National Institute for Public Health
and the Environment
Ministry of Health, Welfare and Sport

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A literature study into the health effects of different time settings

RIVM Report 2019-0173

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This study was commissioned by the Ministry of Health, Welfare and Sport in the context of the European Commission's proposal to abolish the current system of switching between standard time and summer time and to repeal Directive 2000/84/EC (Kennisvraag 2019 ADD.WVZ.06).

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Synopsis

Standard time, summer time and health
A literature study into the health effects of different time settings

The European Commission has proposed in 2018 that all Member States coordinate their clocks to a fixed time setting for the whole year, thus ending the practice of switching between standard time (winter time) and summer time. RIVM has conducted an international literature study into the health effects of the two time settings, including the effects of switching between them. If the Netherlands were to adhere to standard time all year round, this would appear to be beneficial for public health.

In the Netherlands, we currently put our clocks forward or backward twice a year to switch between standard time and summer time. Immediately after this switch, people's sleep is adversely affected; particularly after the clocks are put forwards to summer time, people tend to sleep less. There are also health effects after the switch. For instance, there is an increase in heart attacks following the switch to summer time. These direct effects would no longer occur if a fixed time were used throughout the entire year.

Sunlight, in particular, affects human biorhythms – among others what time we tend to wake up in the morning or feel tired and ready to sleep in the evening. It would therefore be better for public health to stick to one time setting that is aligned with the natural rhythm of day and night. That means a setting whereby the sun rises early, which is the case with standard time. If we were to adopt summer time all year round, on the other hand, it would be less favourable to our health than using standard time all year round. This has become evident from research into sleep and health aspects, such as the duration and quality of our sleep, being overweight, the number of people developing cancer and life expectancy in general.

For public health, it would be even better for the Netherlands to adopt Greenwich Mean Time all year round, which is 1 hour earlier than our current standard time. The current standard time for the Netherlands has been legally in place since the Second World War, although geographically we are located in the prime meridian time zone (GMT).

The literature review was commissioned by the Dutch Ministry of Health, Welfare and Sport. The studies on which these conclusions are based relate to other countries than the Netherlands.

Keywords: summer time, winter time, standard time, health, sleep

Publiekssamenvatting

Standaardtijd, zomertijd en gezondheid
Literatuuronderzoek naar gezondheidseffecten van verschillende tijdinstellingen

De Europese Commissie heeft in 2018 voorgesteld dat alle lidstaten een vaste tijdinstelling kiezen voor het hele jaar, en dus niet meer wisselen tussen standaardtijd (wintertijd) en zomertijd. Het RIVM heeft een internationaal literatuuronderzoek uitgevoerd naar de effecten op de gezondheid van deze twee tijdinstellingen, inclusief de effecten van de wisselingen. Het blijkt beter te zijn voor de volksgezondheid wanneer Nederland het hele jaar door de standaardtijd zou aanhouden.

In Nederland wisselen we nu twee keer per jaar tussen de standaardtijd en zomertijd. Direct na de wisselingen slapen mensen slechter; vooral direct na de wisseling naar de zomertijd slapen mensen korter. Ook zijn er gezondheidseffecten te zien na de wisselingen. Zo komen er meer hartinfarcten voor direct na de wisseling naar de zomertijd. Zulke directe effecten treden niet meer op bij een vaste tijdinstelling voor het hele jaar.

Vooral zonlicht heeft invloed op het bioritme van de mens – het moment waarop we ’s ochtends wakker worden en ’s avonds slaperig. Het is voor de volksgezondheid dan ook het beste om een tijd in te stellen die aansluit op het natuurlijke dag- en nachtritme op aarde. Dat betekent een instelling waarbij de zon vroeg opkomt, wat het geval is bij de standaardtijd. Wanneer we het hele jaar door zomertijd instellen, is dat voor de gezondheid minder gunstig dan het hele jaar door standaardtijd. Dit blijkt uit studies naar slaap- en gezondheidsaspecten, zoals slaapduur en -kwaliteit, overgewicht, het aantal mensen met kanker, en de levensverwachting in het algemeen.

Voor de volksgezondheid zou het zelfs nog beter zijn als Nederland de tijd rond de nulmeridiaan in Greenwich (Engeland) het hele jaar door instelt; dat is 1 uur vroeger dan onze standaardtijd. De huidige standaardtijd voor Nederland is sinds de Tweede Wereldoorlog wettelijk ingesteld, hoewel het geografisch gezien in de zone van de nulmeridiaan ligt.

Dit literatuuronderzoek is in opdracht van het ministerie van VWS uitgevoerd. De studies waarop deze conclusies zijn gebaseerd, gaan over andere landen dan Nederland.

Kernwoorden: zomertijd, wintertijd, standaardtijd, gezondheid, slaap

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Summary

Goals
In 2018, the European Commission proposed the abolition of the current time setting for switching between standard time (= winter time) and summer time in its Member States, and allowing each Member State to choose its own permanent time. A time setting affects many aspects of our society, including health. For this reason, the Ministry of Health, Welfare and Sport, in collaboration with the Ministry of the Interior and Kingdom Relations, asked RIVM to conduct a scientific literature study into the effects of different time settings on public health.

RIVM was asked to provide a summary and explanation of the evidence in the scientific literature in relation to three research questions:

1. What would the positive and negative health effects of the following three options be: (1) maintaining the current time setting, (2) permanent summer time and (3) permanent (present) standard time?
2. What would the positive and negative health effects be if the Netherlands were to adopt a different time setting to its neighbouring countries Germany and Belgium?
3. Which health effects would be more significant: the effects of the three proposed options in question 1, or the effects arising from adopting a different time setting to neighbouring countries?

Background
The earth can be divided into 24 equal parts parallel to its axis of rotation, in which the sun reaches its highest point in the sky in the central longitude at noon: the geographical time zones. According to a global agreement, these time zones are classified by taking the prime meridian, the longitude that runs through Greenwich (UK), as a reference point. Since the end of the 20th century, the geographical time zone around the prime meridian has been referred to as 'Universal Time Coordinated - UTC'. Geographical time zones east of the prime meridian are indicated with a positive number (for example UTC+1) and western time zones with a negative number. For geopolitical and historical reasons, the standard time setting of a country or region does not always match the geographical time zone in which it is located. For example, the Netherlands lies within the geographical time zone of the prime meridian, but it has used Central European Time (UTC+1) as its statutory standard time since the Second World War. At the start of summer time, we move the clocks forward to UTC+2 in the spring, and put the clocks back by one hour in the autumn.

Methods
In order to answer the research questions, scientific literature published in last 30 years (between 1989 and the end of April 2019) was searched systematically for findings on the health effects of different time settings. Outcome measures included in the study are aspects involving sleep and health. Effects on road safety are not part of this study. In order to answer the second research question, a specific search was performed for publications relating to the health effects of people who

commute between time zones; i.e. people who frequently cross a time zone boundary to travel to work, for example. In addition to this search of three scientific literature databases, five chronobiologists were approached and asked to provide relevant scientific literature. All the references found were assessed for their relevance to the research questions asked. A total of 54 scientific publications were included. These studies relate to other countries than the Netherlands.

Results
The literature shows that the existing time setting, which switches between standard time and summer time twice a year, is associated with disturbances in sleep immediately after the switches. However, it is unclear how long these effects last. And although adequate good-quality sleep is important for health, it is not known how significant the health effects of these disruptions are. Immediately after the switch between standard time and summer time, some acute health effects have also been found. The most obvious effect is the increase in the incidence of heart attacks after the switch to summer time. It is not known whether there are cumulative health effects over the years due to the repeated switches between standard time and summer time.

Several studies focused on the differences in health effects between eastern and western regions within a single time zone. The results of these studies are relevant to this study, because a westerly location within a time zone approximates summer time setting. These involve various measures of sleep and health, such as sleep duration and sleep quality, obesity, cancer incidence and cancer mortality, life expectancy and depression. The results of these articles show a consistent picture: in terms of adverse health effects, people living in an easterly location within a time zone (where the sun rises earlier) are less affected than those living in a westerly location. One study, in which different time settings were introduced sequentially, also shows that permanent summer time leads to more adverse health outcomes than permanent standard time. Public health therefore seems to benefit most from a relatively early sunrise within a given time zone.

In the border regions of the Netherlands, around 10,000 Dutch people commute to Belgium for work and around 11,000 Dutch people commute to the German federal states of Lower Saxony and North Rhine-Westphalia (2014 estimate). If the border with Germany and/or Belgium were to become a time zone border in the future, these people would become time zone commuters and have to arrange their lives on the basis of a different time setting to the country where they live. The current literature search did not yield any relevant literature in relation to the possible health effects of such a situation.

Conclusion
The current time setting of switching twice a year between standard time (UTC+1) and summer time (UTC+2) is associated with acute sleep disturbances and health effects, of which the increase in heart attacks is the most obvious when the clocks are put forward in the spring. The acute effects identified would disappear if a permanent time setting were chosen. In relation to such a decision, permanent standard time (UTC+1) would, from a health perspective, clearly be preferable to

permanent summer time (UTC+2) and it would even be worth to consider adopting Greenwich Mean Time (UTC+0) in the Netherlands.

