answer options) Less than 1 hour, between 1 hour and less than 2 hours, between 2 hours and less than 3 hours, between 3 hours and less than 4 hours, between 4 hours and less than 5 hours, between 5 hours and less than 6 hours, 6 hours or more, does not watch television.
Brunei Darussalam	WPRO-East Asia&Pacific	High income	STEPS (4)	2015-2016		See Bangladesh
Bulgaria	EURO-Europe and Central Asia	Upper middle income	Special Eurobarometer 472 - Wave 88.4	2017		See Austria

Burkina Faso	AFRO-Sub-Saharan Africa	Low income	STEPS (8)	2013		The next question is about time spent sitting or lying down, at work, at home, on the road, visiting friends, and includes time spent sitting at a desk, traveling by car, bus, train, reading, playing cards or watching tv but does not include time spent asleep. [INSERT EXAMPLES] (SHOW CARDS) How much time do you spend sitting or lying down on a typical day? Hours and minutes
Cambodia	WPRO-East Asia&Pacific	Lower middle income	STEPS (4)	2010		See Bangladesh
Cameroon	AFRO-Sub-Saharan Africa	Lower middle income	STEPS (9)	2003	Non-national	The following question is about sitting or reclining. Think back over the past 7 days, to time spent at work, at home, at [leisure], including time spent sitting at a desk, visiting friends, reading, or watching television, but do not include time spent sleeping. Over the past 7 days, how much time (in minutes) did you spend sitting or reclining on a typical day? Minutes

Canada	PAHO-North America	High income	Canadian Health Measures Survey (CHMS)	2016/2017		Now, a few additional questions about activities you do in your leisure time, that is excluding activities you do at work, during class time or while travelling in a vehicle. Some of these questions may appear similar, but please only report each activity once. Please report times to the nearest half hour. In the last seven days, that is from ^DateLastWeekE to yesterday, how much of your free time did you spend: reading books, magazines or newspapers, including in electronic formats? Include time spent reading as part of your homework, but do not include time spent reading at work, during class time, while travelling in a vehicle or while exercising. In the last seven days, that is from ^DateLastWeekE to yesterday, how much of your

						free time did you spend:) watching TV, DVDs, movies or Internet videos? Do not include time spent watching while exercising. (In the last seven days, that is from ^DateLastWeekE to yesterday, how much of your free time did you spend:) playing other video or computer games? Include games played on a game console, computer or hand-held electronic device such as a tablet or smart phone. Excluding the activities you have already reported, in/In] the last seven days, that is from ^DateLastWeekE to yesterday, how much of your free time did you spend on a computer, tablet or smart phone, doing activities such as using the Internet, emailing, using Facebook® or doing homework? Do not include time spent at work, during class time or while travelling in a vehicle

Canada	PAHO-North America	High income	Canadian Community Health Survey (CCHS)	2018		The next questions are about the time you spent sitting in the last 7 days. On a school or work day, how much of your free time did you spend watching television or a screen on any electronic device while sitting or lying down? 1: 2 hours or less per day 2: More than 2 hours but less than 4 hours 3: 4 hours to less than 6 hours 4: 6 hours to less than 8 hours 5: 8 hours or more per day 6: Was not at work or school 8: RF 9: DK On a day that was not a school or workday, how much of your free time did you spend watching television or a screen on any electronic device while sitting or lying down? 1: 2 hours or less per day 2: More than 2 hours but less than 4 hours 3: 4 hours to less than 6 hours 4: 6 hours to less than 8 hours 5: 8 hours or more per day 8: RF 9: DK

Cayman Islands	PAHO-Latin America and Caribbean	High income	STEPS (4)	2012		See Bangladesh
Central African Republic	AFRO-Sub-Saharan Africa	Low income	STEPS (10)	2010	Non-national	The next question is about time spent sitting or lying down at work, at home, on the move, visiting friends and includes time spent sitting at a desk, traveling by car, bus, train, reading, playing cards or watching TV but does not include time spent sleeping. How much time do you spend sitting or lying down on a typical day? Hours and minutes
Channel Islands	EURO-Europe and Central Asia	High income	Guernsey and Alderney Wellbeing Survey	2018		How much of your free time in the past week, did you spend sitting, reclining or lying down AND watching TV or using a computer, iPad, tablet or smartphone? On a typical day during the week (Hours and minutes) On a typical day at the weekend (Hours and minutes)

Chile	PAHO-Latin America and Caribbean	High income	Encuesta Nacional de Salud (ENS)	2016-2017		The next question is about how much time you usually spend sitting or lying down at work, at home, on the move, or with your friends. The time spent in front of a table working, sitting with friends, traveling by bus or train, playing cards, sitting in front of the computer or video games or watching television is included, but the time spent sleeping is not included. How much time do you usually spend sitting or lying down (lying down, reclining) in a typical day? Hours and minutes/does not know/no response
Chile	PAHO-Latin America and Caribbean	High income	Encuesta Nacional de Hábitos de Actividad Física y Deportes	2018		Now I will ask you about the time spent sitting during the business days of the past week. This included time spent at work, at home, in a class, and during free time. It can include, for example, the time spent sitting at a desk, visiting friends, reading, traveling by bus or bus, sitting or lying down watching television. During the past week, how much time (hours) did you spend sitting on an average business day? Hours (converted to minutes)

Colombia	PAHO-Latin America and Caribbean	Upper middle income	STEPS (11)	2010	Non-national	On a typical day, how much time do you normally spend sitting or lying down? Minutes
Comoros	AFRO-Sub-Saharan Africa	Lower middle income	STEPS (12)	2011	Non-national	The next question is about time spent sitting or lying down, at work, at home, on the road, visiting friends, and includes time spent sitting in front of a office, car, bus, train, reading, playing cards or watching TV, but does not include time spent sleeping. (INSERT EXAMPLE) (SHOWCARDS) How much time do you spend sitting or lying down on a typical day? Hours and minutes
Congo, Rep.	AFRO-Sub-Saharan Africa	Lower middle income	STEPS (13)	2004		How much time do you usually spend sitting or reclining on a typical day? Hours and minutes Don't know Missing

Costa Rica	PAHO-Latin America and Caribbean	Upper middle income	Encuesta de Actualidades de la Escuela de Estadística de la Universidad de Costa Rica	2016		And speaking of the time you spent sitting, such as sitting at a desk, visiting friends, reading or watching television (exclude sleeping). In the last 7 days, how long did he sit on a regular day? Hours per day/minutes per day/NS/NR
Costa Rica	PAHO-Latin America and Caribbean	Upper middle income	Surveillance of CVD risk factors Caja Costarricense del Seguro Social (CCSS)	2010		How much time do you usually spend sitting or lying down on a typical day? Minutes per day
Costa Rica	PAHO-Latin America and Caribbean	Upper middle income	Encuesta Nacional de Uso del Tiempo (Instituto Nacional de Estadística y Censos) [INEC]	2017		Last week, from Monday, Yes...1 to Sunday No...Or did you... How much time did you spend on this activity from Monday to Friday of last week? Hours and minutes How much time did you dedicate to this activity from Saturday to Sunday of last week? Hours and minutes exclusively, that is, without doing any other activity, did you watch movies, series, documentaries, news, novels or others on television, ipad, tablet, or other means? exclusively, that is, without

						doing any other activity, did you listen to music, news or any program on the radio, cell phone, ipad, tablet or other? exclusively, that is without doing any other activity, did you check email, check social media, talk on the phone or chat? (WhatsApp, Facebook, Skype or others) exclusively, that is, without doing any other activity, did you consult information online or read a book, magazine, newspaper or other digital material that was NOT for work or study? (documents, books, articles or others)... exclusively, that is, without doing any other activity, did you read a book, magazine, newspaper or other printed material that was NOT for work or study? (documents, books, articles or others) ...rest without doing any other activity?
Croatia	EURO-Europe and Central Asia	High income	Special Eurobarometer 472 - Wave 88.4	2017		See Austria

Cyprus	EURO-Europe and Central Asia	High income	Special Eurobarometer 472 - Wave 88.4	2017		See Austria
Czech Republic	EURO-Europe and Central Asia	High income	Global Physical Activity Questionnaire (GPAQ) Study	2011		The following question is about sitting or lying down at work, at home, transporting or moving from place to place, or spending time with friends, including sitting at a table, sitting with friends, traveling in a car, bus, train, reading, playing cards or watching TV. Do not include sleep time in the answer. How much time do you spend sitting or lying down during a typical day? Indicate the total time spent sitting at work, reading, watching television, using the computer handicrafts (knitting) relaxing etc. Do not include sleep time in the answer. Hours and minutes

Czech Republic	EURO-Europe and Central Asia	High income	Special Eurobarometer 472 - Wave 88.4	2017		See Austria
Denmark	EURO-Europe and Central Asia	High income	The Nordic Monitoring System	2014		During the last 7 days, how much time per day on average did you spend sitting and watching TV during your leisure time? Estimate it to the nearest half hour. Include videos, DVD and console games (PlayStation, Xbox, etc) played on TV screen. The interviewer can help the respondent to narrow down the answer to the nearest half hour. It is important to know if average time is less or more than 1 hour and if it is more or less than 2.5 hours. Hours and minutes/don't know.
Denmark	EURO-Europe and Central Asia	High income	Special Eurobarometer 472 - Wave 88.4	2017		See Austria

Egypt, Arab Rep.	EMRO-Middle East&North Africa	Lower middle income	STEPS (4)	2017		See Bangladesh
El Salvador	PAHO-Latin America& Caribbean	Lower middle income	Encuesta Nacional de Enfermedades Cronicas no transmisibles en Poblacion Adulta de El Salvador (ENECA) 2015	2014-2015		The last question asks how long you spent sitting in the last week. Include time sitting at work, home, studying, and in your free time. This may include time sitting at a desk, visiting friends, reading, or sitting or lying down watching television. During the past week, how long did you sit on one day of the week? (not including night time sleep) Hours/day minutes/day, don't know/not sure
England	EURO-Europe and Central Asia	High income	Health Survey for England	2016		IntroSit Now I'd like to ask you some questions about time that you might have spent sitting down. For these questions, I'd like you to think about what you have done in the last four weeks, that is since (date of interview – 4 weeks) when you were not doing your (paid) job. INTERVIEWER: PRESS 1 AND ENTER TO CONTINUE 1..1

						TVWkHr In the last 4 weeks, how much time did you spend sitting down watching TV (including DVDs and videos) on an average weekday (that is Monday to Friday)? INTERVIEWER: This includes multi-tasking (using iPad, phone etc.) while sitting and watching TV. RECORD HOURS SPENT BELOW. ENTER 0 IF LESS THAN 1 HOUR. RECORD MINUTES AT NEXT QUESTION. Range:0..20 TVWkMin RECORD MINUTES HERE. Range::0..59 WkSit2H In the last four weeks, how much time did you spend sitting down doing any other activity on an average weekday (that is Monday to Friday)? Please do not include time spent doing these activities while at work. INTERVIEWER: EXAMPLES OF THESE ACTIVITIES INCLUDE READING, , STUDYING, DRAWING, USING A COMPUTER, PLAYING VIDEO GAMES. RECORD HOURS SPENT BELOW. ENTER 0 IF LESS THAN 1 HOUR. RECORD

						MINUTES AT NEXT QUESTION” Range:0..20 WkSit2H RECORD MINUTES HERE. Range::0..59 WESit1H In the last four weeks, how much time did you spend watching TV (including watching DVDs and videos) on an average weekend day (that is Saturday and Sunday)? INTERVIEWER: This includes multi-tasking (using iPad, phone etc.) while sitting and watching TV. INTERVIEWER: RECORD HOURS SPENT BELOW. ENTER 0 IF LESS THAN 1 HOUR. RECORD MINUTES AT NEXT QUESTION. Range: 0..20 WESit1M RECORD MINUTES HERE. WESit2H 34 In the last 4 weeks, how much time did you spend sitting down doing any other activity on an average weekend day (that is Saturday and Sunday)? Please do not include time spent doing these activities while at work. INTERVIEWER: EXAMPLES

						OF THESE ACTIVITIES INCLUDE READING, STUDYING, DRAWING, USING A COMPUTER, PLAYING VIDEO GAMES. RECORD HOURS SPENT BELOW. ENTER 0 IF LESS THAN 1 HOUR. RECORD MINUTES AT NEXT QUESTION. Range: 0..20 WESit2M RECORD MINUTES HERE. Range: 0..59
Eritrea	AFRO-Sub-Saharan Africa	Low income	STEPS (4)	2010		See Bangladesh
Estonia	EURO-Europe and Central Asia	High income	Special Eurobarometer 472 - Wave 88.4	2017		See Austria

Estonia	EURO-Europe and Central Asia	High income	Health Behaviour among Estonian Adult Population	2018		In your leisure time, how many hours in total a day do you usually watch TV, videos, etc on TV screen; use electronic devices (computer, tablet, smartphone, etc.) to play games (other than exercise or fitness games) or for other purposes (e-mails, internet, etc.)? (Please answer for both working and non-working days) In leisure time on working days: Not at all, about half an hour a day, about 1-3 hours a day, about 4 or more hours a day On days off: Not at all, about half an hour a day, about 1-3 hours a day, about 4 or more hours a day
Ethiopia	AFRO-Sub-Saharan Africa	Low income	STEPS (14)	2015	Non-national	The following question is about sitting or reclining at work, at home, getting to and from places, or with friends including time spent sitting at a desk, sitting with friends, traveling in car, bus, train, reading, playing games/cards or watching television, but do not include time spent sleeping. (USE SHOWCARD) How much time do you usually spend sitting or reclining on a typical day? Hours and minutes