1 Introduction

1.1 Background

In 2018, the European Commission proposed the abolition of the current time setting of switching between standard time[1] and summer time in its Member States, and allowing each Member State to choose its own permanent time[2]. Directive 2000/84/EC[3] would therefore be repealed. Member States would then choose a permanent time to be used throughout the year. The proposal would affect several sections of our society. The Dutch government has therefore begun a multidisciplinary study to gain a better insight into the potential effects[4,5,6]. The Ministry of Health, Welfare and Sport, in collaboration with the Ministry of the Interior and Kingdom Relations, asked RIVM to conduct a scientific literature study into the effects of three different time settings on public health.

1.2 Research question

RIVM was asked to provide a summary and explanation of the evidence in the scientific literature in relation to three research questions:

1. What would the positive and negative health effects of the following three options be: (1) maintaining the current time setting, (2) permanent summer time and (3) permanent (present) standard time?
2. What would the positive and negative health effects be if the Netherlands were to adopt a different setting to its neighbouring countries Germany and Belgium?
3. Which health effects would be more significant: the effects of the three proposed options in question 1, or the effects arising from adopting a different time setting to neighbouring countries?

The assessment of health effects also includes effects on workplace productivity and physical activity (such as sports). Effects on road safety are not part of this study. In order to answer the second research question, the health effects for people who commute between time zones is specifically considered; this means people who frequently cross a time zone boundary to travel to work, for example.

[1] Standard time is popularly known as winter time. In scientific literature, however, it is referred to as 'standard time'.
[2] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52018PC0639
[3] https://eur-lex.europa.eu/eli/dir/2000/84/oj
[4] https://www.rijksoverheid.nl/onderwerpen/zomertijd-wintertijd/documenten/kamerstukken/2019/03/27/kamerbrief-plenaire-behandeling-europees-parlement-van-commissievoorstel-afschaffing-omschakeling-zomertijd-en-wintertijd
[5] https://www.rijksoverheid.nl/onderwerpen/zomertijd-wintertijd/documenten/kamerstukken/2018/12/19/aanbiedingsbrief-bij-het-rapport-%E2%80%98opinies-over-tijdsystemen%E2%80%99
[6] https://www.rijksoverheid.nl/onderwerpen/zomertijd-wintertijd/documenten/publicaties/2018/10/19/bijlage-8-kamerbrief-inzake-informatievoorziening-over-nieuwe-commissievoorstellen

1.3 Background information

1.3.1 A brief history of the current time setting

Until the end of the 19th century, only local time was used. This was calculated by observing the highest point of the sun, which marked 12 noon. There was no need for a standardized time. However, this changed at the end of the 19th century with the advent of train travel and telegraphs.

In 1884, it was decided at the International Meridian Conference that the Greenwich Meridian would be the world's prime meridian and Greenwich Mean Time (GMT) would serve as the reference point, which is nowadays also referred to as Universal Time Coordinated - UTC. This means that the longitude running through Greenwich was chosen as the benchmark for dividing the earth into 360 equal parts such that for every 15th degree of longitude, the natural day-night rhythm is shifted by 1 hour compared to the 15th degree of longitude to the east or the west. Since then, it has been possible to indicate each of the world's time zones in relation to the time in Greenwich. The difference in hours is indicated by a positive value for positions to the east of the prime meridian (for example UTC+1) and by a negative value for positions to the west (for example UTC-6).

In the Netherlands, a national time was first introduced in 1909: Amsterdam time[7,8]. Amsterdam time deviated from UTC by +19 minutes. Summer time was first introduced in the Netherlands in 1916 and calculated from the then-current standard time[9], following the lead of Germany and the occupied territories during the time of the First World War. In 1940, the German occupation led to the adoption of the Central European time zone (UTC+1) in the Netherlands. During the war years, permanent summer time (UTC+2) was introduced from 1940-1942; it was extended to include the winter period. From 1943 to 1945, summer time again alternated with a switch to the chosen standard time (UTC+1) in the autumn. After the capitulation in 1945, the Netherlands remained in the Central European time zone (standard time UTC+1). In 1946, the switch to summer time was abolished[10]. Summer time was introduced again in 1977, together with the rest of Benelux and France. In 1980, Directive 80/737/EEC[11] regulated summer time in Europe, and was followed by other directives which standardized the changeover dates for a certain number of years. With Directive 2000/84/EC[12], the period of summer time ceased to be fixed for a number of years, and was fixed permanently. The first scientific studies investigating the effects on health of switching to and from summer time were also published in the 1970s and 1980s (Monk and Folkard 1976, Monk and Aplin 1980).

[7] Staatsblad 1908/263 (http://www.staff.science.uu.nl/~gent0113/wettijd/downloads/stb_1908_236.pdf)
[8] Staatsblad 1908/336 (http://www.staff.science.uu.nl/~gent0113/wettijd/downloads/stb_1908_336.pdf)
[9] Staatsblad 1916/172 (http://www.staff.science.uu.nl/~gent0113/wettijd/downloads/stb_1916_172.pdf)
[10] Staatsblad 1946/G223 (http://www.staff.science.uu.nl/~gent0113/wettijd/downloads/stb_1946_g223.pdf)
[11] https://eur-lex.europa.eu/eli/dir/1980/737/oj
[12] https://eur-lex.europa.eu/eli/dir/2000/84/oj

1.3.2 *Time zones and daylight hours*

A time zone is an area in which the same standard time is applied. Time zones were introduced at the end of the 19th century, with the international recognition of the prime meridian being the first step. In theory, if the earth is divided into 24 equal zones (due to its 24-hour revolution), each one-hour time zone would measure 15 degrees of longitude. At the central longitude of the geographical time zone, the sun is at its highest point at 12 noon. However for various reasons the link between longitude and time zones has not been strictly applied. As Figure 1 shows, in geographical terms, the Netherlands, like Belgium, Luxembourg, France and Spain, should fall in the same time zone as the United Kingdom but they have adopted UTC+1 as their standard time instead.

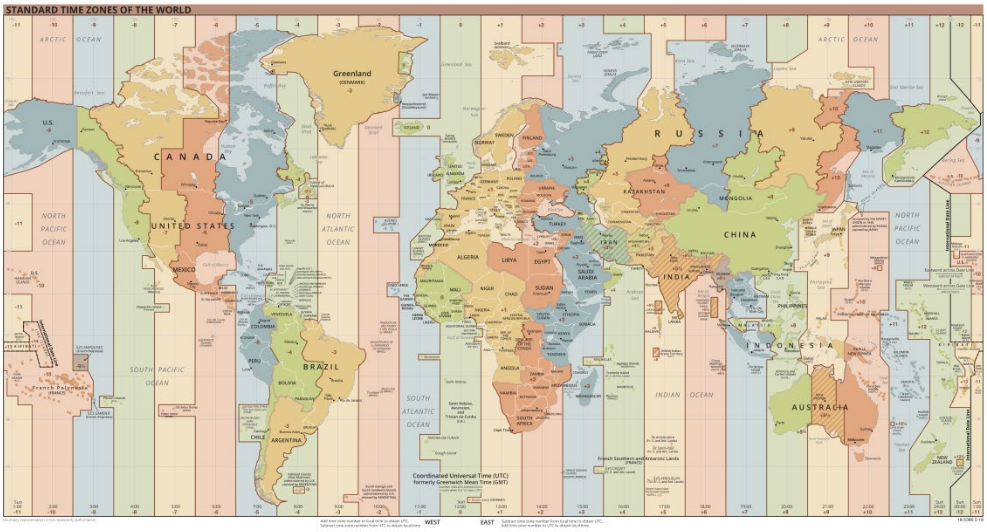

Figure 1. Geographical time zones and actual time zones around the world[13]

1.3.3 *Definitions and key terms in this report*

1.3.3.1 Standard time and summer time

There are various ways of referring to standard time in the Netherlands which are used interchangeably, such as winter time, Central European Time (CET), GMT+1 and UTC+1. This report uses the terms 'standard time' (which is UTC+1 in the Netherlands) and 'summer time' (which is UTC+2 in the Netherlands). In the studies described in this report, standard time always refers to the standard time used in the country in question, and summer time refers to the standard time of that country plus 1 hour. With reference to time in the Netherlands, 'winter time' is synonymous with standard time. The standard time adopted in a country is chosen by the country in question and does not necessarily correspond with its geographical location as described above (1.3.2). This also applies to the Netherlands. The term 'permanent standard time' or 'permanent summer time' is used to indicate a situation in which no switch is made between standard time and summer time twice a year. For permanent summer time, a continuous, adjusted time is actually used, namely standard time plus 1 hour throughout the whole year.

[13] Source: https://commons.wikimedia.org/wiki/File:World_Time_Zones_Map.png; Version: May 7, 2019.

1.3.3.2 Differences in longitude (east-west)

The earth is divided up by 360 imaginary lines that run from pole to pole. Because the earth rotates on its axis in relation to the sun, the sun rises and sets at different times according to the degree of latitude, including within a time zone. The time at which the sun rises and sets changes by on average 4 minutes per degree of longitude, so that the difference between Amsterdam and Berlin (in the same time zone) is approximately 34 minutes, for example. Within a relatively small country such as the Netherlands, that difference is limited (around 15 minutes). However, the difference between Amsterdam and the eastern edge of the UTC+1 time zone is approximately 1 hour and 16 minutes.

This report includes studies that have investigated the effect of living in a more easterly or westerly position within a given time zone (approach A in Figure 2). Approach A compares the eastern limit of one time zone with the western limit of the same time zone. The same clock time will apply in this situation, but the sun will rise earlier in the eastern area than in the western area. With a one-hour difference, the western area serves as the model for summer time and the eastern area for standard time. Studies on the health effects of differences in longitude within a time zone provide an insight into possible health effects of permanent summer time or standard time.

This report also includes studies that compare areas directly on the eastern and western sides of a time zone boundary (approach B in Figure 2). In this approach, the sun rises almost simultaneously, but the clock time is set one hour earlier on the western side compared to the eastern side. Under this approach, the eastern area serves as the model for summer time and the western area for standard time.

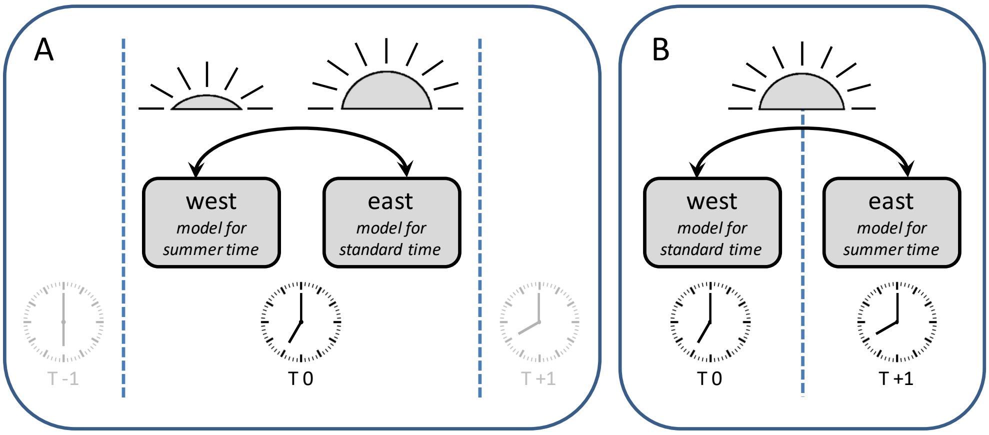

Figure 2. Schematic representation of two study designs for investigating differences between clock time and solar time

Because the axis around which the earth rotates is at an angle relative to the sun, the latitudinal position (how far north or south it is) of a location determines the day length and the differences in day length throughout the year. For example, there are no or minimal differences around the equator, while at the poles it remains day or night for many days. Day length influences a number of the effects investigated in this report. Where this is the case, this will be mentioned wherever possible.

However, latitude itself does not actually relate to the research question, because day lengths are not affected by a time settings.

1.3.3.3 Biological clock

The human body, like most organisms on Earth, has an internal clock, the circadian clock (Dibner, Schibler et al. 2010). This is also referred to as the 'biological clock'. It gives people a day-night rhythm of approximately 24 hours. This rhythm is clearly reflected in our patterns of sleep and wakefulness, but it also affects a large number of other bodily processes. For example, the biological clock follows a 24-hour rhythm in metabolic processes such as hormone release (e.g. melatonin and cortisol) and the glucose cycle, physiological processes such as blood pressure and heart rate, and behaviour. The biological clock thus coordinates some of the body's most important functions.

Every cell in the body has its own biological clock, but there is also a central clock in the brain (the suprachiasmatic nucleus; SCN), which influences the clocks in the other cells in almost all peripheral organs such as the heart, liver and kidneys. The central clock in our brain is driven mainly by light (Dibner, Schibler et al. 2010). This keeps the internally generated rhythm of the central clock moving based on a 24-hour cycle. In the absence of light, the body's central clock will follow its 'own' rhythm, which is usually slightly shorter or longer than 24 hours. The biological clock can also be disrupted by rapid changes in exposure to light, such as when we fly across many time zones.

1.3.3.4 Social jet lag

The term social jet lag refers to the discrepancy between 'social' and 'biological' time (Wittmann, Dinich et al. 2006). The biological clock in our body regulates a wide range of processes, but this does not happen exactly identical for everyone. This is the reason why some people prefer to get up early or go to sleep late (chronotypes). However, within a time zone, many people (and specifically workers and students) need to conform to patterns of activity ('social' time). This can lead to 'social jet lag', especially in people with a later chronotype. Social jet lag therefore refers to the disruption of the biological clock on working days. People with a later chronotype tend to go to bed later, even though they need to get up early on workdays. They often compensate for the sleep deprivation caused by catching up on sleep during the weekends (Wittmann, Dinich et al. 2006). Social jet lag is defined as the difference in the midpoint of sleep on work days versus the midpoint of sleep on days off. The midpoint of sleep is used because people also differ in the duration of their sleep. Some studies use the difference in wake up times on work days and days off. However, sleep duration can play a greater role in this case. The chronic experience of social jet lag is associated with various adverse health effects, mainly metabolic disorders (Roenneberg, Allebrandt et al. 2012, Larcher, Gauchez et al. 2016, Yong, Fischer et al. 2016, Koopman, Rauh et al. 2017).

1.3.3.5 Sleep

Sleep is an essential part of the day-night rhythm, during which important processing and recovery mechanisms take place that contribute to people's health (Grandner 2017). It is therefore important that people get enough sleep, in terms of both duration and quality. As described above (1.3.3.3), sunlight has a major influence on the biological clock and therefore on the day-night rhythm which the body follows, including sleep. Clock setting influences light exposure, and thus also people's sleep (1.3.3.4). Therefore, the time setting and the daylight period affect sleep, and sleep affects health. For example, a period of sleep that is too long or too short increases the risk of stroke, depression, type II diabetes and coronary heart disease (Lu, Tian et al. 2013, Shan, Ma et al. 2015, Zhai, Zhang et al. 2015, Wang, Li et al. 2016). For this reason, this study not only focusses on direct health aspects, but also at sleep.

2 Methods

2.1 Search strategy for literature study

2.1.1 Approach

In line with the research question (see 1.2), the sources used in this report are restricted to peer-reviewed scientific literature. Institutional reports, conference summaries and other forms of 'grey' literature are excluded. To the extent that we encountered relevant forms of such literature, these were used to verify the references collected, to search specifically for scientific publications on a particular subject by the same authors, or as background information for the introduction and discussion sections. For the literature used in section 'Findings' this grey literature provided no additional references compared to the search strategy adopted, as described below.

With the help of information specialists from RIVM, a search strategy was carried out using the scientific literature databases Embase, PubMed and Scopus to identify relevant publications from the last thirty years; that is, published between 1989 and April 2019. Some examples of keywords used in the search strategy include 'daylight saving time', 'time zone', 'latitude', 'circadian disruption', 'season', 'disease', 'public health', 'activity', 'sleep', and 'social jet lag'. A full overview of the search strategy is presented in Appendix 1. For validation purposes, the search strategy needed to find at least the following relevant articles: (Randler 2008), (Allebrandt, Teder-Laving et al. 2014), (Gu, Xu et al. 2017) and (Borisenkov, Tserne et al. 2017). The search yielded a total of 1162 unique references. At a later stage, on the advice of an external reviewer, the term 'circadian disturbance' was also added. This did not yield any additional references.

The references found were divided into the groups 'include', 'exclude', 'reviews' and 'doubtful cases', based on the title and abstract. Reviews were excluded, but the references from the reviews were compared with the references from the search strategy. If the search strategy did not yield a reference, the article was still assessed for usability. Meta-analyses were only included if they yielded new data. References that were classified as 'doubtful cases' were reassessed by a different project worker and/or the entire article was requested for further assessment. Wherever possible, the additional articles found in this way were included. Responses to original articles were only included if they contained additional data. Opinion pieces, letters and the like were excluded.

The following criteria were used for inclusion:

a) The exposure concerns one or more of the following aspects:
    - Switches between standard time and summer time (daylight-saving time; DST).
    - Adoption of permanent summer time compared to another time setting.
    - Adoption of permanent standard time compared to another time setting.

    - Changes to time zone (changing from one time zone to an earlier or later time zone).
    - Differences in longitude within a time zone (east-west differences within a time zone).
    - Time zone commuters (people who frequently pass between one time zone and another for work, for example).
    - Experimental studies investigating shifts in circadian rhythms / sleep-wakefulness rhythms / light exposure of 1-2 hours.
b) The outcome measure concerns one or more of the following aspects:
    - sleep (including time of falling asleep/waking up, sleep duration and sleep quality);
    - social jet lag;
    - illness and recovery;
    - general health and well-being;
    - labour productivity (including absenteeism) and school performance;
    - occupational safety;
    - physical activity.
c) Other criteria:
    - human study;
    - full text of the article available in Dutch or English;
    - studies published since 1989 (30 years);
    - original scientific publication with peer review.

The full version of the articles included was requested and analysed. The analysis focused on the following aspects:

- type of time change and time setting studied (see above under 'Inclusion criterion a');
- characteristics of the study population;
- study period;
- statistical analysis;
- results, broken down by type of outcome measure (see above under 'Inclusion criterion b').

This strategy ultimately yielded 54 articles as the basis for this research.