Fiji	WPRO-East Asia&Pacific	Upper middle income	STEPS (4)	2011		See Bangladesh
Finland	EURO-Europe and Central Asia	High income	Special Eurobarometer 472 - Wave 88.4	2017		See Austria
Finland	EURO-Europe and Central Asia	High income	The National FinRisk Study	2012		How many hours on average do you sit in a weekday? During the workday or in office or equivalent (Hours and minutes) At home watching television or videos (Hours and minutes) At home at a computer (Hours and minutes) In a vehicle (Hours and minutes) Elsewhere (Hours and minutes)

Finland	EURO-Europe and Central Asia	High income	Health 2000/2011 Study	2011		How many hours do you spend sitting on an average weekday? If you never sit, please enter 0. During the working day at the office, etc. |___|___| hours |___|___| minutes a day At home watching TV or videos |___|___| hours |___|___| minutes a day At home at the computer |___|___| hours |___|___| minutes a day In transport (car, bus, plane) |___|___| hours |___|___| minutes a day Elsewhere |___|___| hours |___|___| minutes a day
Finland	EURO-Europe and Central Asia	High income	FinHealth	2017		How many hours on average do you sit in a weekday? Mark 0 if not at all During the workday in office or equivalent ___h ____ min At home, in front of the TV, computer, or mobile device ___h ___min In a vehicle ____h ____min Other sitting ____h ____min

France	EURO-Europe and Central Asia	High income	Baromètre Santé Nutrition (National Nutrition Barometer/ Nutrition and Health Barometer)	2008		The next question concerns the time spent sitting or lying down at work, at home, in the car, on the bus..., but does not include the time spent sleeping. How much time do you usually spend sitting or lying down during a day? Interviewer: code hours/minutes. If necessary, if the interviewee says that it depends on the periods (seasons), follow up with: "Currently, how long..."
France	EURO-Europe and Central Asia	High income	Special Eurobarometer 472 - Wave 88.4	2017		See Austria
France	EURO-Europe and Central Asia	High income	Baromètre Santé	2004-2005		1) Finally, let's move on to the time you spent sitting on a weekday (excluding weekends), during the last seven days. This includes time spent sitting at work, at home, studying and in your free time. This could include, for example, time spent sitting at a desk, in transport, with friends, reading, sitting or lying down to watch TV or use a computer. During the past seven days, how much time did you spend sitting down on a typical day? Hours and minutes per day.

						2) How long were you sitting yesterday? Hours and minutes 3) How much time did you spend reading yesterday? Hours and minutes 4) How long did you watch TV yesterday? Hours and minutes 5) How much time have you spent in front of a computer, including on the internet, or on a video game console, counting the time spent at home and at your place of work or study? Hours and minutes
French Polynesia	WPRO-East Asia&Pacific	High income	STEPS (15)	2010		The next question is about time spent sitting or lying down, at work, at home, on the road, visiting friends, and includes time spent [sitting at a desk, traveling in a car, on a bus, reading, being at a computer, playing cards or watching television] but does not include time spent asleep. How much time do you spend sitting or lying down on a typical day? Hours and minutes Don't know/refused

Gabon	AFRO-Sub-Saharan Africa	Upper middle income	STEPS (16)	2009	Non-national	The following question includes time spent sitting or lying down, at work, at home, on the road, visiting friends, and includes time spent (sitting at a desk, traveling in a car, on a bus, reading, playing cards or watching TV) but does not include time spent sleeping [INSERT EXAMPLES] (USE CARDS). How much time do you spend in a sitting position or lying down on a typical day? Hours and minutes
Gambia, The	AFRO-Sub-Saharan Africa	Low income	STEPS (4)	2010		See Bangladesh
Georgia	EURO-Europe and Central Asia	Upper middle income	STEPS (4)	2016		See Bangladesh

Germany	EURO-Europe and Central Asia	High income	Special Eurobarometer 472 - Wave 88.4	2017		See Austria
Greece	EURO-Europe and Central Asia	High income	Special Eurobarometer 472 - Wave 88.4	2017		See Austria
Grenada	PAHO-Latin America& Caribbean	Upper middle income	STEPS (4)	2010-2011		See Bangladesh

Guatemala	PAHO-Latin America& Caribbean	Upper middle income	STEPS (17)	2015		The next question asks how much time you spend sitting or reclining at work, at home, moving between places or with friends, including time spent sitting at a desk, meeting with friends, traveling by car, bus or train, reading, playing cards or watching television; time spent sleeping is not included. [INSERT EXAMPLES] (SHOW GRAPHIC HELP) On a typical day, how much time did you spend sitting or lying down? Hours and minutes
Guinea	AFRO-Sub-Saharan Africa	Low income	STEPS (18)	2009	Non-national	The next question is about time spent sitting or lying down, at work, at home, on the road, visiting friends, and includes time spent sitting at a desk, driving around in a car, by bus, train, reading, playing cards or watching TV but does not include time spent asleep. (SHOW CARDS) How much time do you spend sitting or lying down on a typical day? Hours and minutes

Hong Kong SAR, China	WPRO-East Asia&Pacific	High income	The Behavioural Risk Factor Surveillance System (BRFSS)	2016		During the last 7 days, how much time on average did you usually spend sitting on a weekday? This includes time spent sitting at work, at home or other places, visiting friends, traveling on public transport, reading and lying down to watch television. (Interviewer's prompts: If the respondent cannot answer the daily average time, then say: Please try to make an estimate as accurate as possible) Hours and minutes
Hungary	EURO-Europe and Central Asia	High income	Special Eurobarometer 472 - Wave 88.4	2017		See Austria
Iceland	EURO-Europe and Central Asia	High income	Health and Wellbeing of Icelanders	2017		How long a day did you usually spend sitting last week? Weekdays only. Include time spent at work, at home, and in your free time. (This can include time spent at a desk, dining table, visiting, reading, or in front of a television or computer.) Less than an hour a day, about 1 hour, about 2-3 hours a day, about 4-5 hours a day, about 6-7 hours a day, about 8-10

						hours a day, about 11-13 hours a day, about 14-16 hours a day, more than 16 hours a day.
India	SEARO-South Asia	Lower middle income	STEPS (4)	2007/2008	Non-national	See Bangladesh
Iraq	EMRO-Middle East&North Africa	Upper middle income	STEPS (19)	2015		The following questions relate to the position of sitting or lying down when working or at home and going to and from some places with friends. It includes time spent sitting, commuting and traveling by car, bus, train, reading or watching tv or calculator, but not bedtimes. How much time do you usually spend sitting or lying down in a typical day? (Examples: watching tv, computer, office work, or while traveling by car) Hours and minutes

Ireland	EURO-Europe and Central Asia	High income	Special Eurobarometer 472 - Wave 88.4	2017		See Austria
Ireland	EURO-Europe and Central Asia	High income	The Irish Longitudinal Study of Ageing (TILDA)	2009-2011		The last question is about the time you spent sitting on weekdays during the last 7 days. Include time spent at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading, or sitting or lying down to watch television. During the last 7 days, how much time (per day) did you spend sitting on a week day? (This question is looking for the usual number of hours spent sitting on a typical week day. If respondent has difficulty calculating, interviewer may suggest they approximate by subtracting time spent sleeping, walking, standing, exercising etc. from the 24 hours). Hours and minutes per day Don't know/not sure RF

Ireland	EURO-Europe and Central Asia	High income	Healthy Ireland Survey	2018-2019		The following questions are about the time you spent sitting on weekdays/workdays, and separately, on weekends/days off during the last 7 days. Include time spent sitting at work, while travelling and during leisure time. CAN'T BE MORE THAN 1440. DON'T ALLOW '0'- Validate if more than 120 mins, or less than 60 mins - "You have indicated that the respondent has spent X minutes doing sitting, please confirm that this is correct? Please ensure you are entering minutes and not hours" Q.407 During the last 7 days, how much time did you spend sitting on a weekday or work day? Minutes per day, Don't Know/Not Sure (DNRO) Q408. During the last 7 days, how much time did you spend sitting on a weekend day or day off? Minutes per day, Don't Know/Not Sure (DNRO)

Italy	EURO-Europe and Central Asia	High income	Special Eurobarometer 472 - Wave 88.4	2017		See Austria
Jamaica	PAHO-Latin America& Caribbean	Upper middle income	Jamaica Health and Lifestyle Survey II	2007-2008		The last question is about the time you spent sitting on weekdays during the last 7 days. Include time spent at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading, or sitting or lying down to watch television. During the last 7 days, how much time did you spend sitting on a week day? Hours and minutes per day Don't know/Not sure, No response
Jordan	EMRO-Middle East&North Africa	Upper middle income	STEPS (20)	2019		The following question is about sitting or reclining at work, at home, getting to and from places, or with friends including time spent sitting at a desk, sitting with friends, traveling in car, bus, reading, playing cards or watching television, but do not include time spent sleeping. (USE SHOWCARD) How much time do you usually spend sitting or reclining on a

						typical day? Hours and minutes
Kenya	AFRO-Sub-Saharan Africa	Lower middle income	STEPS (4)	2015		See Bangladesh
Kiribati	WPRO-East Asia&Pacific	Lower middle income	Kiribati NCD Steps Survey (3)	2015-2016		See Armenia

Korea, Rep.	WPRO-East Asia&Pacific	High income	The Korea National Health and Nutrition Examination Survey (KNHANES)	2019		Aside from sleeping time, here are some questions about sitting or lying down when working or at home, moving from place to place, and with friends.* Examples: sitting at a desk, sitting with friends, traveling by car, bus, or train, reading a book, writing, playing cards, watching TV, playing games (Nintendo, computer, PlayStation), internet use, listening to music, etc. How many hours do you usually sit or lie down in a day? Hours and minutes per day
Kuwait	EMRO-Middle East&North Africa	High income	STEPS (21)	2014		The following question is about sitting or reclining at work, at home, getting to and from places, or with friends including time spent sitting at a desk, sitting with friends, traveling in car, bus, train, reading, playing cards in dewaniya or watching television, but do not include time spent sleeping. [INSERT EXAMPLES] (USE SHOWCARD) How much time do you usually spend sitting or reclining on a typical day? Hours and minutes

Kyrgyz Republic	EURO-Europe and Central Asia	Lower middle income	STEPS (4)	2013		See Bangladesh
Lao PDR	WPRO-East Asia&Pacific	Lower middle income	STEPS (4)	2013		See Bangladesh
Latvia	EURO-Europe and Central Asia	High income	Special Eurobarometer 472 - Wave 88.4	2017		See Austria

Lebanon	EMRO-Middle East&North Africa	Upper middle income	STEPS (4)	2017		See Bangladesh
Lesotho	AFRO-Sub-Saharan Africa	Lower middle income	STEPS (22)	2012		The following question is about sitting or reclining at work, at home, getting to and from places, or with friends including time spent sitting at a desk, sitting with friends, traveling in car, taxi, bus, reading, playing cards or watching television, but do not include time spent sleeping. (USE SHOWCARD) How much time do you usually spend sitting or reclining on a typical day? Hours and minutes
Liberia	AFRO-Sub-Saharan Africa	Low income	STEPS (4)	2011		See Bangladesh

Libya	EMRO-Middle East&North Africa	Upper middle income	STEPS (4)	2009		See Bangladesh
Lithuania	EURO-Europe and Central Asia	High income	Special Eurobarometer 472 - Wave 88.4	2017		See Austria
Lithuania	EURO-Europe and Central Asia	High income	Lithuania Health Behavior Among the Adult Population	2014		How much time do you sit during your normal working day (at your desk, driving a vehicle, visiting guests, at home, reading or watching TV)? Hours during the day How long do you sit on weekends? Hours during the day

Luxembourg	EURO-Europe and Central Asia	High income	ORISCAV-LUX2	2016-2017		This question concerns the time that you spent daily sitting during the last week including at work, around the house, at school and during your relaxation time. This does not include days last weekend. It may, for example, include time spent sitting at the office, on transportation, at friends', reading, or sitting or laying down to watch television or use a computer. During the last 7 days (without taking the weekend into account), how much time did you spend sitting during a normal day? Including time spent at home or at your place of work or study. Hours and minutes/day or don't know During the last 7 days, how much time did you spend watching television (including DVD) during a …? Working day - Hours and minutes/day do not know/ n/a Rest day - Hours and minutes/day do not know During the last 7 days, how much time did you spend at home, in front of a computer including Internet, video game console, visiting websites, checking emails, going on Facebook, Twitter, Netlog; a

						...? Working day - Hours and minutes/day do not know/ N/A Rest day - Hours and minutes/day do not know
Luxembourg	EURO-Europe and Central Asia	High income	Special Eurobarometer 472 - Wave 88.4	2017		See Austria
Luxembourg	EURO-Europe and Central Asia	High income	Eurostat - The European Health Interview Survey (EHIS)	2019		The last question in this module is about sitting at work, at home, getting to and from places, or with friends including time spent sitting at a desk, sitting with friends, travelling in car, bus, train, reading, playing cards or watching television on a typical day; but time spent sleeping should not be included here. How much time do you usually spend sitting and reclining on a typical day (without sleeping)? 1. Less than 4 hours 2. 4 hours to less than 6 hours 3. 6 hours to less than 8 hours 4. 8 hours to less than 10

						hours 5. 10 hours to less than 12 hours 6. 12 hours or more
Macao SAR, China	WPRO-East Asia&Pacific	High income	Relatorio da Avaliacai da Condicao Fisica da Populacao da Regiao Administrativa Especial de Macau de 2015 (Physical Fitness Monitoring of Macao Citizens)	2015		Adults (20-39, 40-59,60-69) - Total time per day spent sitting down (including working, watching tv, driving, using the computer, eating, talking, etc). Less than 3 hours, 3 to 6 hours, 6 to 9 hours, 9-12 hours, 12 hours or more.
Madagascar	AFRO-Sub-Saharan Africa	Low income	STEPS (23)	2005	Non-national	How much time do you usually spend sitting or reclining on a typical day? Hours and minutes Don't know Missing

Malawi	AFRO-Sub-Saharan Africa	Low income	STEPS (4)	2009		See Bangladesh
Malaysia	WPRO-East Asia&Pacific	Upper middle income	National Health and Morbidity Survey	2019		Normally in a day, how many hours do you spend on sitting or lying down including the workplace, in the house, in your free time and while travelling, BUT NOT INCLUDING the time spent sleeping? Hours THESE QUESTIONS ARE ABOUT HOW YOU TRAVELLED FROM PLACE TO PLACE, INCLUDING TO PLACES LIKE WORK, STORES, MOVIES, AND SO ON. How much time did you usually spend on one of those days travelling in a train, bus, car, tram, or other kind of motor vehicle? Hours per day/minutes per day

Maldives	SEARO-South Asia	Upper middle income	STEPS (4)	2011	Non-national	See Bangladesh
Malta	EURO-Middle East&North Africa	High income	Special Eurobarometer 472 - Wave 88.4	2017		See Austria
Marshall Islands	WPRO-East Asia&Pacific	Upper middle income	STEPS (24)	2002		This question is about sitting or reclining. Think back over the past 7 days to time spent at work, at home, or during recreation time, including time spent sitting at a desk, visiting friends, reading, or watching television - but not counting time spent sleeping. How much time do you spend sitting or reclining on a typical day? Hours and minutes

Mexico	PAHO-Latin America& Caribbean	Upper middle income	Study on Global Ageing and Adult Health (SAGE)	2009-2010		The following question is about sitting or reclining at work, at home, getting to and from places, or with friends including time spent [sitting at a desk, sitting with friends, travelling in car, bus, train, reading, playing cards or watching television], but do not include time spent sleeping. INSERT EXAMPLES & USE SHOWCARD How much time do you usually spend sitting or reclining on a typical day? Hours and minutes
Mexico	PAHO-Latin America& Caribbean	Upper middle income	Encuesta Nacional de Salud y Nutricion (ENSANUT)	2018-2019		Now think about time that you were seated during the last seven days. Include time spent sitting (at work, at home, studying, and during break time. This may include time spent sitting at a desk, visiting friends, reading, sitting, or lying down watching television. During the past seven days, how much total time were you sitting on one of those days of the week? Hours and minutes/does not respond/does not know

Micronesia, Fed. Sts.	WPRO-East Asia&Pacific	Lower middle income	STEPS (4)	2016		See Bangladesh
Moldova	EURO-Europe and Central Asia	Lower middle income	STEPS (25)	2013		The following question is about sitting or reclining at work, at home, getting to and from places, or with friends, including time spent sitting at a desk; sitting with friends, traveling in a car, bus, or train; reading playing cards or other games; watching television or using a computer. Do not include time spent sleeping. How much time do you usually spend sitting or reclining on a typical day? Hours and minutes
Mongolia	WPRO-East Asia&Pacific	Lower middle income	STEPS (4)	2019		See Bangladesh

Morocco	EMRO-Middle East&North Africa	Lower middle income	Enquête Nationale sur les facteurs de risque communs des MNT 2017-2018 (National survey on common risk factors for NCDs 2017-2018, stepwise survey (GPAQ)	2017		The next question is about time spent sitting or lying down, at work, at home, on the road, visiting friends, and includes time spent sitting at a desk, traveling by car, bus, train, reading, playing cards or watching TV but does not include time spent asleep [INSERT EXAMPLES] (SHOW CARDS). How much time do you spend sitting or lying down on a typical day outside of sleep? Hours and minutes
Mozambique	AFRO-Sub-Saharan Africa	Low income	STEPS (26)	2005		The next questions are about sitting or reclining at work, at home, or with friends including spending time (sitting at the table with friends, traveling by train, reading playing cards or watching television, but not including time spent sleeping. On a typical day, how much time do you normally spend sitting or reclining? Hours and minutes
Myanmar	SEARO-East Asia&Pacific	Lower middle income	STEPS (4)	2014		See Bangladesh

Nepal	SEARO-South Asia	Lower middle income	STEPS (20)	2019		See Jordan
Netherlands	EURO-Europe and Central Asia	High income	Netherlands National Monitoring System/ Health Survey/ Lifestyle Monitor, Statistics Netherlands (CBS) in collaboration with National Institute for Public Health and the Environment (RIVM) 2014-2019 (SQUASH)	2019		Now some questions about how much time (you/your child) per day spends sitting or lying down during different activities. Think of a normal week in the past few months. How much time spent (you/your child) sitting through in the following situations on a normal weekday and on a normal weekend day? During transport, such as sitting in a car seat or in a bicycle seat. During transport, such as sitting in a car, bus, train, or on the back of a bicycle. Self-cycling does not count. Tell both the outward and return journey. Hours and minutes (Weekday transport) Hours and minutes (Weekend transport) During work. For example sitting behind a desk or using a computer or tablet at work or at

						home. Hours and minutes (Weekday work) Hours and minutes (Weekend work) Watching television. Hours and minutes (Weekday tv) Hours and minutes (Weekend tv) Using a computer, tablet or smartphone at home. For example, for email, computer games, looking up information, or chatting, but not for school or work. Hours and minutes (weekday computer) Hours and minutes (weekend computer) Other seated leisure activities. For example, chatting, eating, reading (newspaper), doing puzzles, crafts, playing a musical instrument, going to the cinema. We do not mean watch tv or use a computer/tablet/smartphone. Hours and minutes (weekday other seated leisure activities) Hours and minutes (weekend other seated leisure activities)

Netherlands	EURO-Europe and Central Asia	High income	Special Eurobarometer 472 - Wave 88.4	2017		See Austria
New Zealand	WPRO-East Asia&Pacific	High income	ACTIVE NZ: The New Zealand Participation Survey	2018-2019		In total over the last 7 days how many hours have you spent looking at a screen for paid employment, study or at school? This includes computer monitors, televisions and mobile devices including phones and tablets. Please make your best estimate to the closest 1/4 hour based on the entire week. If none, please write 'zero'. Hours And in total over the last 7 days how many hours have you spent looking at a screen outside of your paid employment, study or school? Please make your best estimate to the closest 1/4 hour. If none, please write 'zero'. Hours And how many, if any, of these hours were spent gaming (i.e. on an Xbox, Playstation or

						computer)? Please make your best estimate to the closest 1/4 hour. If none, please write 'zero'. Hours
Niger	AFRO-Sub-Saharan Africa	Low income	STEPS (27)	2007	Non-national	The next question relates to time spent spent sitting or lying down, at work, at home, on the road, visiting friends, and includes time spent (sitting at a desk, traveling by car, bus, train, reading, playing cards or watching TV) but does not include time spent asleep. (INSERT EXAMPLES) (USE CARDS). How much time do you spend sitting or lying down on a typical day? Hours and minutes
Nigeria	AFRO-Sub-Saharan Africa	Lower middle income	Physical Activity Survey/ Physical Activity Prevalence Study 2011	2011	Non-national	The last question applies to how long you/you have taken a sit-in on work days in the last seven days. This includes time spent at work and at home, while relaxing. Could this include spending time sitting in an office, visiting friends, studying or lyind down, watching tv? In the last seven days, how much time did you spend sitting on weekdays? Hours____everyday

						Minutes____everyday I don't know/I'm not sure
Northern Ireland	EURO-Europe and Central Asia	High income	Health Survey for Northern Ireland	2016/2017		Now I'd like to ask you some questions about time that you might have spent sitting down. For these questions, I'd like you to think about what you have done in the last four weeks, that is since (date of interview – 4 weeks) when you were not doing your (paid) job. In the last 4 weeks, how much time did you spend sitting down watching TV (including DVDs and videos) on an average weekday (that is Monday to Friday)? RECORD HOURS SPENT BELOW. ENTER 0 IF LESS THAN 1 HOUR. RECORD MINUTES AT NEXT QUESTION. In the last four weeks, how much time did you spend sitting down doing any other activity on an average weekday (that is Monday to Friday)? Please do not include time spent doing these activities

						while at work. INTERVIEWER: EXAMPLES OF THESE ACTIVITIES INCLUDE READING, , STUDYING, DRAWING, USING A COMPUTER, PLAYING VIDEO GAMES. RECORD HOURS SPENT BELOW. ENTER 0 IF LESS THAN 1 HOUR. RECORD MINUTES AT NEXT QUESTION" In the last four weeks, how much time did you spend watching TV (including watching DVDs and videos) on an average weekend day (that is Saturday and Sunday)? INTERVIEWER: RECORD HOURS SPENT BELOW. ENTER 0 IF LESS THAN 1 HOUR. RECORD MINUTES AT NEXT QUESTION. In the last 4 weeks, how much time did you spend sitting down doing any other activity on an average weekend day (that is Saturday and Sunday)? Please do not include time spent doing these activities while at work. INTERVIEWER: EXAMPLES OF THESE ACTIVITIES INCLUDE READING, STUDYING, DRAWING, USING A COMPUTER, PLAYING VIDEO GAMES. RECORD HOURS SPENT BELOW. ENTER 0 IF LESS

						THAN 1 HOUR. RECORD MINUTES AT NEXT QUESTION.
Northern Ireland	EURO-Europe and Central Asia	High income	Special Eurobarometer 472 - Wave 88.4	2017		See Austria
Norway	EURO-Europe and Central Asia	High income	KaN2 Study	2014/2015		Home activities The next questions deal with activities that are usually done in and around the home. For each activity, we ask you to specify how much time you spend on this activity. Take as a starting point how much time you have spent on the various activities on average in the last 4 weeks. TV, DVD or video - watching (please tick one line for each line) Average over the last 4 weeks Hours watch TV DVD or video per day On a weekday before 6pm (No,

						1 to 2 hours per day, 2 to 3 hours per day, less than 1 hour per day, 3 to 4 hours per day, more than 4 hours per day) On a weekday after 6pm (same as above) On a weekend before 6pm (same as above) On a weekend after 6pm (same as above) Use of a computer at home, not at work (internet, e-mail, social media, games, etc.) please put a cross for each line). Average over the last 4 weeks. Hours spent in front of the computer at home per day. On a weekday before 6pm (No, 1 to 2 hours per day, 2 to 3 hours per day, less than 1 hour per day, 3 to 4 hours per day, more than 4 hours per day) On a weekday after 6pm (same as above) On a weekend before 6pm (same as above) On a weekend after 6pm (same as above) This question includes all the time you spend at rest (sitting) at work, at home, on courses, and in your free time. It could be the time you sit at a desk, with friends, while reading or lying down to watch TV. During the last 7 days, what country time did you usually

						spend in total sitting on a regular weekday? Hours, minutes, do not know/do not remember.
Oman	EMRO-Middle East&North Africa	High income	STEPS (28)	2006		The next question relates to sitting or lying down, whether at work or at home, going or coming back from different places, including the time you spend sitting at the office (sitting with friends, traveling by car or bus, reading, watching tv, or sitting in front of the computer, but it does not include the time you spend sleeping. On a normal day: how much time do you usually spend sitting or lying down (this includes all the time you spend sitting at work or at a desk, reading, watching tv, using a computer, doing crafts, sewing, embroidery, drawing, etc) Hours and minutes

Palau	WPRO-East Asia&Pacific	High income	STEPS (29)	2016		How much time do you usually spend sitting or reclining on a regular day? (THIS DOES NOT INCLUDE TIME SPENT SLEEPING) USE SHOWCARD Hours/minutes/don't know/refused
Palestine/ West Bank and Gaza	EMRO-Middle East&North Africa	Lower middle income	STEPS (30)	2010-2011		The following questions relate to sitting or lying down at work or at home and going to and from places with friends. They include time spent sitting, traveling by car, bus, or train, reading, playing cards, or watching TV but sleep times do not include. How much time do you spend sitting or lying down in a typical day? Hours and minutes
Poland	EURO-Europe and Central Asia	High income	Special Eurobarometer 472 - Wave 88.4	2017		See Austria

Poland	EURO-Europe and Central Asia	High income	Examination of the level of physical activity of the society 2018 Ministry of Sport and Tourism (other) - Polish IPAQ-LF	2018		Please indicate how much time you spend on one of these (average) days traveling by car, bus, train, tram, or other vehicle (please do not include cycling) Hours per day Minutes per day The questions in this section relate to the time you spend sitting at work, at home, while studying and in your free time. This may include time spent sitting at a desk, visiting friends, reading, watching tv while lying or sitting (not including sleeping time). Please do not take into account the time spent sitting in a motor vehicle, because we have already mentioned this. Taking into account the last 7 days, please specify how much time, on average, you spent sitting on a weekday. Hours and minutes Taking into account the last 7 days, please indicate how much time on average you spent sitting on a non-working day. Hours and minutes

Portugal	EURO- Europe and Central Asia	High income	Special Eurobarometer 472 - Wave 88.4	2017		See Austria
Portugal	EURO- Europe and Central Asia	High income	Inquérito Alimentar Nacional e de Atividade Física, IAN-AF (National Food, Nutrition and Physical Activity Survey)	2015-2016		This question is related to the time spent sitting during weekdays (and not weekends) in the last 7 days. Also include time spent on activities such as sitting at a desk, visiting friends, reading, sitting or resting watching television, or listening to music. Include time spent lying down but awake. In the last 7 days how much time did you generally spend sitting on a weekday? Hours and minutes per day Don't know/not sure
Qatar	EMRO- Middle East and North Africa	High income	STEPS (31)	2012		The following questions relate to sitting or lying down at work, at home or with friends, and they include time spent sitting or traveling by car by bus, reading or watching TV, but not bedtime. In the past week, how much time did you spend sitting or lying down in a day (other than bedtimes)? Hours and minutes

Romania	EURO-Europe and Central Asia	High income	Special Eurobarometer 472 - Wave 88.4	2017		See Austria
Rwanda	AFRO-Sub-Saharan Africa	Low income	STEPS (4)	2012-2013		See Bangladesh
Samoa	WPRO-East Asia&Pacific	Upper middle income	STEPS (20)	2013		See Jordan