2.1.2 *Specific search strategy for living and working situations in relation to time zone boundaries*

When screening the literature found under 2.1.1, it quickly became clear that no relevant literature was available concerning living and working situations around time zone boundaries, other than studies in which health aspects were compared between the western and eastern sides of a time zone boundary. For this reason, an in-depth search strategy was set up for Embase and Scopus, based on the key words 'time zone', 'border' and 'occupation/work'. The references of relevant articles were also checked. A full overview of the search strategy is presented in Appendix 2. Unfortunately, this search strategy did not result in additional literature compared to the general search strategy.

2.2 Consultation with chronobiological experts

2.2.1 Additional literature

To supplement and validate the search strategy, a group of five Dutch experts, mainly chronobiologists who had previously given advice to the Ministry of the Interior, were asked to provide new and additional literature regarding the research questions to be answered. In addition, they were asked specifically to provide literature on living and working situations around time zone boundaries. A joint database of 87 entries, consisting of 73 unique literature references, was received from this network. Forty unique references corresponded to literature found in the search strategy (see 2.1.1), and the other 33 references did not meet the criteria mentioned in 2.1.1. The experts' database therefore provided no additions to the literature that was included.

2.2.2 Assessment of report

For an external assessment of the completeness and quality of this report, three experts were willing to read a draft version of the report. The comments received were incorporated into the final document; final responsibility for the content resides with the authors of the report.

3 Findings

Below, a large number of studies are described into the health effects of different time settings. The findings are ordered according to time setting and then according to health measure. Where several studies describe a particular health measure, these are briefly summarised in italics at the end of the relevant section. A clear overview of the findings per health measure is provided in Table 1. Not every finding is supported in the studies to the same extent. The fine grain of this overview is discussed in the various paragraphs of this chapter.

3.1 Effects of switching from or to summer time twice a year

To investigate the positive and negative health effects of maintaining current practices with regard to the time settings, the scientific literature was searched for information about the effect of the switch to and from summer time twice a year on sleep, social jet lag, diseases and disorders, general health and well-being, labour productivity and safety and physical activity.

3.1.1 Sleep and social jet lag

Thirteen studies were found that investigated the effects of switching between summer time and standard time on sleep. The findings of these studies are described below with regard to various aspects of sleep.

3.1.1.1 Sleep duration

Seven studies investigated the acute effects of switching between summer time and standard time on sleep duration: three studies used self-reporting and four studies used portable actigraphy meters. Actigraphy involves the use of wearable sensors (on the wrist, leg or ankle for example) which detect movement and thereby also provide information about sleep.
Two studies using data from the *American Time Use Survey*-database (self-report; n = 14,310 and n = 20,720 respectively) found that participants slept for a shorter period (~ 40 minutes) (Barnes and Wagner 2009, Michelson 2011) the day after the switch to summer time compared to the rest of the year or to the week before and after. In both studies, this effect was no longer apparent on the Monday after the switch. When switching to standard time, one of the two studies found that participants sleep 40 minutes longer (Michelson 2011), while the other study found no effect (Barnes and Wagner 2009). It should be noted that the study by Michelson et al. did not use statistical analysis to determine this difference. Both studies found no differences in sleep duration on the second day after the switch. The third study to use self-reporting was conducted among young people in Brazil (n = 378). No effect was found here on the average sleep duration during five school days following the switch to summer time compared to the average sleep duration during the five school days before the switch (Toth Quintilham, Adamowicz et al. 2014).

Table 1. Findings regarding health effects of different time settings

Health Measure	**Switch to**		**Permanent summer time***
	summer time	**standard time**	
Sleep			
Sleep duration	decrease	no clear effect	decrease
Sleeping times	adjustment problems	adjustment problems	-
Social jet lag	-	-	increase
Sleep quality	no clear effect	decrease	decrease
Sleepiness	increase	no effect	-
Illnesses and disorders			
Heart attack	increase	no clear effect	-
Death from cardiovascular disease	no clear effect	no effect	-
Psychological disorders	no clear effect	no clear effect	-
Brain disorders	no clear effect	no clear effect	-
General health and well-being			
General mortality	increase	no effect	-
Use of health care	no clear effect	no clear effect	-
Miscarriage	no clear effect	no effect	-
Well-being	decrease	-	decrease
Abuse	decrease	increase	-
Overweight	-	-	increase
Cancer	-	-	increase
Death due to cancer	-	-	increase
Life expectancy	-	-	decrease
Depression	-	-	no clear effect
Suicide	no effect	-	-
Labour productivity and safety, performance at school			
Functioning at school	-	-	no effect
Cognitive functioning in adults	no clear effect	-	-
Accidents at work	no clear effect	no effect	-
Physical activity			
Physical activity	no clear effect	decrease	-

Red text indicates a negative effect on health and green text indicates a positive effect. 'no effect': examined and no effect found; 'no clear effect': contradictory findings in different studies; '-': no (useful) studies found.
*Relative to permanent standard time and/or switching between summer time and standard time.

In two of the four studies that used actigraphy data, a Finnish study (n = 10) and a study in the US (n = 35) reported a shorter sleep duration in the weekdays following the switch to summer time (average ~30-60 minutes shorter) compared to the weekdays in the week before the switch (Lahti, Leppämäki et al. 2006, Medina, Ebben et al. 2015). By contrast, in an Italian study (n = 14) a longer sleep duration was found in the weekdays after the switch to summer time (average ~30 minutes longer) and a shorter sleep duration after the switch to standard time (average ~25 minutes shorter) (Tonetti, Erbacci et al. 2013). A UK study (n = 35) reported that the effect on sleep duration differs between participants who normally sleep for longer or shorter times. When sleep duration in the week before and after the switch to standard time is compared separately for shorter sleepers (less than 7.5 hours), average sleepers and longer sleepers (more than 8.5 hours), results show that sleep duration for shorter sleepers increases (by 20 minutes on average), while for average and longer sleepers it decreases (by 14 minutes and 19 minutes, respectively) (Harrison 2013). This study did not consider the switch to summer time. None of these studies examined the effects on sleep duration for longer than a week. However, Harrison et al*.* report that the effects decrease at the end of the week and Medina et al*.* report that the effects are no longer evident on weekend days after the switch (compared to weekend days before the switch).

Finally, there are two studies that examined how sleep duration varies during a year (Kantermann, Juda et al. 2007, Allebrandt, Teder-Laving et al. 2014). In a study based on the Munich ChronoType Questionnaire (n = 55,000), a longer sleep duration (~20 min) in the months of standard time was reported (Kantermann, Juda et al. 2007). A similar effect was found in a study involving 9,765 individuals from six cohorts from four European populations (Allebrandt, Teder-Laving et al. 2014). However, in this study a longer sleep duration was only found in relation to late chronotypes. The sleep duration for early chronotypes was the same throughout the year. In both studies, the data analysis did not look at the acute effects of the switch to and from summer time (Kantermann et al. do look at this for sleeping times, see paragraph below) and no comparison was made with sleep duration during a summer without summer time setting. As a result, it is not possible to differentiate seasonal effects from the effects of a summer time setting.

In summary, the results of these studies indicate that the switch between standard time and summer time has an effect on sleep duration. It seems that these effects are temporary, although there is a lack of robust long-term studies (>1 week). When switching to summer time, the majority of studies find a decrease in sleep duration (4/6 studies decrease, 1/6 increase, 1/6 no effect). When switching to standard time this is more diverse: 2/5 studies find an increase, 2/5 find a decrease and 1/5 finds no effect. *Here, the study by Harrison et al. is included as two separate studies, split into shorter sleepers and longer sleepers. The results show that the duration of sleep can both decrease and increase, which may depend on the usual sleep pattern and/or chronotype that an individual has. Effects are found in both adults and young persons.*

3.1.1.2 Sleeping times and social jet lag

Five studies have investigated the effects of switching between summer time and standard time on sleeping times. Two studies were based on self-reporting, three studies used actigraphy and one used Twitter messages as an indicator of the times at which people wake up.

Both an Italian study based on self-reporting (n = 14) and a Brazilian study based on actigraphy (n = 378) show that participants wake up later in the week after the switch to summer time: ~30-40 minutes relative to the new time setting (summer time) (Tonetti, Erbacci et al. 2013, Toth Quintilham, Adamowicz et al. 2014). Because summer time is one hour ahead of standard time, it indicates that people experience difficulty adjusting to the new clock time immediately. Compared to standard time, people wake up ~20-30 minutes earlier rather than the full hour that the clock has moved forwards. Tonetti et al. also examined sleeping times after the switch to standard time; then, participants wake up almost half an hour earlier than standard time. In this case too, it appears that people do not adjust to the new clock time immediately. A UK study (n = 35) using actigraphy shows that, just as with sleep duration, the effect on sleeping times depends on the type of sleeper. In the week after the switch to standard time, short sleepers wake up later (~20-60 minutes), while long sleepers wake up earlier (~30-60 minutes). Both groups go to bed earlier (~20-60 min). None of these effects are still visible by the end of the following week (Harrison 2013).

In a study that used Twitter messages containing the text *'guten morgen'* as an indicator of waking times, data from 206,633 users were used. This study shows that the time of waking shifts by 1 hour on weekdays and weekend days following the switch to and from summer time (Scheffler and Kyba 2016). This is consistent with the findings of Kantermann et al.'s study, in which sleeping times during the four weeks before the switch and the four weeks after the switch to and from summer time were determined using self-reporting (n = 55,000) and actigraphy (n = 49) (Kantermann, Juda et al. 2007). Following both switches, a shift occurred in the midpoint of sleep by around one hour within the first week, in the same direction as the switch in the clock time. This remained constant in the other three weeks.