Saudi Arabia	EMRO-Middle East&North Africa	High income	The Saudi Health Interview Survey	2013		The following question is about sitting or reclining at work, at home, getting to and from places, or with friends including time spent sitting at a desk, sitting with friends, traveling in car, bus, train, reading, playing cards or watching television, but do not include time spent sleeping [INSERT EXAMPLES] (USE SHOWCARD) How much time do you usually spend sitting or reclining on a typical day? Hours and minutes Don't know Decline to respond In a typical week, how much time do you usually spend in front of the television or on the computer? Enter number of hours Don't know Decline to respond
Scotland	EURO-Europe and Central Asia	High income	Special Eurobarometer 472 - Wave 88.4	2017		See Austria

Senegal	AFRO-Sub-Saharan Africa	Lower middle income	STEPS (8)	2015		See Burkina Faso
Seychelles	AFRO-Sub-Saharan Africa	High income	STEPS (31)	2013-2014		In a typical weekday, how many hours do you spend watching TV, working on a computer, or Using internet, per day? n(hours/day, if 30 min=0.5 hour) In a typical weekend, how many hours do you spend watching TV, working on a computer, or using internet, per day? n(hours/day, if 30 min=0.5hour)
Sierra Leone	AFRO-Sub-Saharan Africa	Low income	STEPS (4)	2009		See Bangladesh

Singapore	WPRO-East Asia&Pacific	High income	National Health Surveillance Survey	2007-2008		The following question is about sitting or reclining at work, at home, getting to and from places, or with friends, including time spent [sitting at a desk, sitting with friends, travelling in car, bus, train, reading, playing cards or watching television], but do not include time spent sleeping. [INSERT EXAMPLES] [USE SHOWCARD How much time do you usually spend sitting or reclining on a typical day? Hours and minutes
Singapore	WPRO-East Asia&Pacific	High income	National Health Survey	2010		The following question is about sitting or reclining at work, at home, getting to and from places, or with friends, including time spent [sitting at a desk, sitting with friends, travelling in car, bus, train, reading, playing cards or watching television], but do not include time spent sleeping. [INSERT EXAMPLES] [USE SHOWCARD How much time do you usually spend sitting or reclining on a typical day? Hours and minutes

Singapore	WPRO-East Asia&Pacific	High income	National Population Health Survey	2018-2019		The next question is about sitting or reclining at work, at home, getting to and from places, or with friends, including time spent sitting at a desk, sitting with friends, travelling in car, bus, train, reading, playing cards or watching television but DO NOT include time spent sleeping. On a typical day, how much time in total do you usually spend sitting or reclining? Hours and minutes/Refused/don't know, not sure
Slovak Republic	EURO-Europe and Central Asia	High income	Special Eurobarometer 472 - Wave 88.4	2017		See Austria
Slovenia	EURO-Europe and Central Asia	High income	Slovenian Health Monitor Survey	2016		How many hours do you usually sit? Take into account sitting at work, at home, reading, in front of the TV or computer, on the road, at rest, etc. Please enter the number of sitting hours per working day Please enter the number of sitting hours per day at the weekend

Slovenia	EURO-Europe and Central Asia	High income	Special Eurobarometer 472 - Wave 88.4	2017		See Austria
Solomon Islands	WPRO-East Asia&Pacific	Lower middle income	STEPS (4)	2015		See Bangladesh

South Africa	AFRO-Sub-Saharan Africa	Upper middle income	South Africa Demographic and Health Survey	2003		Now I would like to ask you about the time spent sitting or resting, not including sleeping, in the past 7 days. This may include time sitting at a desk, visiting friends, reading, or sitting down to watch television during working hours and leisure or spare time. Over the past 7 days, how much time did you spend sitting or reclining (lying) on a usual day (excluding sleeping)? Hours and minutes
Spain	EURO-Europe and Central Asia	High income	Special Eurobarometer 472 - Wave 88.4	2017		See Austria
Spain	EURO-Europe and Central Asia	High income	National Health Survey of Spain	2017		The last question refers to the time you spent sitting in the last 7 days. Include time sitting at work, at home, in class studying, reading and on transportation, free time or watching television. In the last 7 days, how long did you sit on a typical weekday? Hours per day Minutes per day Does not know Does not answer

Sri Lanka	SEARO-South Asia	Lower middle income	STEPS (4)	2014-2015		See Bangladesh
St. Kitts and Nevis	PAHO-Latin America& Caribbean	High income	STEPS (4)	2007-2008	Non-national	See Bangladesh

Swaziland	AFRO-Sub-Saharan Africa	Lower middle income	STEPS (4)	2014		See Bangladesh
Sweden	EURO-Europe and Central Asia	High income	Special Eurobarometer 472 - Wave 88.4	2017		See Austria
Switzerland	EURO-Europe and Central Asia	High income	Schweizerische Gesundheitsbefragung (The Swiss Health Survey)	2017		How much time per day do you normally spend in your free time on the following activities? a) watch television or videos b) play computer or video games c) other use of a computer, smartphone, tablet but not to watch television or video, nor to play computer or video games or to make phone calls. never/not every day, less than 1 hour a day, 1 to 2 hours a day, over 2 hours to less than 5 hours a day. Now it's about sitting, for example, at work, at home, on the way from one place to

						another or during leisure time, at the table, in front of the television or while reading. All in all, how many hours do you spend sitting down on a normal weekday? Hours per day INT - Please give an average per day. From 30 minutes round up to 1 hour. Monday to Friday only. Don't know/no answer
Tanzania	AFRO-Sub-Saharan Africa	Lower middle income	STEPS (4)	2012		See Bangladesh
Thailand	SEARO-East Asia & Pacific	Upper middle income	Health and Welfare Survey	2015		Usually….(name)….is there a sitting or reclining, playing computer, watching TV that does not include sleep? No, Yes (record number of days and minutes)

Timor-Leste	SEARO-East Asia & Pacific	Lower middle income	STEPS (20)	2014		See Jordan
Togo	AFRO-Sub-Saharan Africa	Low income	STEPS (8)	2010-2011		See Burkina Faso
Tonga	WPRO-East Asia&Pacific	Upper middle income	STEPS (4)	2011-2012		See Bangladesh

Trinidad and Tobago	PAHO-Latin America& Caribbean	High income	STEPS/Chronic Disease Risk Factor Surveillance in Trinidad and Tobago (13)	2011		See Congo Republic
Turkey	EURO-Europe and Central Asia	Upper middle income	STEPS (3)	2017		See Armenia
Turkey	EURO-Europe and Central Asia	Upper middle income	Turkstat - Turkish Nutrition and Health Survey	2017		The following questions are about time spent at work, at home, while traveling, or while sitting or lying down with friends (travelling by car, bus and train, reading a book or newspaper, playing cards, using a computer and smartphone, or watching television). But the time spent sleeping is not included. How much time do you usually spend sitting or lying down in a day? Hours and minutes I will ask you questions about the activities you do during a

						day. What time did you wake up yesterday morning? What time did you go to bed the night before? What did you do after waking up? Write the appropriate activity code for all activities in the time activity box. Activities done while lying down (resting, watching TV, reading a book-newspaper, listening to music). Hours, minutes, activity. Sitting jobs - Watching TV, Office work (typewriter, computer, desk jobs) Housework (vegetable picking, knitting, sewing, ironing) Other (driving a car - tractor, painting, playing musical instruments, playing paper, carpet weaving, etc) shoeshine, fishing etc) Hours, minutes, activity.
Turkey	EURO-Europe and Central Asia	Upper middle income	Turkish IPAQ - short form			The last question is about the time spent sitting in the past week. This includes time spent at work, at home, working or relaxing. This includes the time you spend sitting at your desk, visiting a friend, reading, sitting or watching television while lying down. How much time have you spent sitting per day in the past week? I don't know/I'm not sure, minutes per day, hours per day

Turkey	EURO-Europe and Central Asia	Upper middle income	Eurobarometer 64.3	2005		How much time do you spend sitting on usual day? This may include time spent at a desk, visiting friends, reading, studying or watching television. Hours and minutes
Turkmenistan	EURO-Europe and Central Asia	Upper middle income	STEPS (8)	2013-2014		See Burkina Faso

Tuvalu	WPRO-East Asia&Pacific	Upper middle income	STEPS (20)	2015		See Jordan
Uganda	AFRO-Sub-Saharan Africa	Low income	STEPS (4)	2014		See Bangladesh
United States	PAHO-North America	High income	National Health and Nutrition Examination Survey (NHANES)	2017-2018		The following question is about sitting at work, at home, getting to and from places, or with friends, including time spent sitting at a desk, traveling in a car or bus, reading, playing cards, watching television, or using a computer. Do not include time spent sleeping. How much time {do you/does SP} usually spend sitting on a typical day? Enter number of minutes or hours Refused Don't know Now I will ask you first about

						TV watching and then about computer use. Over the past 30 days, on average how many hours per day did {you/SP} sit and watch TV or videos? Would you say . . . Less than 1 hour (0) 1 hour, (1) 2 hours (2) 3 hours (3) 4 hours (4) 5 hours or more or, (5) (You do/SP does) not watch TV or videos (8) Refused (77) Don't know (99) Over the past 30 days, on average how many hours per day did {you/SP} use a computer or play computer games outside of school? Include time spent on things such as Xbox, PlayStation, an iPod, an iPad or other tablet, a smart phone, YouTube, Facebook or other social networking tools, and the internet. Would you say less than 1 hour, (0) 1 hour, (1) 2 hours, (2) 3 hours, (3) 4 hours, (4) 5 hours or more, or (5) {You do/SP does} not use a computer outside of work or school (8)

						REFUSED (77) DON'T KNOW (99)
Uruguay	PAHO-Latin America& Caribbean	High income	STEPS (32)	2013-2014		The next question asks how much time you usually spend sitting or lying down at work, at home, on the road, or with your friends. Time spent at a work table, sitting with friends, traveling on buses, playing cards, or watching television is included. But time spent sleeping is not included. How much time do you usually spend sitting or lying down on a typical day? Hours and minutes
Vanuatu	WPRO-East Asia&Pacific	Lower middle income	STEPS (20)	2011		See Jordan

Venezuela, RB	PAHO-Latin America& Caribbean	Upper middle income	Estudio Venezolano de Salud Cardio-metabólica (EVESCAM)	2014-2017		Now think about the time you spent SITTING in the week for the last 7 days. Include time at work, at home, studying, and during break time. This may include time spent sitting at a desk, visiting friends, reading, sitting, or lying down watching television. During the past 7 days, how much time in total did you usually spend sitting on one day of the week? Hours per day Minutes per day Don't know/not sure Does not want to answer
Vietnam	WPRO-East Asia&Pacific	Lower middle income	STEPS (33)	2015		The following question is about sitting or reclining at work, at home, getting to and from places, or with friends including time spent sitting at a desk, sitting during meals, sitting with friends, traveling in car, bus, train, reading, playing cards or watching television, but do not include time spent sleeping. (USE SHOWCARD) How much time do you usually spend sitting or reclining on a typical day?

Wales	EURO-Europe and Central Asia	High income	Special Eurobarometer 472 - Wave 88.4	2017		See Austria
Zambia	AFRO-Sub-Saharan Africa	Lower middle income	STEPS (4)	2017		See Bangladesh

Glossary

DESI	Digital Economy and Society Index
DVDs	Digital Versatile Discs
ESOMAR	European Society for Opinion and Market Research
GDP	Gross Domestic Product
GoPA!	Global Observatory for Physical Activity
GPAQ	Global Physical Activity Questionnaire
HDI	Human Development Index
IAB	Interactive Advertising Bureau
ICATUS	International Classification of Activities for Time-Use Statistics
IPAQ	International Physical Activity Questionnaire
JITAIs	Just-In-Time Adaptive Interventions
METs	Metabolic Equivalents
NHANES	National Health and Nutrition Examination Survey
PC	Personal Computer
PSU	Primary Sampling Unit
SIT	Sedentary Behaviour International Taxonomy
STEPS	STEPwise Approach to Surveillance
TASST	Taxonomy of Self-reported Sedentary Behaviour Tools
TV	Television
UK	United Kingdom
UKTUS	United Kingdom Time Use Survey
USA	United States of America
WHO	World Health Organization

References

Aadahl, M. *et al.* (2013) 'Recent temporal trends in sleep duration, domain-specific sedentary behaviour and physical activity. A survey among 25–79-year-old Danish adults', *Scandinavian Journal of Public Health*, 41(7), pp. 706–711. Available at: https://doi.org/10.1177/1403494813493151.

Aguilar-Farias, N. and Leppe Zamora, J. (2017) 'Is a single question of the Global Physical Activity Questionnaire (GPAQ) valid for measuring sedentary behaviour in the Chilean population?', *Journal of Sports Sciences*, 35(16), pp. 1652–1657. Available at: https://doi.org/10.1080/02640414.2016.1229010.

Alley, S. *et al.* (2017) 'Impact of increasing social media use on sitting time and body mass index', *Health Promotion Journal of Australia*, 28(2), pp. 91–95. Available at: https://doi.org/10.1071/HE16026.

Altschuler, A. *et al.* (2009) 'Physical activity questionnaire comprehension', *Medicine & Science in Sports & Exercise*, 41(2), pp. 336–343. Available at: https://doi.org/10.1249/MSS.0b013e318186b1b1.

Alzhrani, A.M. *et al.* (2022) 'Using touchscreen mobile devices — when , where and how : A one-week field study', *Ergonomics*, 65(4), pp. 561–572. Available at: https://doi.org/10.1080/00140139.2021.1973577.

Arundell, L. *et al.* (2019) 'Informing behaviour change: What sedentary behaviours do families perform at home and how can they be targeted?', *International Journal of Environmental Research and Public Health*, 16(22), pp. 1–12. Available at: https://doi.org/10.3390/ijerph16224565.

As, D. (1978) 'Studies of time-use : Problems and prospects', *Acta Sociologica*, 21(2), pp. 125–141.

Atkin, A.J. *et al.* (2012) 'Methods of measurement in epidemiology: Sedentary behaviour', *International Journal of Epidemiology*, 41(5), pp. 1460–1471. Available at: https://doi.org/10.1093/ije/dys118.

Aunger, J. and Wagnild, J. (2022) 'Objective and subjective measurement of sedentary behavior in human adults: A toolkit', *American Journal of Human Biology*, 34(1), pp. 1–22. Available at: https://doi.org/10.1002/ajhb.23546.

Bainbridge, L. (2017) *'What is a postcode sector?'* Available at: https://traveltime.com/blog/postcode-sector-defintion#:~:text=A postcode sector combines a postcode area%2C a,up of %27SW%27 which indicates South West London. (Accessed: 2 January 2023).

Bakker, E.A. *et al.* (2020) 'Validity and reliability of subjective methods to assess sedentary behaviour in adults: A systematic review and meta-analysis', *International Journal of Behavioral Nutrition and Physical Activity*, 17(75), pp. 1–31. Available at: https://doi.org/10.1186/s12966-020-00972-1.

Barkley, J.E., Lepp, A. and Salehi-Esfahani, S. (2016) 'College students' mobile telephone use is positively associated with sedentary behavior', *American Journal of Lifestyle Medicine*, 10(6), pp. 437–441. Available at: https://doi.org/10.1177/1559827615594338.

Bauman, A. *et al.* (2006) 'Physical activity measurement- A primer for health promotion', *Promotion & Education*, 13(2), pp. 92–103. Available at: https://doi.org/10.1177/10253823060130020103.

Bauman, A.E. *et al.* (2012) 'Correlates of physical activity: Why are some people physically active and others not?', *The Lancet*, 380(9838), pp. 258–271. Available at: https://doi.org/10.1016/S0140-6736(12)60735-1.

Bauman, A., Bittman, M. and Gershuny, J. (2019) 'A short history of time use research; Implications for public health', *BMC Public Health*, 19(Suppl 2), pp. 1–7. Available at: https://doi.org/10.1186/s12889-019-6760-y.

Bennie, J.A. *et al.* (2013) 'The prevalence and correlates of sitting in European adults - a comparison of 32 Eurobarometer-participating countries', *International Journal of Behavioral Nutrition and Physical Activity*, 10(107), pp. 1–13. Available at: https://doi.org/10.1186/1479-5868-10-107.

Biddle, S.J.H. *et al.* (2016) 'Too much sitting and all-cause mortality: Is there a causal link?', *BMC Public Health*, 16(635), pp. 1–10. Available at: https://doi.org/10.1186/s12889-016-3307-3.

Biddle, S.J.H. *et al.* (2017) 'Screen time, other sedentary behaviours, and obesity risk in adults: A review of reviews', *Current Obesity Reports*, 6(2), pp. 134–147.

Available at: https://doi.org/10.1007/s13679-017-0256-9.

Birken, C.S. *et al.* (2011) 'Parental factors associated with screen time in pre-school children in primary-care practice: A TARGet Kids! study', *Public Health Nutrition*, 14(12), pp. 2134–2138. Available at: https://doi.org/10.1017/S1368980011000516.

Biswas, A. *et al.* (2015) 'Sedentary time and its association with risk for disease incidence, mortality, and hospitalization in adults a systematic review and meta-analysis', *Annals of Internal Medicine*, 162(2), pp. 123–132. Available at: https://doi.org/10.7326/M14-1651.

Brinberg, M. *et al.* (2021) 'The idiosyncrasies of everyday digital lives: Using the Human Screenome Project to study user behavior on smartphones', *Computers in Human Behavior*, 114, pp. 1–27. Available at: https://doi.org/10.1016/j.chb.2020.106570.

Brown, W.J., Bauman, A.E. and Owen, N. (2009) 'Stand up, sit down, keep moving: Turning circles in physical activity research?', *British Journal of Sports Medicine*, 43(2), pp. 86–88. Available at: https://doi.org/10.1136/bjsm.2008.055285.

Buck, C. *et al.* (2019) 'Factors influencing sedentary behaviour: A system based analysis using Bayesian networks within DEDIPAC', *PLoS ONE*, 14(1), pp. 1–18. Available at: https://doi.org/10.1371/journal.pone.0211546.

Bull, F.C. *et al.* (2020) 'World Health Organization 2020 guidelines on physical activity and sedentary behaviour', *British Journal of Sports Medicine*, 54(24), pp. 1451–1462. Available at: https://doi.org/10.1136/bjsports-2020-102955.

Byrom, B. *et al.* (2016) 'Objective measurement of sedentary behaviour using accelerometers', *International Journal of Obesity*, 40(11), pp. 1809–1812. Available at: https://doi.org/10.1038/ijo.2016.136.

Cameron, A.J. *et al.* (2013) 'Macroenvironmental factors including GDP per capita and physical activity in Europe', *Medicine and Science in Sports and Exercise*, 45(2), pp. 278–285. Available at: https://doi.org/10.1249/MSS.0b013e31826e69f0.

Chaput, J.-P., Olds, T. and Tremblay, M.S. (2020) 'Public health guidelines on

sedentary behaviour are important and needed: A provisional benchmark is better than no benchmark at all', *British Journal of Sports Medicine*, 54(5), pp. 308–309. Available at: https://doi.org/10.1136/bjsports-2018-099964.

Chastin, S.F.M. *et al.* (2018) 'Systematic comparative validation of self-report measures of sedentary time against an objective measure of postural sitting (activPAL)', *International Journal of Behavioral Nutrition and Physical Activity*, 15(21), pp. 1–12. Available at: https://doi.org/10.1186/s12966-018-0652-x.

Chastin, S.F.M., Culhane, B. and Dall, P.M. (2014) 'Comparison of self-reported measure of sitting time (IPAQ) with objective measurement (activPAL)', *Physiological Measurement*, 35(11), pp. 2319–2328. Available at: https://doi.org/10.1088/0967-3334/35/11/2319.

Chastin, S.F.M., Schwarz, U. and Skelton, D.A. (2013) 'Development of a Consensus Taxonomy of Sedentary Behaviors (SIT): Report of Delphi Round 1', *PLoS ONE*, 8(12), pp. 1–16. Available at: https://doi.org/10.1371/journal.pone.0082313.

Chau, J.Y. *et al.* (2012) 'Temporal trends in non-occupational sedentary behaviours from Australian Time Use Surveys 1992, 1997 and 2006', *International Journal of Behavioral Nutrition and Physical Activity*, 9(76), pp. 1–8. Available at: https://doi.org/10.1186/1479-5868-9-76.

Clark, B.K. *et al.* (2013) 'Adults' past-day recall of sedentary time: Reliability, validity, and responsiveness', *Medicine and Science in Sports and Exercise*, 45(6), pp. 1198–1207. Available at: https://doi.org/10.1249/MSS.0b013e3182837f57.

Cleland, C.L. *et al.* (2014) 'Validity of the Global Physical Activity Questionnaire (GPAQ) in assessing levels and change in moderate-vigorous physical activity and sedentary behaviour', *BMC Public Health*, 14(1255), pp. 1–11. Available at: https://doi.org/10.1186/1471-2458-14-1255.

Collings, P.J. *et al.* (2022) 'Device-measured physical activity and sedentary time in a national sample of Luxembourg residents: The ORISCAV-LUX 2 study', *International Journal of Behavioral Nutrition and Physical Activity*, 19(161), pp. 1–15. Available at: https://doi.org/10.1186/s12966-022-01380-3.

Craig, C.L. *et al.* (2003) 'International Physical Activity Questionnaire: 12-Country reliability and validity', *Medicine and Science in Sports and Exercise*, 35(8), pp. 1381–1395. Available at: https://doi.org/10.1249/01.MSS.0000078924.61453.FB.

Craig, R., Mindell, J. and Hirani, V. (eds) (2009) *Health Survey for England 2008 physical activity and fitness summary of key findings*. Available at: https://files.digital.nhs.uk/publicationimport/pub00xxx/pub00430/heal-surv-phys-acti-fitn-eng-2008-rep-v1.pdf.

Crowley, P. *et al.* (2022) 'The surveillance of physical activity, sedentary behavior, and sleep: Protocol for the development and feasibility evaluation of a novel measurement system', *JMIR Research Protocols*, 11(6), pp. 1–11. Available at: https://doi.org/10.2196/35697.

Cusatis, R. and Garbarski, D. (2018) 'Which activities count? Using experimental data to understand conceptualizations of physical activity', *SSM - Population Health*, 6, pp. 286–294. Available at: https://doi.org/10.1016/j.ssmph.2018.10.002.

Dall, P.M. *et al.* (2017) 'TAxonomy of Self-reported Sedentary behaviour Tools (TASST) framework for development, comparison and evaluation of self-report tools: Content analysis and systematic review', *BMJ Open*, 7(4), pp. 1–12. Available at: https://doi.org/10.1136/bmjopen-2016-013844.

De Craemer, M. *et al.* (2018) 'Data on determinants are needed to curb the sedentary epidemic in Europe. Lessons learnt from the DEDIPAC European Knowledge Hub', *International Journal of Environmental Research and Public Health*, 15(7), pp. 1–6. Available at: https://doi.org/10.3390/ijerph15071406.

Dempsey, P.C. *et al.* (2020) 'New global guidelines on sedentary behaviour and health for adults: Broadening the behavioural targets', *International Journal of Behavioral Nutrition and Physical Activity*, 17(151), pp. 1–12. Available at: https://doi.org/10.1186/s12966-020-01044-0.

DiPietro, L. *et al.* (2020) 'Advancing the global physical activity agenda: recommendations for future research by the 2020 WHO physical activity and sedentary behavior guidelines development group', *International Journal of Behavioral Nutrition and Physical Activity*, 17(143), pp. 1–11. Available at: https://doi.org/10.1186/s12966-020-01042-2.

Edwardson, C.L. *et al.* (2016) ‘Accuracy of posture allocation algorithms for thigh- and waist-worn accelerometers’, *Medicine & Science in Sports & Exercise*, 48(6), pp. 1085–1090. Available at: https://doi.org/10.1249/MSS.0000000000000865.

Edwardson, C.L. *et al.* (2017) ‘Considerations when using the activPAL monitor in field-based research with adult populations’, *Journal of Sport and Health Science*, 6(2), pp. 162–178. Available at: https://doi.org/10.1016/j.jshs.2016.02.002.

Ekelund, U. *et al.* (2016) ‘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), pp. 1302–1310. Available at: https://doi.org/10.1016/S0140-6736(16)30370-1.

Ekelund, U. *et al.* (2019) ‘Dose-response associations between accelerometry measured physical activity and sedentary time and all cause mortality: Systematic review and harmonised meta-analysis’, *The BMJ*, 366(4570), pp. 1–10. Available at: https://doi.org/10.1136/bmj.l4570.

European Commission (2012a) ‘Eurobarometer 58.2 (Oct-Dec 2002)’. Cologne: Gesis Data Archive. Available at: https://doi.org/https://doi.org/10.4232/1.10954.

European Commission (2012b) ‘Eurobarometer 64.3 (Nov-Dec 2005)’. Cologne: Gesis Data Archive. Available at: https://doi.org/https://doi.org/10.4232/1.10971.

European Commission (2017) ‘Eurobarometer 80.2 (2013)’. Cologne: Gesis Data Archive. Available at: https://doi.org/https://doi.org/10.4232/1.12792.

European Commission (2022a) ‘Eurobarometer 88.4 (2017)’. Cologne: GESIS. Available at: https://doi.org/https://doi.org/10.4232/1.14003.

European Commission (2022b) *‘Digital Economy and Society Index (DESI) 2022’*. Available at: https://digital-strategy.ec.europa.eu/en/library/digital-economy-and-society-index-desi-2022 (Accessed: 24 February 2023).

European Society for Opinion and Market Research (2021) *‘Code and guidelines’*. Available at: https://esomar.org/codes-and-guidelines (Accessed: 24 January 2021).

European Union (2022a) *‘Eurobarometer’*. Available at:

https://europa.eu/eurobarometer/surveys/browse/all/series/8923 (Accessed: 28 October 2022).

European Union (2022b) *'About Eurobarometer'*. Available at: https://europa.eu/eurobarometer/about/eurobarometer (Accessed: 26 September 2022).

European Union (2022c) *Special Eurobarometer SP525 : Sport and physical activity*. Available at: https://data.europa.eu/data/datasets/s2668_97_3_sp525_eng?locale=en (Accessed: 10 February 2024).

Eurostat (2022a) *'How do women and men use their time - Statistics'*. Available at: https://ec.europa.eu/eurostat/statistics-explained/index.php?oldid=463738#Multitasking:_two_activities_at_the_same_time (Accessed: 22 January 2023).

Eurostat (2022b) *'Digital economy and society statistics - Households and individuals'*. Available at: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Digital_economy_and_society_statistics_-_households_and_individuals#Use_of_internet (Accessed: 21 April 2023).

Evenson, K.R., Goto, M.M. and Furberg, R.D. (2015) 'Systematic review of the validity and reliability of consumer-wearable activity trackers', *International Journal of Behavioral Nutrition and Physical Activity*, 12(159), pp. 1–22. Available at: https://doi.org/10.1186/s12966-015-0314-1.

Ferguson, T. *et al.* (2021) 'Annual, seasonal, cultural and vacation patterns in sleep, sedentary behaviour and physical activity: A systematic review and meta-analysis', *BMC Public Health*, 21(1384), pp. 1–14. Available at: https://doi.org/10.1186/s12889-021-11298-3.