The studies by Kantermann et al. and Scheffler et al. also studied sleeping times, or an indicator of sleeping times, throughout the whole year (Kantermann, Juda et al. 2007, Scheffler and Kyba 2016). The authors of both studies observe that waking times in the months with standard time correlate with sunrise, but that this is not the case during the months of summer time. However, no correlation coefficients are given for these correlations in either of the studies. Moreover, it is difficult to interpret the data produced because there is no comparison with participants who do not switch to summer time; it is therefore not possible to separate seasonal effects from the effects of the switch to summer time. In the study by Kantermann et al., the authors also state that in the week after the switch to standard time, there is a shift in the midpoint of sleep to a later time, while no clear shift is visible after the switch to summer time. However, the authors did not provide any statistical analysis of this comparison.

There are two studies that specifically looked at the occurrence of 'social jet lag' (Allebrandt, Teder-Laving et al. 2014, Scheffler and Kyba 2016). Social jet lag means the difference in sleeping times between working days and days off. It thus refers to disruption to the biological clock on working days (see 1.3.3.4). The study by Allebrandt et al. reports that in five of the six cohorts studied, the difference in social jet lag between early and late chronotypes is smaller during standard time than during summer time (Allebrandt, Teder-Laving et al. 2014). In addition, late chronotypes experience more social jet lag than early chronotypes. However, this study makes no direct comparison between social jet lag during standard time and summer time, which means that its relevance to our research question is limited. The differences between the cohorts indicate that geographical differences can also play a role, such as climate and day length.

In the study that used Twitter messages with the text '*guten morgen*' as an indicator of waking times, the estimated waking time on weekdays was compared to that on Saturdays and Sundays (Scheffler and Kyba 2016). This difference is used as an indicator for social jet lag and changes throughout the year. Social jet lag is greatest in January: waking time ~99 minutes later on Saturdays compared to weekdays, and ~140 minutes later on Sundays compared to weekdays. This difference diminishes every week as the sun rises earlier during the spring. The difference is smallest at the weekend when summer time starts (~50 minutes on Saturday and ~55 minutes on Sunday). The following weekend, the difference increases again (~84 minutes on Saturday, and 102 minutes on Sunday). The authors describe that this difference remains relatively stable during the summer time period while increasing again after summer time ends in the autumn. However, the effects described are not statistically tested.

In summary, these studies indicate that sleeping times are influenced by the switch to and from summer time: people seem to wake up later after the switch to summer time and, conversely, to wake up earlier after the switch to standard time. However, these effects may depend on a person’s usual sleep pattern (chronotype, short or long sleepers). It seems that the effects on sleeping times occur mainly in the first week after the switch. With respect to any effects on social jet lag and any correlation of sleeping times with sunrise, good (statistical) data and good controls regarding seasonal effects are lacking, so it is not possible to draw any conclusions about these.

3.1.1.3 Sleep quality and sleepiness

Five studies have investigated the effects of switching from and/or to summer time on sleep quality. These all report on different indicators of sleep quality based on actigraphy data. All studies compare the week before the switch with the week after it.
Three studies, two from Finland (n = 10 and n = 9 respectively) and one from the UK (n = 35), show a decrease in sleep efficiency: the proportion of actual sleeping time of the total time spent in bed. The decrease in sleep efficiency varies from 6-10% in the week after the switch to standard time, compared to the previous week (Lahti, Leppämäki et al. 2006, Lahti, Leppämäki et al. 2008, Harrison 2013).
One study, from Italy (n = 14), reports no difference in sleep efficiency

when switching to standard time (Tonetti, Erbacci et al. 2013). This study reports a decrease in sleep efficiency when switching to summer time (~2%). However, one of the Finnish studies (n = 9) and a study in the US (n = 40) report no effect on sleep efficiency when switching to summer time (Lahti, Leppämäki et al. 2008, Medina, Ebben et al. 2015).

One study, the Italian study (n = 14), also used self-reporting in relation to sleep complaints using the Mini Sleep Questionnaire (MSQ). In the week following the switch to summer time, self-reported sleep complaints diminished; no effect was found in the week following the switch to standard time (Tonetti, Erbacci et al. 2013).

Five studies have investigated the effect of switching to and from summer time on daytime sleepiness. These studies used a range of methods for self-reporting on sleepiness: the MSQ (Tonetti, Erbacci et al. 2013), the Karolinska Sleepiness Scale (KSS) (Medina, Ebben et al. 2015), the Paediatric Daytime Sleepiness Scale (PDSS) (Schneider and Randler 2009), the Visual Analogue Scale (VAS) (Toth Quintilham, Adamowicz et al. 2014), and the Epworth Sleepiness Scale (ESS) (Fetter, Lefaucheur et al. 2014). All studies focused on relatively young participants (school children or students), with the exception of a French study by Fetter et al., in which Parkinson's patients (n = 83) were investigated specifically. Three studies, a German study (n = 532), a Brazilian study (n = 378) and a US study (n = 35), found an increase in daytime sleepiness in the week following the switch to summer time (Schneider and Randler 2009, Toth Quintilham, Adamowicz et al. 2014, Medina, Ebben et al. 2015). The study by Schneider et al. investigated the difference between the week before the switch and the three weeks afterwards (Schneider and Randler 2009). This suggests that the effects on sleepiness may last for some time, but the three weeks were not analysed separately. This study also reports that the effects on sleepiness are greater for young people with a late chronotype. The study by Toth Quintilham et al. used a measure of sleepiness immediately after the switch but only found an effect at 8.00 a.m., and not at noon, 6 p.m. or 8 p.m. An Italian study (n = 14) found no effect on sleepiness in the week after the switch to summer time compared to the previous week, nor in the week after the switch to standard time (Tonetti, Erbacci et al. 2013). Among one specific group, namely Parkinson's patients, no difference in sleepiness was found in the week before or after the switch (both to and from summer time) (Fetter, Lefaucheur et al. 2014).

In conclusion, together these studies show that in addition to the effect on sleep duration and sleeping times, switching between summer time and standard time may also have an effect on sleep quality and daytime sleepiness. Sleep efficiency decreases temporarily following the switch to standard time (a decrease in 3/4 studies, no effect in 1/4 studies). This effect is less evident following the switch to summer time (a decrease in 1/3 studies, no effect in 2/3 studies). With respect to daytime sleepiness after the switch to summer time, an increase in sleepiness was the predominant finding (an increase in 3/4 studies, no effect in 1/4 studies). Sleepiness after the switch to standard time has only been investigated in one study, which found no effect. The results from the study of sleepiness in Parkinson's patients were not included because of the specific nature of the research group (no effect was found). All in all, *the results indicate that the effects on sleep quality and sleepiness depend on the direction of the switch (to or from summer time). Data are lacking on how long any effects on sleep quality and sleepiness last.*

3.1.2 Illnesses and disorders

Nineteen studies were found that have investigated the effects of switching between summer time and standard time on illnesses and disorders. Of these studies, eleven relate to cardiovascular disorders, five to psychological disorders and three to brain disorders. The findings of these studies are described below.

3.1.2.1 Cardiovascular disorders

Eleven studies investigated the acute effects of switching between summer time and standard time on cardiovascular disorders. Eight studies investigated the incidence of heart attacks, based on hospital visits or hospital admissions. Three studies examined mortality due to, among other things, heart attacks based on autopsy reports or mortality figures.

Incidence of heart attacks

Among a Croatian population, questionnaires were carried out among persons who visited a hospital in relation to a heart attack in the period 1990-1996 (n = 2,412). In the first four working days after the switch to summer time, a 29% increase was reported in the incidence of non-fatal heart attacks compared to the average incidence in all weeks without a time switch (Čulić 2013). The highest incidence occurred on the Monday. Men suffered a heart attack more often, while patients taking certain heart medication (calcium channel blockers) suffered fewer. After the switch to standard time, the incidence of non-fatal heart attacks in the first four working days was 44% higher than the average incidence in all weeks without a time switch. The highest incidence was four working days after the switch. Women suffered from a heart attack more often, and patients on certain heart medication (β blockers) less often.

Using a Swedish register, the incidence of heart attacks in the period from 1987 to 2006 were compared (Janszky and Ljung 2008). On average, the incidence of heart attacks increased by 5% over the entire first week following the switch to summer time. The effect was slightly more apparent in women than in men. Overall, the switch to standard time had no effect, except on the Monday following the switch where the incidence was lower (around 5%). Following this switch, the difference was somewhat more pronounced in men. The effect of both switches was more pronounced in patients below the age of 65 years. However, subgroup analyses were not described methodologically and the data were not presented in the article. The authors suggest that the effects of the time switch can probably be explained by the negative effect of lack of sleep on cardiovascular disease.

Using data from another Swedish register, obtained between 1995 and 2007, there was also a slight increase (around 4%) in the incidence of acute heart attacks in the first week following the switch to summer time compared to the average incidence in the two weeks before and after the switch (Janszky, Ahnve et al. 2012). The increase was most evident in patients with low cholesterol and triglyceride levels and in patients who were already using heart medication. The switch to standard time had no effect when the entire population was taken into account. However, the incidence appeared to be lower in patients with hyperlipidemia (based on cholesterol levels, triglycerides, or statin use), as well as in patients who were already using calcium channel blockers.

The incidence of two types of heart attacks was studied based on hospital visits in the state of Michigan (US) in the period from 2006 to 2012 (Jiddou, Pica et al. 2013). The incidence in the first week after the switch to summer time (n = 171) and standard time (n = 157) was compared with the average incidence over the two weeks before and after the switch to summer time (n = 292) and standard time (n = 315). In the week after the switch to summer time, there was a trend towards increased incidence (17%) of heart attacks compared to the control period, but only the increase on the following Sunday was significant (71%). It was striking that only the number of heart attacks without coronary artery occlusion (NSTEMI: non–ST-segment elevation myocardial infarction) increased after the switch to summer time and not the number of heart attacks with coronary artery occlusion (STEMI: ST-segment elevation myocardial infarction). The switch to standard time had no effect on the incidence of heart attacks. The authors suggest that the increase in the number of NSTEMIs may be caused by lack of sleep, as this can lead to a temporary increase in blood pressure and coronary vasoconstriction.

A German study analysed all cases of non-fatal heart attacks and deaths from coronary problems based on data from a German register (n = 25,499) obtained between 1985 and 2010 (Kirchberger, Wolf et al. 2015). The incidence in the first three days and the week following the switch to and from summer time was compared with the incidence across all years and with the incidence in the month before and after the switch across all years. Overall, no difference in the incidence was found around the time of the switch; in a subgroup analysis, however, the incidence increased by approximately 20% on the Monday and Tuesday after the switch to summer time, and decreased by approximately 15% on the Monday after the switch to standard time. In addition, the subgroup analysis showed that men are more likely to suffer a heart attack after the switch to summer time, as well as patients who have already used ACE inhibitors. After the switch to standard time, patients who had previously suffered a heart attack ran a greater risk of another heart attack.

Register data from the state of Michigan (USA) from the period 2010-2013 were used (Sandhu, Seth et al. 2014) to investigate the effect of switching to and from summer time on the number of percutaneous coronary interventions performed in relation to a heart attack (n = 42,060). On the Monday after the switch to summer time, the incidence was elevated by 24%, whereas it was reduced by 21% on the Tuesday after the switch to standard time. The authors note that a vulnerable group had been studied, namely patients who needed percutaneous coronary intervention therapy, and that these outcomes do not allow any conclusions to be drawn regarding any more generalized effect of switching to and from summer time on the overall incidence of heart attacks.

In a Finnish register, the incidence of two types of heart attacks in the first week after switching to summer time (n = 1,269) and standard time (n = 1,628) was compared with the average incidence of heart attacks in the two weeks before and after the switch to summer time (n = 5,029) and standard time (n = 6,533) (Sipilä, Rautava et al. 2016). Overall, no difference was found in the incidence in relation to the switches to and from summer time, and no difference in mortality due to heart attacks either. Subgroup analysis showed an increase in incidence of around 16% on the Wednesday following the switch to summer time. After the switch to standard time, the incidence was reduced by around 15% on the Monday but then increased again by around 15% on Thursday. After both switches, there was no difference in incidence between men and women, nor between STEMI and NSTEMI patients.

A meta-analysis was also carried out into the impact of switching between summer time and standard time on the incidence of heart attacks (Manfredini, Fabbian et al. 2019). In this study, MedLine and Scopus were searched for cohort and case control studies in which the incidence of acute heart attacks around the switches to and from summer time was studied. Seven studies met the inclusion criteria. These were all included in our study and have already been described above. In a comprehensive meta-analysis in which data from both switches were combined, a small increase in the incidence of heart attacks (3%) was found. This was largely attributable to the effects of switching to summer time (increase of 5%). Stratification by gender had no effect, but stratification by age for the switch to summer time showed that the risk was greatest in the age group of 65 years and over (7% higher incidence). The explanatory power of the stratified analyses is limited, however; the authors therefore emphasize that this does not mean that previous findings in individual studies are incorrect.

In summary, the results of these studies indicate that the switch between standard time and summer time has an effect on the incidence of heart attacks. The effect is greatest after the switch to summer time: all eight studies, including a meta-analysis, show a higher incidence of heart attacks after the switch to summer time. Certain subgroups seem to be at greater risk, such as patients taking particular heart medication. Some studies also show differences between men and women in the incidence of heart attacks after the switch to or from summer time, as well as between patients who are younger and older than 65 years. No consistent effects are found for the switch to standard time.

Deaths due to cardiovascular disorders

In a southern German population, over a period of ten years (2006-2015), the number of forensic autopsies was studied two weeks before and two weeks after the switch to and from summer time (n = 690) (Lindenberger, Ackermann et al. 2018). The number of autopsies in the first week after the switch to summer time increased, but there was no change after the switch to standard time (also see section 3.1.3). In a specific analysis of the number of deaths due to cardiovascular conditions, however, no changes were found around the switch to and from summer time. The authors note that the sample size of the subgroup analysis was small (n = 117).

In a study in which over 10,000 deaths due to circulatory disorders were studied among a northern Italian population in the period from 2000-2015, no changes were generally observed around the switch to and from summer time (Manfredini, Fabbian et al. 2019). Only in a subgroup analysis for individual days of the week there was an increase in the number of circulatory deaths on the Tuesday after the switch to summer time.

A third study investigating the number of deaths from heart attacks was conducted in Brazil, where some federal states switch to and from summer time while other states do not (Toro, Tigre et al. 2015). In the federal states that do switch, there was an increase of 7.4-8.5% in the number of deaths around the switch to summer time. The switch back to standard time had no effect. However, information about the study population and other methodological aspects was lacking, so the results can only be interpreted as indicative.

In summary, based on the diverging results of these three studies (1/3 increase, 1/3 increase in subgroup analysis, 1/3 no effect), no firm conclusion can be drawn regarding whether switching to summer time has any effect on mortality as a result of cardiovascular diseases. The switch to standard time has no effect.

3.1.2.2 Psychological disorders

Five studies were found that investigated the effects of switching between summer time and standard time on psychological disorders. Two studies focused on suicides and suicide attempts (Shapiro, Blake et al. 1990, Berk, Dodd et al. 2008), two dealt with psychological and behavioural problems more generally (Berk, Dodd et al. 2008, Heboyan, Stevens et al. 2018), one with manic episodes (Lahti, Haukka et al. 2008) and one focused on depression and bipolar disorders (Hansen, Sønderskhov et al. 2017). More information about mood changes after the switch to summer time is provided in section 3.1.3 of this report. All studies on psychological disorders in this section are based on registration data and focused on the switch to summer time and the switch back to standard time. Acute effects were investigated in all studies, and chronic effects were also included in one study.

In an Australian study, no consistent differences in suicide rates were found after the switches to and from summer time. Using registered data (n = 47,215 men and n = 14,383 women) from 1971 to 2001, the suicide rate in a number of Australian states was compared before and after the switch to and from summer time (Berk, Dodd et al. 2008). This involved making a comparison between registered suicides two and four weeks after the switches to summer and standard time and registered suicides over the rest of the year, the rest of the season and the weeks following the switch in the opposite direction. Among women, there were no differences in suicides in the weeks following the switches to and from summer time. In men, significant differences were only found after the switch to summer time, but these differences were largely explained by the season and were only significant prior to 1986 and not afterwards. During the research period, some states experimented with the introduction of switches between summer time and standard time. It is not clear whether these states were included in the study for the entire research period or for part of it.

In a Scottish study, no consistent differences in suicide rates were found after the switches to and from summer time (Shapiro, Blake et al. 1990). The authors examined changes in the numbers of suicide attempts, suicides, psychiatric admissions and outpatient contacts during the days and the week before and after the switch to and from summer time using registration data. This involved registered suicide attempts after the switches to and from summer time (n = 1,170) in Edinburgh between 1962 and 1987, psychiatric admissions (n = 4,722) between 1970 and 1987 and an unknown number of outpatient contacts between 1977 and 1986. The number of suicides (n = 4,734) comes from a Scottish registration between 1974 and 1983. No differences were found in any of the populations studied before and after the switch to and from summer time with respect to any of these outcome measures. In-depth analyses of the diagnoses of psychiatric admissions (mood disorders, psychoses) also showed no differences. Neither were there any changes in the number of crisis contacts.

Two other studies found no effects on the use of care for psychological problems and disorders around the switches. No consistent differences were found in a US study of emergency department visits relating to psychological or behavioural problems around the switch to and from summer time (Heboyan, Stevens et al. 2018). Researchers used data on the registration of emergency department visits by adults in Augusta (US) between 2013 and 2015 (n = 139,598), comparing the numbers in the two weeks before the switch with the two weeks after the switch. In a Finnish study, no effects were found around the switches between summer time and standard time on the number of manic episodes treated in a hospital (Lahti, Haukka et al. 2008). Registration data relating to an unknown number of hospital discharges between 1987 and 2003 were analysed in order to compare the number of manic episodes in the two weeks before the switches to and from summer time with the two weeks afterwards. Geographical location was one of the factors taken into account.