Ferrari, G. *et al.* (2022) 'Relationship between socio-demographic correlates and human development index with physical activity and sedentary time in a cross-sectional multicenter study', *BMC Public Health*, 22(669), pp. 1–8. Available at: https://doi.org/10.1186/s12889-022-13117-9.

Fewell, Z., Davey Smith, G. and Sterne, J.A.C. (2007) 'The impact of residual and

unmeasured confounding in epidemiologic studies: A simulation study', *American Journal of Epidemiology*, 166(6), pp. 646–655. Available at: https://doi.org/10.1093/aje/kwm165.

Fulton, J.E. *et al.* (2016) 'Strategic priorities for physical activity surveillance in the United States', *Medicine and Science in Sports and Exercise*, 48(10), pp. 2057–2069. Available at: https://doi.org/10.1249/MSS.0000000000000989.

Gesis (2017) *'Eurobarometer Data Service'*. Available at: https://www.gesis.org/en/eurobarometer-data-service/survey-series/standard-special-eb/study-overview/eurobarometer-884-za6939-december-2017 (Accessed: 7 September 2022).

Gesis (2022) *'Sampling and fieldwork'*. Available at: https://www.gesis.org/en/eurobarometer-data-service/survey-series/standard-special-eb/sampling-and-fieldwork (Accessed: 26 September 2022).

Global Observatory for Physical Activity (2020) *'Second set of country cards: Detailed appendix'*. Available at: https://new.globalphysicalactivityobservatory.com/appendix/Appendix.pdf (Accessed: 2 March 2022).

Global Observatory for Physical Activity (2021) *'Country cards'*. Available at: https://new.globalphysicalactivityobservatory.com/countrycards/ (Accessed: 11 August 2021).

Grant, P.M. *et al.* (2006) 'The validation of a novel activity monitor in the measurement of posture and motion during everyday activities', *British Journal of Sports Medicine*, 40(12), pp. 992–997. Available at: https://doi.org/10.1136/bjsm.2006.030262.

Guthold, R. *et al.* (2018) 'Worldwide trends in insufficient physical activity from 2001 to 2016: A pooled analysis of 358 population-based surveys with 1·9 million participants', *The Lancet Global Health*, 6(10), pp. e1077–e1086. Available at: https://doi.org/10.1016/S2214-109X(18)30357-7.

GWI (2020) '"Research and methodology"', pp. 4–21.

GWI (2021a) *'About us'*. Available at: https://www.gwi.com/about-us (Accessed:

16 September 2021).

GWI (2021b) *'Home page'*. Available at: https://www.gwi.com/ (Accessed: 16 September 2021).

GWI (2021c) *'Our data'*. Available at: https://www.gwi.com/data (Accessed: 16 September 2021).

GWI (2021d) *'Our coverage'*. Available at: https://www.gwi.com/data-coverage (Accessed: 16 September 2021).

Hagströmer, M. *et al.* (2012) 'A checklist for evaluating the methodological quality of validation studies on self-report instruments for physical activity and sedentary behavior.', *Journal of Physical Activity & Health*, 9 Suppl 1(Suppl 1), pp. 29–36. Available at: https://doi.org/10.1123/jpah.9.s1.s29.

Hallgren, M. *et al.* (2018) 'Passive and mentally-active sedentary behaviors and incident major depressive disorder: A 13-year cohort study', *Journal of Affective Disorders*, 241, pp. 579–585. Available at: https://doi.org/10.1016/j.jad.2018.08.020.

Hallgren, M. *et al.* (2020) 'Cross-sectional and prospective relationships of passive and mentally active sedentary behaviours and physical activity with depression', *British Journal of Psychiatry*, 217(2), pp. 413–419. Available at: https://doi.org/10.1192/bjp.2019.60.

Hallgren, M., Dunstan, D.W. and Owen, N. (2020) 'Passive versus mentally active sedentary behaviors and depression', *Exercise and Sport Sciences Reviews*, 48(1), pp. 20–27. Available at: https://doi.org/10.1249/JES.0000000000000211.

Hamer, M. and Stamatakis, E. (2014) 'Prospective study of sedentary behavior, risk of depression, and cognitive impairment', *Medicine & Science in Sports & Exercise*, 46(4), pp. 718–723. Available at: https://doi.org/10.1249/MSS.0000000000000156.

Hardeman, W. *et al.* (2019) 'A systematic review of just-in-time adaptive interventions (JITAIs) to promote physical activity', *International Journal of Behavioral Nutrition and Physical Activity*, 16(31), pp. 1–21. Available at: https://doi.org/10.1186/s12966-019-0792-7.

Harvey, D.L. *et al.* (2022) 'International trends in screen-based behaviours from 2012 to 2019', *Preventive Medicine*, 154, pp. 1–9. Available at: https://doi.org/10.1016/j.ypmed.2021.106909.

Healy, G.N. *et al.* (2011) 'Measurement of adults' sedentary time in population-based studies', *American Journal of Preventive Medicine*, 41(2), pp. 216–227. Available at: https://doi.org/10.1016/j.amepre.2011.05.005.

Herman, K.M. and Saunders, T.J. (2016) 'Sedentary behaviours among adults across Canada', *Canadian Journal of Public Health*, 107(4–5), pp. e438–e446. Available at: https://doi.org/10.17269/CJPH.107.5587.

Heron, L. *et al.* (2019) 'Direct healthcare costs of sedentary behaviour in the UK', *Journal of Epidemiology and Community Health*, 73(7), pp. 625–629. Available at: https://doi.org/10.1136/jech-2018-211758.

Hill, A.B. (2015) 'The environment and disease: Association or causation?', *Journal of the Royal Society of Medicine*, 108(1), pp. 32–37. Available at: https://doi.org/10.1177/0141076814562718.

Hollman, H. *et al.* (2022) 'Perceptions of physical activity and sedentary behaviour guidelines among end-users and stakeholders: A systematic review', *International Journal of Behavioral Nutrition and Physical Activity*, 19(21), pp. 1–14. Available at: https://doi.org/10.1186/s12966-022-01245-9.

Hu, F.B. (2003) 'Television watching and other sedentary behaviors in relation to risk of obesity and type 2 diabetes mellitus in women', *JAMA*, 289(14), pp. 1785–1791. Available at: https://doi.org/10.1001/jama.289.14.1785.

Interactive Advertising Bureau Europe (2021) *'Policy positions and guidance documents'*. Available at: https://iabeurope.eu/policy-positions-guidance-documents/ (Accessed: 24 January 2021).

Interactive Advertising Bureau United Kingdom (2021) *'About us'*. Available at: https://www.iabuk.com/about-us (Accessed: 24 January 2021).

International Labour Organization (2023) *'ILO Modelled Estimates (ILOEST database)'*. Available at: https://ilostat.ilo.org/resources/concepts-and-definitions/ilo-modelled-estimates/ (Accessed: 16 March 2023).

International Telecommunication Union (2023) *'Statistics'*. Available at: https://www.itu.int/en/ITU-D/Statistics/Pages/stat/default.aspx (Accessed: 7 March 2023).

Jakes, R.W. *et al.* (2003) 'Television viewing and low participation in vigorous recreation are independently associated with obesity and markers of cardiovascular disease risk: EPIC-Norfolk population-based study', *European Journal of Clinical Nutrition*, 57(9), pp. 1089–1096. Available at: https://doi.org/10.1038/sj.ejcn.1601648.

Jelsma, J.G.M. *et al.* (2019) 'Time trends between 2002 and 2017 in correlates of self-reported sitting time in European adults', *PLoS ONE*, 14(11), pp. 1–15. Available at: https://doi.org/10.1371/journal.pone.0225228.

Katzmarzyk, P.T. and Mason, C. (2009) 'The physical activity transition', *Journal of Physical Activity and Health*, 6, pp. 269–280.

Kelly, P., Fitzsimons, C. and Baker, G. (2016) 'Should we reframe how we think about physical activity and sedentary behaviour measurement? Validity and reliability reconsidered', *International Journal of Behavioral Nutrition and Physical Activity*, 13(1), pp. 1–10. Available at: https://doi.org/10.1186/s12966-016-0351-4.

Kikuchi, H. *et al.* (2014) 'Distinct associations of different sedentary behaviors with health-related attributes among older adults', *Preventive Medicine*, 67, pp. 335–339. Available at: https://doi.org/10.1016/j.ypmed.2014.08.011.

King, G. and Persily, N. (2020) 'A new model for industry-academic partnerships', *PS - Political Science and Politics*, 53(4), pp. 703–709. Available at: https://doi.org/10.1017/S1049096519001021.

Koohsari, M.J. *et al.* (2020) 'Built environment correlates of objectively-measured sedentary behaviours in densely-populated areas', *Health & Place*, 66, pp. 1–7. Available at: https://doi.org/10.1016/j.healthplace.2020.102447.

Kowal, M. *et al.* (2021) 'Gaming your mental health: A narrative review on mitigating symptoms of depression and anxiety using commercial video games', *JMIR Serious Games*, 9(2), pp. 1–13. Available at: https://doi.org/10.2196/26575.

Kozey-Keadle, S. *et al.* (2011) 'Validation of wearable monitors for assessing

sedentary behavior', *Medicine & Science in Sports & Exercise*, 43(8), pp. 1561–1567. Available at: https://doi.org/10.1249/MSS.0b013e31820ce174.

Kurosawa, S. *et al.* (2020) 'Accelerometer-measured diurnal patterns of sedentary behavior among Japanese workers: A descriptive epidemiological study', *International Journal of Environmental Research and Public Health*, 17(11), pp. 1–13. Available at: https://doi.org/10.3390/ijerph17113814.

Lakerveld, J. *et al.* (2017) 'Sitting too much: A hierarchy of socio-demographic correlates', *Preventive Medicine*, 101, pp. 77–83. Available at: https://doi.org/10.1016/j.ypmed.2017.05.015.

LeBlanc, A. *et al.* (2017) 'The ubiquity of the screen: An overview of the risks and benefits of screen time in our modern world', *Translational Journal of the American College of Sports Medicine*, 2(17), pp. 104–113. Available at: https://doi.org/10.1249/TJX.0000000000000039.

Lepp, A. *et al.* (2013) 'The relationship between cell phone use, physical and sedentary activity, and cardiorespiratory fitness in a sample of U.S. college students', *International Journal of Behavioral Nutrition and Physical Activity*, 10(79), pp. 1–9. Available at: https://doi.org/10.1186/1479-5868-10-79.

Levin, K.A. (2006) 'Study design VI - Ecological studies', *Evidence-Based Dentistry*, 7(4), p. 108. Available at: https://doi.org/10.1038/sj.ebd.6400454.

López-Valenciano, A. *et al.* (2020) 'Changes in sedentary behaviour in European Union adults between 2002 and 2017', *BMC Public Health*, 20(1206), pp. 1–10. Available at: https://doi.org/10.1186/s12889-020-09293-1.

Loyen, A. *et al.* (2016) 'European sitting championship: Prevalence and correlates of self-reported sitting time in the 28 European Union member states', *PLOS ONE*, 11(3), pp. 1–17. Available at: https://doi.org/10.1371/journal.pone.0149320.

Loyen, A. *et al.* (2017) 'Sedentary time and physical activity surveillance through accelerometer pooling in four European countries', *Sports Medicine*, 47(7), pp. 1421–1435. Available at: https://doi.org/10.1007/s40279-016-0658-y.

Loyen, A. *et al.* (2019) 'Prevalence and correlates of domain-specific sedentary time of adults in the Netherlands: Findings from the 2006 Dutch time use survey',

BMC Public Health, 19(S2), pp. 1–12. Available at: https://doi.org/10.1186/s12889-019-6764-7.

Marconcin, P. *et al.* (2021) 'Sedentary behaviour – A contemporary view', in A. Marques and É.R. Gouveia (eds). London: IntechOpen, pp. 1–19. Available at: https://doi.org/10.5772/intechopen.99567.

Market Research Society (2021) *'MRS policy and standards review 2017/18'*. Available at: https://www.mrs.org.uk/standards/standards-review (Accessed: 24 January 2021).

Marquardt, D.W. (1970) 'Generalised inverses, ridge regression, biased linear estimation, and nonlinear estimation', *Technometrics*, 12(3), pp. 591–612.

Mclaughlin, M. *et al.* (2020) 'Worldwide surveillance of self-reported sitting time: A scoping review', *International Journal of Behavioral Nutrition and Physical Activity*, 17(111), pp. 1–12. Available at: https://doi.org/10.1186/s12966-020-01008-4.

McVeigh, J.A. *et al.* (2016) 'Objectively measured patterns of sedentary time and physical activity in young adults of the Raine study cohort', *International Journal of Behavioral Nutrition and Physical Activity*, 13(1), pp. 1–12. Available at: https://doi.org/10.1186/s12966-016-0363-0.

Memon, A.R. *et al.* (2021) 'Sedentary behaviour research in adults: A scoping review of systematic reviews and meta-analyses', *Journal of Sports Sciences*, 39(19), pp. 2219–2231. Available at: https://doi.org/10.1080/02640414.2021.1928382.

Mielke, G.I. *et al.* (2020) 'Reliability of a multi-domain sedentary behaviour questionnaire and comparability to an overall sitting time estimate', *Journal of Sports Sciences*, 38(3), pp. 351–356. Available at: https://doi.org/10.1080/02640414.2019.1701794.

Milton, K. *et al.* (2015) 'Trends in prolonged sitting time among European adults: 27 country analysis', *Preventive Medicine*, 77, pp. 11–16. Available at: https://doi.org/10.1016/j.ypmed.2015.04.016.

Milton, K. *et al.* (2018) 'A review of global surveillance on the muscle strengthening and balance elements of physical activity recommendations',

Journal of Frailty, Sarcopenia and Falls, 03(02), pp. 114–124. Available at: https://doi.org/10.22540/jfsf-03-114.