Finally, in a study into contacts relating to psychiatric disorders, an 11% increase in hospital contacts for unipolar depression was found around the switch to standard time (Hansen, Sønderskhov et al. 2017). This effect continued for ten weeks after the switch. The increase did not apply to bipolar disorders. No increase or decrease was found in contacts relating to depression or bipolar disorders after the switch to summer time. These findings are based on Danish registration data on 185,419 hospital contacts for unipolar depression and 92,180 for bipolar depression between 1995 and 2012. A selection was made for acute cases that were not planned in advance. The weekly incidences in the weeks following the switch were compared with the estimated weekly incidences based on a time series analysis. This analysis is not clearly defined and therefore not reproducible.

In summary, based on the two studies found, there is no evidence that the switch to summer time or standard time could lead to an increase in suicide or suicide attempts. Furthermore, most studies into care *contacts for specific or general psychological or psychiatric problems do not show any increase or decrease in patient contacts around the period of the switches to and from summer time. Only one of the four studies shows an increase in consultations for depression. Based on these studies, there is insufficient evidence that the switch to and from summer time leads to an increase in psychological illness.*

3.1.2.3 Brain disorders

Three studies investigated the effect of the switch to and from summer time on various brain disorders. All studies compared outcome measures in the days before and after the switches to and from summer time in both seasons.

In a French study involving 83 Parkinson's patients on stable medication regimens, the number of hours of off-fluctuations (the phases in which dopaminergic medication was not effective or not sufficiently effective) and the scores for non-motor symptoms such as drowsiness, depression and psychosis were compared on the basis of self-reporting (Fetter, Lefaucheur et al. 2014). No significant differences were found before or after the switches to and from summer time for any of the endpoints studied or any combinations thereof. The authors' conclusion is therefore that Parkinson's patients on stable medication regimens do not experience any acute worsening in the Parkinson's-related symptoms that were investigated due to the switches between standard time and summer time.

Using a self-reporting database in the US, ‘SeizureTracker’, the number of seizures in the week as a whole and on individual days following the switches to and from summer time with the days and weeks immediately before the switches and with other weeks of the year were compared for 12,401 individuals with epilepsy (Schneider, Moss et al. 2019). A slight decrease was found in the number of seizures in the week and the individual days following the start of summer time. No differences were found for the switch back to standard time. It should be noted that during the 2008-2016 research period, participants joined and dropped out, which complicates the analysis. Data on, among other things, sleep, chronotype and geographical location were lacking, which meant that the influence of these types of variables could not be evaluated. In the context of this report, the lack of location data was important because a number of states (and even parts of states) in the US do not switch between standard time and summer time. Although the number of participants in these areas can be assumed to be a minority, some effect on the results cannot be excluded. A cautious conclusion is therefore that switching between standard time and summer time is not associated with any increase in the incidence of seizures.

In Finland, hospital admissions for ischemic strokes were analysed using the national health register for the years 2004 to 2013 during the days around the switch to and from summer time (Sipilä, Ruuskanen et al. 2016). A total of 14,834 strokes were included, spread over the week following a switch to or from summer time (20.5%) and the adjacent control weeks (79.6%). The relative risk of a stroke was increased in the first two days after the switch to or from summer time. Considered over the week as a whole, however, there was no difference, because there was a lower relative risk on the Wednesday and Friday following the switch. A breakdown of the switches to and from summer time produced no significant differences; there was a trend towards a higher relative risk in the first two days after the switch to summer time compared to the switch to standard time. Mortality in hospitals as a result of the strokes was not influenced by the switches to and from summer time. The conclusion is that the switches between standard time and summer time lead to temporary shifts in relative risks of strokes on some days of the subsequent week, but do not produce any differences when the entire week is considered.

In summary, the literature on brain disorders that was found, which related to Parkinson's-related symptoms, seizures and strokes, shows that there are no differences due to the switches between standard time and summer time at the week level. For strokes, there are indications that on some days of the week after the switch, changes may occur in the relative risks but these even out over the week as a whole.

3.1.3 General health and well-being

Six studies investigated the effect of the switches between summer time and standard time on various aspects of health, health-related behaviours and the use of health care. These concerned effects on mortality, emergency department consultations, spontaneous deliveries and miscarriage with IVF, general well-being and cases of abuse. Four studies focused on acute effects immediately after both switches, one study on the acute effect of the switch to summer time, and one study compared effects over longer periods during and outside summer time.

Mortality

In a German study, higher mortality rates were found after the switch to summer time. This was based on an analysis of forensic autopsies (Lindenberger, Ackermann et al. 2018). Mortality rates immediately after the switch were compared with average mortality in the four weeks around the switch. The mortality rates were based on 690 post mortem autopsies around both time switches in a number of German cities over a ten-year period. The higher mortality rate only applies to deaths where the cause of death was natural and only to women (and therefore not to non-natural causes of death or to men). By week 2 after the switch, there were no longer any significant differences. In the one or two weeks following the switch to standard time, no increase or decrease in natural or non-natural causes of death was found. In addition, there were no significant changes in mortality due to specific disorders after either switch, either in natural or non-natural causes of death. The question is what these results imply for overall mortality, because the number of forensic autopsies gives a different picture to total mortality. Moreover, due to the selection, the numbers involved are relatively small.

Other sections of this report describe two studies on the relationship between the switches to summer time and standard time and deaths due to cardiovascular disease (paragraph 3.1.2.1) and the number of suicides (paragraph 3.1.2.2).

Use of health care
An Italian study shows a difference in repeat emergency department consultations in the weeks before and after the switches. In this study, registrations from 366,527 first consultations and 84,380 repeat consultations at the emergency departments of Italian hospitals between 2007 and 2016 were investigated (Ferrazzi, Romualdi et al. 2018). They compared registrations of consultations two weeks before the switch to summer time and standard time and consultations 1-19 weeks after the switch to summer time, and 1-4 weeks after the switch to standard time. In the majority of the 19 weeks after the switch to summer time, there are approximately 10% more repeat consultations compared to two weeks before the switch, even after correction for daylight hours. The total number of consultations also increased, but this appeared to be explained by daylight hours. After the switch to standard time, the number of repeat visits decreased again by around 10% in the first four weeks following the switch (only significant in weeks 3 and 4). Here too, the number of first consultations was not different from the period before the switch.

Pregnancy
Two studies investigated whether the switch to summer time or standard time influences pregnancy outcomes. In a Swedish study, no differences were found in the number of spontaneous births and gestational age in the weeks before and after the switch to summer time and standard time (László, Cnattingius et al. 2016). This analysis is based on registrations in the Swedish Medical Birth Register between 1993 and 2006 (n = 18,519 around the switch to summer time and n = 19,073 around the switch to standard time). In a US study, an increase in miscarriages in cases of IVF was found immediately after the switch to summer time (Liu, Politch et al. 2017). The authors examined the effects of the switch to summer time and standard time on pregnancy outcomes during various phases of IVF procedures (n = 1,654). In group 1, the switch took place between the start of ovulation stimulation and the replacement of the embryo; in group 2 within three weeks of the embryo being implanted. Both groups were compared with a control group where the switch to or from summer time took place at least ten weeks after ovulation stimulation. With the switch to summer time, miscarriage appeared to be higher in group 2 (switch within three weeks after implantation) (24.3%) than in group 1 (10.2%) or group 3 (12.5%). After subgroup analysis, the authors found this increased rate of miscarriage more often in women who have previously experienced a miscarriage and in women under the age of 40. The authors suggest that stress may play a role in this, but this was not investigated. No differences in miscarriage rates between groups were found with the switch to standard time.

Well-being
A German study investigated the acute effects of the switch to summer time on two measures of general well-being (Kountouris and Remoundou 2014). These were level of satisfaction with life (1986-2010; n = 44,530) and mood (2007-2010; n = 23,537). The study was based on self-reporting through interviews as part of a German study panel. In the week following the switch to summer time, participants were found to score lower on satisfaction and higher on a scale for negative mood compared to the rest of the year. ‘Anxiety’ occurred

more often in the week after the switch to summer time, and 'joy' less often. No differences in 'worry' or 'sadness' were found.

Other effects: cases of abuse
A study in four US cities found a relationship between the switches to summer time and standard time and the number of cases of abuse registered (Umbach, Raine et al. 2017). This involved the registration of cases of abuse between 2001 and 2014 (switch to summer time n = 60,333; switch to standard time n = 62,546). The number of cases of abuse on the Monday following the switch was compared with the number on the Monday one week later. After the switch to summer time, 3% fewer cases of abuse were registered on Mondays immediately after the switch. After the switch to standard time, there was an increase of 2.8%. A number of additional analyses also showed an increase between weeks 1 and 2 after the switch to standard time, so the increase before and after the switch cannot be attributed clearly to the switch itself. According to the authors, fatigue may explain why there are fewer cases of abuse following the switch to summer time; this may make the perpetrators less aggressive. However, this was not investigated.

In summary, there are some indications from the literature that the switch to summer time has a negative effect on various aspects of health: specific forms of mortality (but not all deaths), loss of pregnancy during IVF and feelings of well-being (satisfaction with life and negative mood). More repeat consultations are also registered in emergency departments, but on the other hand there is no increase in first consultations. The switch to summer time may have an acute beneficial effect on the number of cases of abuse. The health effects of the switch to standard time are less clear. However, the registration of repeat consultations in emergency departments declines, with no effect on first consultations being found here either.