Moreno-Llamas, A., García-Mayor, J. and De la Cruz-Sánchez, E. (2020) 'The impact of digital technology development on sitting time across Europe', *Technology in Society*, 63, pp. 1–6. Available at: https://doi.org/10.1016/j.techsoc.2020.101406.

Morgenstern, H. (1995) 'Ecologic studies in epidemiology: Concepts, principles, and methods', *Annual Review of Public Health*, 16(1), pp. 61–81. Available at: https://doi.org/10.1146/annurev.pu.16.050195.000425.

Morris, J.N. *et al.* (1953) 'Coronary heart-disease and physical activity of work', *The Lancet*, 262(6795), pp. 1053–1057. Available at: https://doi.org/10.1016/S0140-6736(53)90665-5.

Morris, S. *et al.* (2016) *'The UK Time Diary Study 2014-2015 Technical Report'*. London.

Morton, S. *et al.* (2022) 'What works to reduce sedentary behavior in the office, and could these intervention components transfer to the home working environment?: A rapid review and transferability appraisal', *Frontiers in Sports and Active Living*, 4, pp. 1–24. Available at: https://doi.org/10.3389/fspor.2022.954639.

Müller, A.M., Blandford, A. and Yardley, L. (2017) 'The conceptualization of a Just-In-Time Adaptive Intervention (JITAI) for the reduction of sedentary behavior in older adults', *mHealth*, 3(2), pp. 1–12. Available at: https://doi.org/10.21037/mhealth.2017.08.05.

Nielsen (2018) *'Time flies: U.S. adults now spend nearly half a day interacting with media'*. Available at: https://www.nielsen.com/insights/2018/time-flies-us-adults-now-spend-nearly-half-a-day-interacting-with-media/ (Accessed: 20 February 2021).

Nielsen (2020) *'About us'*. Available at: https://www.nielsen.com/about-us/ (Accessed: 25 June 2020).

Nielsen (2023) *'Nielsen ONE'*. Available at: https://www.nielsen.com/solutions/audience-measurement/nielsen-one/

(Accessed: 28 June 2023).

O'Donoghue, G. *et al.* (2016) 'A systematic review of correlates of sedentary behaviour in adults aged 18–65 years: A socio-ecological approach', *BMC Public Health*, 16(163), pp. 1–25. Available at: https://doi.org/10.1186/s12889-016-2841-3.

O'keeffe, N., Scheid, J.L. and West, S.L. (2020) 'Sedentary behavior and the use of wearable technology: An editorial', *International Journal of Environmental Research and Public Health*, 17(12), pp. 1–6. Available at: https://doi.org/10.3390/ijerph17124181.

Ofcom (2018) *'Adults' media use and attitudes report'*. Available at: https://www.ofcom.org.uk/__data/assets/pdf_file/0011/113222/Adults-Media-Use-and-Attitudes-Report-2018.pdf (Accessed: 20 February 2021).

Ofcom (2020) *'Research and data'*. Available at: https://www.ofcom.org.uk/research-and-data (Accessed: 25 June 2020).

Organisation for Economic Co-Operation and Development (2021a) *'State of health in the EU Norway, Country health profile 2021'*. Brussels. Available at: https://health.ec.europa.eu/system/files/2021-12/2021_chp_no_english.pdf.

Organisation for Economic Co-Operation and Development (2021b) *State of health in the EU Portugal, Country health profile 2021*. Brussels. Available at: https://health.ec.europa.eu/system/files/2021-12/2021_chp_pt_english.pdf.

Owen, N. *et al.* (2011) 'Adults' sedentary behavior: Determinants and interventions', *American Journal of Preventive Medicine*, 41(2), pp. 189–196. Available at: https://doi.org/10.1016/j.amepre.2011.05.013.

Owen, N. *et al.* (2020) 'Sedentary behavior and public health: Integrating the evidence and identifying potential solutions', *Annual Review of Public Health*, 41, pp. 265–287. Available at: https://doi.org/10.1146/annurev-publhealth-040119-094201.

Page, M.J. *et al.* (2021) 'The PRISMA 2020 statement: an updated guideline for reporting systematic reviews', *BMJ*, 372(n71), pp. 1–9. Available at: https://doi.org/10.1136/bmj.n71.

Patterson, R. *et al.* (2018) ‘Sedentary behaviour and risk of all-cause, cardiovascular and cancer mortality, and incident type 2 diabetes: A systematic review and dose response meta-analysis’, *European Journal of Epidemiology*, 33(9), pp. 811–829. Available at: https://doi.org/10.1007/s10654-018-0380-1.

Peachey, M.M. *et al.* (2020) ‘Environmental, behavioural and multicomponent interventions to reduce adults’ sitting time: A systematic review and meta-analysis’, *British Journal of Sports Medicine*, 54(6), pp. 315–325. Available at: https://doi.org/10.1136/bjsports-2017-098968.

Perez, O. *et al.* (2023) ‘Validated assessment tools for screen media use: A systematic review’, *PLoS ONE*, 18(4), pp. 1–21. Available at: https://doi.org/10.1371/journal.pone.0283714.

Pfister, T. *et al.* (2017) ‘Comparison of two accelerometers for measuring physical activity and sedentary behaviour’, *BMJ Open Sport & Exercise Medicine*, 3(e000227), pp. 1–8. Available at: https://doi.org/10.1136/bmjsem-2017-000227.

Prince, S. A. *et al.* (2017) ‘Correlates of sedentary behaviour in adults: A systematic review’, *Obesity Reviews*, 18(8), pp. 915–935. Available at: https://doi.org/10.1111/obr.12529.

Prince, S.A. *et al.* (2017b) ‘Measurement of sedentary behaviour in population health surveys: a review and recommendations’, *PeerJ*, 5(e4130), pp. 1–22. Available at: https://doi.org/10.7717/peerj.4130.

Prince, S.A. *et al.* (2018) ‘Single versus multi-item self-assessment of sedentary behaviour: A comparison with objectively measured sedentary time in nurses’, *Journal of Science and Medicine in Sport*, 21(9), pp. 925–929. Available at: https://doi.org/10.1016/j.jsams.2018.01.018.

Prince, S.A. *et al.* (2019) ‘Developing content for national population health surveys: An example using a newly developed sedentary behaviour module’, *Archives of Public Health*, 77(53), pp. 1–7. Available at: https://doi.org/10.1186/s13690-019-0380-y.

Prince, S.A. *et al.* (2020a) ‘A comparison of self-reported and device measured sedentary behaviour in adults: A systematic review and meta-analysis’,

International Journal of Behavioral Nutrition and Physical Activity, 17(31), pp. 1–17. Available at: https://doi.org/10.1186/s12966-020-00938-3.

Prince, S.A. *et al.* (2020b) 'Sedentary behaviour surveillance in Canada: Trends, challenges and lessons learned', *International Journal of Behavioral Nutrition and Physical Activity*, 17(34), pp. 1–21. Available at: https://doi.org/10.1186/s12966-020-00925-8.

Prince, S.A. *et al.* (2020c) 'Gender and education differences in sedentary behaviour in Canada: an analysis of national cross-sectional surveys', *BMC Public Health*, 20(1170), pp. 1–17. Available at: https://doi.org/10.1186/s12889-020-09234-y.

Pulsford, R.M. *et al.* (2023) 'The impact of selected methodological factors on data collection outcomes in observational studies of device-measured physical behaviour in adults: A systematic review', *International Journal of Behavioral Nutrition and Physical Activity*, 20(26), pp. 1–14. Available at: https://doi.org/10.1186/s12966-022-01388-9.

Qi, M. *et al.* (2023) 'Development and validity of a mentally-passive and mentally-active sedentary time questionnaire in nursing college students', *Frontiers in Public Health*, 11(September), pp. 1–8. Available at: https://doi.org/10.3389/fpubh.2023.1180853.

Ramirez Varela, A. *et al.* (2018) 'Worldwide use of the first set of physical activity Country Cards: The Global Observatory for Physical Activity - GoPA!', *International Journal of Behavioral Nutrition and Physical Activity*, 15(29), pp. 1–14. Available at: https://doi.org/10.1186/s12966-018-0663-7.

Reeves, B. *et al.* (2021) 'Screenomics : A framework to capture and analyze personal life experiences and the ways that technology shapes them', *Human–Computer Interaction*, 36(2), pp. 150–201. Available at: https://doi.org/10.1080/07370024.2019.1578652.

Reeves, B., Robinson, T. and Ram, N. (2020) 'Time for the Human Screenome Project', *Nature*, 577(7790), pp. 314–317. Available at: https://doi.org/10.1038/d41586-020-00032-5.

Rezende, L.F.M. *et al.* (2014) ‘Sedentary behavior and health outcomes: An overview of systematic reviews’, *PLoS ONE*, 9(8), pp. 1–7. Available at: https://doi.org/10.1371/journal.pone.0105620.

Rezende, L.F.M. *et al.* (2016) ‘All-cause mortality attributable to sitting time’, *American Journal of Preventive Medicine*, 51(2), pp. 253–263. Available at: https://doi.org/10.1016/j.amepre.2016.01.022.

Rhodes, R.E., Mark, R.S. and Temmel, C.P. (2012) ‘Adult sedentary behavior: A systematic review’, *American Journal of Preventive Medicine*, 42(3), pp. e3–e28. Available at: https://doi.org/10.1016/j.amepre.2011.10.020.

Ringin, E. *et al.* (2023) ‘Differential associations of mentally-active and passive sedentary behaviours and physical activity with putative cognitive decline in healthy individuals and those with bipolar disorder: Findings from the UK Biobank cohort’, *Mental Health and Physical Activity*, 24, pp. 1–9. Available at: https://doi.org/10.1016/j.mhpa.2023.100514.

Rivière, F. *et al.* (2018) ‘Taxonomy-based content analysis of sedentary behavior questionnaires: A systematic review’, *PLOS ONE*, 13(3), pp. 1–25. Available at: https://doi.org/10.1371/journal.pone.0193812.

Rosenberg, D.E. *et al.* (2010) ‘Reliability and validity of the sedentary behavior questionnaire (SBQ) for adults’, *Journal of Physical Activity and Health*, 7(6), pp. 697–705. Available at: https://doi.org/10.1123/jpah.7.6.697.

Ross, R. *et al.* (2020) ‘Canadian 24-hour movement guidelines for adults aged 18–64 years and adults aged 65 years or older: An integration of physical activity, sedentary behaviour, and sleep’, *Applied Physiology, Nutrition, and Metabolism*, 45(10 (Suppl. 2)), pp. S57–S102. Available at: https://doi.org/10.1139/apnm-2020-0467.

Sallis, J.F., Owen, N. and Fisher, E.B. (2008) ‘Ecological models of health behavior’, in K. Glanz, B.K. Rimer, and K. Viswanath (eds) *Health Behavior and Health Education*. 4th edn. San Francisco: Jossey-Bass, pp. 465–485.

Sallis, J.F., Owen, N. and Fotheringham, M.J. (2000) ‘Behavioral epidemiology: A systematic framework to classify phases of research on health promotion and

disease prevention', *Annals of Behavioral Medicine*, 22(4), pp. 294–298. Available at: https://doi.org/10.1007/BF02895665.

Salmon, J. *et al.* (2000) 'The association between television viewing and overweight among Australian adults participating in varying levels of leisure-time physical activity', *International Journal of Obesity*, 24(5), pp. 600–606. Available at: https://doi.org/10.1038/sj.ijo.0801203.

Saunders, T.J. *et al.* (2020) 'Sedentary behaviour and health in adults: An overview of systematic reviews', *Applied Physiology, Nutrition, and Metabolism*, 45(10 (Suppl. 2)), pp. S197–S217. Available at: https://doi.org/10.1139/apnm-2020-0272.

Scholes, A. (2017) *'Health Survey for England 2016 physical activity in adults'*. Available at: http://healthsurvey.hscic.gov.uk/media/63730/HSE16-Adult-phy-act.pdf (Accessed: 8 April 2023).

Scholes, S. *et al.* (2016) 'Comparison of the physical activity and sedentary behaviour assessment questionnaire and the short-form international physical activity questionnaire: An analysis of health survey for England data', *PLoS ONE*, 11(3), pp. 1–31. Available at: https://doi.org/10.1371/journal.pone.0151647.

Silver, L. (2019) *'Digital connectivity growing rapidly in emerging economies'*. Available at: https://www.pewresearch.org/global/2019/02/05/digital-connectivity-growing-rapidly-in-emerging-economies/ (Accessed: 19 February 2019).

Sivanesan, H. *et al.* (2020) 'The association between screen time and cardiometabolic risk in young children', *International Journal of Behavioral Nutrition and Physical Activity*, 17(41), pp. 1–10. Available at: https://doi.org/10.1186/s12966-020-00943-6.

Stamatakis, E. *et al.* (2019) 'Is the time right for quantitative public health guidelines on sitting? A narrative review of sedentary behaviour research paradigms and findings', *British Journal of Sports Medicine*, 53(6), pp. 377–382. Available at: https://doi.org/10.1136/bjsports-2018-099131.

Stamatakis, E. and Bull, F.C. (2020) 'Putting physical activity in the "must-do" list of the global agenda', *British Journal of Sports Medicine*, 54(24), pp. 1445–1446.

Available at: https://doi.org/10.1136/bjsports-2020-103509.

Stamatakis, E., Hamer, M. and Dunstan, D.W. (2011) 'Screen-based entertainment time, all-cause mortality, and cardiovascular events: Population-based study with ongoing mortality and hospital events follow-up', *Journal of the American College of Cardiology*, 57(3), pp. 292–299. Available at: https://doi.org/10.1016/j.jacc.2010.05.065.

StataCorp (2019) '"Stata statistical software: Release 16"'. College Station, Texas: StataCorp.

Statista (2021) *'Number of smartphone users from 2016 to 2021'*. Available at: https://www.statista.com/statistics/330695/number-of-smartphone-users-worldwide/ (Accessed: 31 August 2021).

Statista (2023) *'Share of individuals using the internet 2022, by country income level'*. Available at: https://www.statista.com/statistics/1361735/internet-penetration-rate-by-country-income-level/ (Accessed: 10 February 2024).

Stephenson, A. *et al.* (2017) 'Using computer, mobile and wearable technology enhanced interventions to reduce sedentary behaviour: A systematic review and meta-analysis', *International Journal of Behavioral Nutrition and Physical Activity*, 14(1), pp. 1–17. Available at: https://doi.org/10.1186/s12966-017-0561-4.

Stockwell, S. *et al.* (2021) 'Changes in physical activity and sedentary behaviours from before to during the COVID-19 pandemic lockdown: A systematic review', *BMJ Open Sport and Exercise Medicine*, 7(1), pp. 1–8. Available at: https://doi.org/10.1136/bmjsem-2020-000960.

Strain, T. *et al.* (2020) 'How are we measuring physical activity and sedentary behaviour in the four home nations of the UK? A narrative review of current surveillance measures and future directions', *British Journal of Sports Medicine*, 54(21), pp. 1269–1276. Available at: https://doi.org/10.1136/bjsports-2018-100355.

Sugiyama, T. *et al.* (2008) 'Is television viewing time a marker of a broader pattern of sedentary behavior?', *Annals of Behavioral Medicine*, 35(2), pp. 245–250. Available at: https://doi.org/10.1007/s12160-008-9017-z.

Sullivan, O. *et al.* (2020) 'Time use diary design for our times - An overview, presenting a Click-and-Drag Diary Instrument (CaDDI) for online application', *Journal of Time Use Research*, 15(1), pp. 1–17. Available at: https://doi.org/10.32797/jtur-2020-1.

Sullivan, O. *et al.* (2021) 'Using time-use diaries to track changing behavior across successive stages of COVID-19 social restrictions', *Proceedings of the National Academy of Sciences of the United States of America*, 118(35), pp. 1–7. Available at: https://doi.org/10.1073/pnas.2101724118.

Sullivan, O. and Gershuny, J. (2022) *United Kingdom Time Use Survey 2014-2015*. UK Data Service. Available at: https://doi.org/http://doi.org/10.5255/UKDA-SN-8128-1.

Thacker, S.B. and Berkelman, R.L. (1988) 'Public health surveillance in the United States', *Epidemiologic Reviews*, 10(1), pp. 164–190. Available at: https://doi.org/10.1093/oxfordjournals.epirev.a036021.

The Canadian Society for Exercise Physiology (2021) *'24 Hour Movement Guidelines'*. Available at: https://csepguidelines.ca/guidelines/adults-18-64/ (Accessed: 5 September 2022).

The World Bank (2021) *'World Bank country and lending groups'*. Available at: https://datahelpdesk.worldbank.org/knowledgebase/articles/906519 (Accessed: 19 February 2021).

The World Bank (2022a) *'Life expectancy at birth, total (years) - Norway, Portugal'*. Available at: https://data.worldbank.org/indicator/SP.DYN.LE00.IN?locations=NO-PT (Accessed: 11 February 2024).

The World Bank (2022b) *'Metadata glossary employment in services'*. Available at: https://databank.worldbank.org/metadataglossary/world-development-indicators/series/SL.SRV.EMPL.ZS (Accessed: 26 September 2022).

The World Bank (2022c) *'Metadata glossary GDP per capita'*. Available at: https://databank.worldbank.org/metadataglossary/world-development-indicators/series/NY.GDP.PCAP.CD (Accessed: 26 September 2022).

The World Bank (2022d) *'Metadata glossary individuals using the internet'*. Available at: https://databank.worldbank.org/metadataglossary/world-development-indicators/series/IT.NET.USER.ZS (Accessed: 26 September 2022).

The World Bank (2022e) *'Metadata glossary population density'*. Available at: https://databank.worldbank.org/metadataglossary/world-development-indicators/series/EN.POP.DNST#:~:text=Population density is midyear population divided by land,by World Bank staff from variety of sources (Accessed: 26 September 2022).

Thiese, M.S. (2014) 'Observational and interventional study design types; an overview', *Biochemia Medica*, 24(2), pp. 199–210. Available at: https://doi.org/10.11613/BM.2014.022.

Thomas, G.J. and Bond, D.S. (2015) 'Behavioral response to a just-in-time adaptive intervention (JITAI) to reduce sedentary behavior in obese adults: Implications for JITAI optimization', *Health Psychology*, 34, pp. 1261–1267. Available at: https://doi.org/10.1037/hea0000304.

Tremblay, M. (2012) 'Letter to the editor: Standardized use of the terms "sedentary" and "sedentary behaviours"', *Applied Physiology, Nutrition and Metabolism*, 37(3), pp. 540–542. Available at: https://doi.org/10.1139/H2012-024.

Tremblay, M.S. *et al.* (2017) 'Sedentary Behavior Research Network (SBRN) – Terminology consensus project process and outcome', *International Journal of Behavioral Nutrition and Physical Activity*, 14(1), pp. 1–17. Available at: https://doi.org/10.1186/s12966-017-0525-8.

Troiano, R.P. *et al.* (2014) 'Evolution of accelerometer methods for physical activity research', *British Journal of Sports Medicine*, 48(13), pp. 1019–1023. Available at: https://doi.org/10.1136/bjsports-2014-093546.

Troiano, R.P., Stamatakis, E. and Bull, F.C. (2020) 'How can global physical activity surveillance adapt to evolving physical activity guidelines? Needs, challenges and future directions', *British Journal of Sports Medicine*, 54(24), pp. 1468–1473. Available at: https://doi.org/10.1136/bjsports-2020-102621.

TV Licensing (2022) *'Report reveals latest UK TV watching trends'*. Available at:

https://www.tvlicensing.co.uk/about/media-centre/news/report-reveals-latest-uk-tv-watching-trends-NEWS35 (Accessed: 11 November 2022).

United Kingdom Government (2017) *'Gross domestic product: What it means and why it matters'*. Available at: https://www.gov.uk/government/news/gross-domestic-product-gdp-what-it-means-and-why-it-matters (Accessed: 28 October 2022).

United Kingdom Government Department of Health and Social Care (2019) *'Physical activity for adults and older adults'*. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1054541/physical-activity-for-adults-and-older-adults.pdf (Accessed: 8 April 2023).

United Nations Development Programme (2022a) *'Human development index'*. Available at: https://hdr.undp.org/data-center/human-development-index#/indicies/HDI (Accessed: 26 September 2023).

United Nations Development Programme (2022b) *'Data downloads'*. Available at: https://hdr.undp.org/data-center/documentation-and-downloads (Accessed: 26 September 2022).

United Nations Statistical Division (2021) *'United Nations digital library'*. Available at: https://digitallibrary.un.org/record/3937980 (Accessed: 28 June 2023).

University of Oxford (2016) *'United Kingdom Time Use Survey 2014-2015'*. Oxford.

Ussery, E.N. *et al.* (2018) 'Joint prevalence of sitting time and leisure-time physical activity among US adults, 2015-2016', *JAMA*, 320(19), pp. 2036–2038. Available at: https://doi.org/10.1001/jama.2018.17797.

Väisänen, D. *et al.* (2020) 'Lifestyle-associated health risk indicators across a wide range of occupational groups: a cross-sectional analysis in 72,855 workers', *BMC Public Health*, 20(1), pp. 1–13. Available at: https://doi.org/10.1186/s12889-020-09755-6.

Van Cauwenberg, J. *et al.* (2018) 'Differential influences of population densification and economic growth on Europeans' physical activity and sitting

time', *Cities*, 82, pp. 141–149. Available at: https://doi.org/10.1016/j.cities.2018.07.006.

Van Cauwenberge, A., Schaap, G. and van Roy, R. (2014) '"TV no longer commands our full attention": Effects of second-screen viewing and task relevance on cognitive load and learning from news', *Computers in Human Behavior*, 38, pp. 100–109. Available at: https://doi.org/10.1016/j.chb.2014.05.021.

Van Der Ploeg, H.P. *et al.* (2013) 'Non-occupational sedentary behaviors population changes in the Netherlands, 1975-2005', *American Journal of Preventive Medicine*, 44(4), pp. 382–387. Available at: https://doi.org/10.1016/j.amepre.2012.11.034.

Varela, A.R. *et al.* (2017) 'Worldwide surveillance, policy, and research on physical activity and health: The Global Observatory for Physical Activity', *Journal of Physical Activity and Health*, 14(9), pp. 701–709. Available at: https://doi.org/10.1123/jpah.2016-0626.

Varela, A.R. *et al.* (2018) 'Mapping the historical development of physical activity and health research: A structured literature review and citation network analysis', *Preventive Medicine*, 111, pp. 466–472. Available at: https://doi.org/10.1016/j.ypmed.2017.10.020.

Visser, M. and Koster, A. (2013) 'Development of a questionnaire to assess sedentary time in older persons – A comparative study using accelerometry', *BMC Geriatrics*, 13(80), pp. 1–8. Available at: https://doi.org/10.1186/1471-2318-13-80.

Vizcaino, M. *et al.* (2019) 'Reliability of a new measure to assess modern screen time in adults', *BMC Public Health*, 19(1386), pp. 1–9. Available at: https://doi.org/10.1186/s12889-019-7745-6.

Vizcaino, M. *et al.* (2020) 'From TVs to tablets: the relation between device-specific screen time and health-related behaviors and characteristics', *BMC Public Health*, 20(1295), pp. 1–10. Available at: https://doi.org/10.1186/s12889-020-09410-0.

Wang, X., Li, Y. and Fan, H. (2019) 'The associations between screen time-based

sedentary behavior and depression: A systematic review and meta-analysis', *BMC Public Health*, 19(1524), pp. 1–10. Available at: https://doi.org/10.1186/s12889-019-7904-9.

Werneck, A.O. *et al.* (2020) 'Macroeconomic, demographic and human developmental correlates of physical activity and sitting time among South American adults', *International Journal of Behavioral Nutrition and Physical Activity*, 17(163), pp. 1–13. Available at: https://doi.org/10.1186/s12966-020-01068-6.

Wijndaele, K. *et al.* (2015) 'Utilization and harmonization of adult accelerometry data: Review and expert consensus', *Medicine and Science in Sports and Exercise*, 47(10), pp. 2129–2139. Available at: https://doi.org/10.1249/MSS.0000000000000661.

Winkler, E.A.H. *et al.* (2016) 'Identifying adults' valid waking wear time by automated estimation in activPAL data collected with a 24 h wear protocol', *Physiological Measurement*, 37(10), pp. 1653–1668. Available at: https://doi.org/10.1088/0967-3334/37/10/1653.

Woessner, M.N. *et al.* (2021) 'The evolution of technology and physical inactivity: The good, the bad, and the way forward', *Frontiers in Public Health*, 9(May), pp. 1–7. Available at: https://doi.org/10.3389/fpubh.2021.655491.

World Health Organization (2003) 'A framework for surveillance The WHO STEPwise approach to Surveillance of noncommunicable diseases (STEPS)', pp. 1–42. Available at: http://www.who.int/ncd_surveillance%0A©.

World Health Organization (2010) *'Global recommendations on physical activity for health'*. Available at: https://www.who.int/publications/i/item/9789241599979 (Accessed: 8 April 2023).

World Health Organization (2017) *'World Health Organization STEPS surveillance manual'*. Available at: https://cdn.who.int/media/docs/default-source/ncds/ncd-surveillance/steps/steps-manual.pdf?sfvrsn=c281673d_8 (Accessed: 10 February 2024).

World Health Organization (2020a) 'WHO Guidelines on Physical Activity and

Sedentary Behaviour'. Geneva: World Health Organization, p. 3. Available at: https://www.who.int/publications/i/item/9789240015128.

World Health Organization (2020b) *STEPS: A framework for surveillance*. Available at: https://cdn.who.int/media/docs/default-source/ncds/ncd-surveillance/steps/steps-manual_f0075411-1e6d-46ef-85be-fe826d2b9c47.pdf?sfvrsn=c281673d_5 (Accessed: 25 March 2022).

World Health Organization (2022) *'Physical activity'*. Available at: https://www.who.int/news-room/fact-sheets/detail/physical-activity (Accessed: 23 July 2023).

World Population Review (2022) *'Human development index'*. Available at: https://worldpopulationreview.com/country-rankings/hdi-by-country (Accessed: 26 September 2022).

Yang, H. *et al.* (2023) 'Impact of economic growth on physical activity and sedentary behaviors: A systematic review', *Public Health*, 215, pp. 17–26. Available at: https://doi.org/10.1016/j.puhe.2022.11.020.

Yang, L. *et al.* (2019) 'Trends in sedentary behavior among the US population, 2001-2016', *JAMA - Journal of the American Medical Association*, 321(16), pp. 1587–1597. Available at: https://doi.org/10.1001/jama.2019.3636.

Yee, A.Z.H. *et al.* (2023) 'ScreenLife Capture: An open-source and user-friendly framework for collecting screenomes from Android smartphones', *Behavior Research Methods*, 55(8), pp. 4068–4085. Available at: https://doi.org/10.3758/s13428-022-02006-z.

Yerrakalva, D. *et al.* (2017) 'The descriptive epidemiology of the diurnal profile of bouts and breaks in sedentary time in older English adults', *International Journal of Epidemiology*, 46(6), pp. 1871–1881. Available at: https://doi.org/10.1093/ije/dyx123.

YouGov (2020) *'What are common reading habits?'* Available at: https://yougov.co.uk/topics/entertainment/articles-reports/2020/03/05/world-book-day-britons-reading-habits (Accessed: 11 November 2022).

Zabor, E.C., Kaizer, A.M. and Hobbs, B.P. (2020) 'Randomized controlled trials',

Chest, 158(1), pp. S79–S87. Available at: https://doi.org/10.1016/j.chest.2020.03.013.