3.1.4 Labour productivity, safety at work, performance at school
A total of eight studies were found relating to the effects on various aspects of labour productivity, safety at work or performance at school. Four of these studies relate to the effects on functioning at work, at school, or in general, and four studies examined work-related accidents.

Functioning at work or school
Four studies focused on the effects of the switch to summer time on functioning at work, at school, or in general. Three studies used test results and one study was based on internet usage.

Two US studies examined the chronic effect of the switch to summer time on the cognitive functioning of children in school. One study compared high schools in areas of Indiana with and without the switches to and from summer time. It was found that children at school scored lower on average on a maths and language in districts switching between standard time and summer time compared to schools in districts without these time switches twice a year (Gaski and Sagarin 2011). The average SAT (Scholastic Aptitude Test) scores at these schools were compared: a total of 339,893 SAT scores and 3,501 average SAT scores per school per year. Corrections were made for factors such as the number of pupils per school and the distance of the school from the meridian of the time zone. The analysis in the article is based on a score with a high level of abstraction, meaning other confounders may also influence the average SAT scores per school, and it does not take into account of students moving between areas with and without summer time. A second study in New York found reduced alertness / cognitive performance of students at a high school immediately after the switch to summer time (Medina, Ebben et al. 2015). They carried out the Psychomotor Vigilance Test with forty students in the week before and after the switch to summer time. This test measures responsiveness, among other things. Data on sleep was also collected (see section 3.1.1). The researchers noted a reduction in performance on the Psychomotor Vigilance Test and an increase in sleepiness after the switch to summer time. It should be noted, however, that this study is limited in terms of the number of participants (forty, all from one school).

Two studies examine the effect on the (cognitive) functioning of adults immediately after the switch to summer time. The studies do not focus specifically on work situations. In an Australian study, no differences in test results for cognitive functioning and risk-taking behaviour were found after the switch to summer time (Schaffner, Sarkar et al. 2018). In this study, cognitive functioning (alertness and attention) and risk-taking behaviour in general were investigated, not specifically in work situations. Participants from two neighbouring Australian states were compared: Queensland, with no switch to summer time (n = 91) and New South Wales (n = 47) with a switch to summer time. All the participants lived close to the border between the two states. Participants took online tests at three separate times: one week before the start of the summer time, on the day of the switch and one week after the switch. No differences in cognitive functioning and risk-taking behaviour were found in the test results between the three measurements. One disadvantage of this study is the small number of participants involved; its strengths, on the other hand, include the presence of a control group in a similar geographical location and the fact that a correction was applied for the time of the day at which testing was carried out.

In a US study, an increase in the percentage of non-work-related internet use was found on the Monday following the switch to summer time (Wagner, Barnes et al. 2012). The researchers used data from google.com in 203 urban areas in the US from 2004-2009 for this. They compared the data on the Mondays before the switch, immediately after the switch and the week after the switch to summer time. This included data over 3,492 days in total. There appears to be an increase of 3.1% in non-work-related internet use on the Monday after the switch to summer time compared to the previous Monday, and 6.8% more than the Monday one week later. It is not known whether this internet use actually takes place in the workplace, and therefore whether there is actually any effect on labour productivity.

In summary, there is not enough evidence to confirm any possible relationship between school performance and (the switch to) summer time. Two studies indicate that (the switch to) summer time may be related to lower cognitive performance among high school students. One study involved a chronic effect and the other study an acute effect.

However, the number of studies is limited and there are significant reservations with respect to the results of both studies. The two studies among adults showed no clear relationship between cognitive functioning and productivity after the switch to summer time, although the studies were not carried out in work situations.

Accidents at work
Four studies investigated the relationship between work-related accidents and the switches to and from summer time. All of these studies focused on acute effects after both switches. All studies were based on accident registration data.

In one study, an increase in work accidents in mines in the US was found after the switch to summer time (Barnes and Wagner 2009). For this, 576,292 registered accidents were investigated between 1983 and 2006. The number of accidents on the Monday following the switch was compared with accidents on all other working days. After the switch to summer time, the number of accidents increased by 5.7% (an average of 3.6 accidents). There was an increase of 67.6% in missed workdays due to these accidents. Work experience did not appear to play any role in this. No increase or decrease in accidents was found following the switch to standard time. In a second study in the article by Barnes et al. (2009), sleep duration on the Mondays following the switch was also investigated in a different population; see section 3.1.1.1 for that.

In three other studies, no effects were found on the number of accidents at work after the switches to and from summer time. In a Finnish study, work-related accidents in Finland were investigated in the week before and after the switches to summer time and standard time (Lahti, Sysi-Aho et al. 2011). This was based on registered accidents between 2002 and 2006 around the time of the switches to summer time (n = 7,716) and standard time (n = 6,435). There were no differences in the number of accidents before and after both switches. In Ontario (Canada), work-related accidents were investigated using registered injuries around the time of both switches (Morassaei and Smith 2010). A distinction was made between the number of accidents with and without the loss of working days (n = 69,336 and 130,510 around the switch to summer time and n = 95,304 and 173,796 around the switch to standard time, respectively). No differences were found in the number of accidents in the week before and after the switches to summer time and standard time. Finally, accidents involving construction workers in Washington were investigated based on registered injuries (Holland 2000). In addition, the number of accidents on the Monday immediately following both switches was compared with the numbers on the Mondays before and after between 1990 and 1996 (n = 4,000). The number of accidents from the Monday to Friday before the switches was also compared with the numbers during the Monday to Friday following the switches. No significant differences were found before or after the switches.

In summary, no evidence has been found for an increase in accidents at work immediately after either of the switches. In one of the four studies, an increase in workplace accidents in mines was found after the switch to summer time, but the other three studies showed no effects.

3.1.5 *Physical activity*

Four studies investigated the effects of the switches between summer time and standard time on various forms of physical activity. Three studies only related to the switch to summer time; in one study, the switch to standard time was also included. Data on physical activity were collected using accelerometers (one study), infrared observations (one study) and self-reporting (two studies). In one study, the acute effects were investigated immediately around the time of the switch; the other studies focused on the long-term effects of summer time.

In a study of physical activity patterns in children, a small increase in evening physical activity was found after the start of summer time (Goodman, Page et al. 2014). The physical activity patterns of 439 children from nine different countries were compared in the weeks before and after the switches to summer time and standard time. The data was collected with accelerometers. At the time of the switch to summer time, there was an increase of two minutes or more in moderate to intensive physical activity in the evening between 5 and 9 p.m. At the time of the switch to standard time, there was a decrease of two minutes. There were no differences during the daytime.

In a study in Indianapolis, an increase in the use of city paths by non-motorised traffic was found after the switch to summer time (Holmes, Lindsey et al. 2009). Using infrared observations (n = 22,007), users of the paths were counted before and after the switch. After the start of summer time, the use of the paths increased by 2.5%. The weather conditions and temperature were taken into account. Because in this study the entire summer time period is compared to standard time, it is not possible to exclude seasonal effects, despite extensive correction for weather conditions.

In one study, differences in physical activity between residents of American states with and without switches to and from summer time were investigated (Zick 2014). No differences were found. This involved a comparison of a total of 2,411 adult residents of Arizona (no summer time) and Colorado, New Mexico and Utah (with summer time). These states all share the same time zone and are similar in geographic location and climate. The focus was on self-reported physical activity of moderate to high intensity during the summer time period. Both the duration and the probability that participants engaged in moderate to high-intensity physical activity did not vary between states with and without switching between standard and summer time twice a year.

In a study into self-reported physical activity in New Zealand during summer time, no overall increase or decrease was found after the switch (Rosenberg and Wood 2010). In this study, self-reported physical activity (time and duration) was investigated in 1,083 adults during the switch to summer time. More than a quarter of the participants (27%) indicated more physical activity during the summer time; just under a quarter reported less physical activity (22%), and more than half reported no difference. The average number of exercise sessions decreased during summer time period.

The two studies which showed a positive relationship between physical activity and the switch to summer time used objective measurements of physical activity with accelerometers and infrared measurements, respectively.

In summary, only one of the four studies investigated and described the acute effect of the switch to summer time: children were shown to be physically active for two minutes longer in the evening. The other studies investigated chronic effects over the whole summer time period, so seasonal effects may have played a role. Two of these three studies showed no clear effect; a third study showed an increase in the use of city paths during the summer time period. These studies provide insufficient evidence of any significant effect of the switch to summer time on physical activity.

3.2 Effects of longitude and permanent summer time or standard time

In order to investigate the positive and negative health effects of permanent summer time or permanent standard time, the scientific literature was searched for the effects of these time settings on the same outcome measures as in section 3.1. The effect on these outcome measures was also investigated in the case of a difference in longitude within a time zone and when both sides of a time zone boundary are compared. For an explanation of these study designs, see 1.3.3.2 and Figure 2.

3.2.1 Difference in longitude (east-west): sleep

There are two studies that have investigated whether a difference in longitude between places in the same time zone influences sleep. One study examined young people from Eastern Germany (Leipzig, 12° East) and Western Germany (Stuttgart, 9° East) (n = 674; 10-16 years) (Randler 2008). By way of illustration, the difference in longitude between the two test locations corresponds to an approximately 12-minute difference in the time at which the sun rises. The other study examined 18,639 US adults living within 250 miles east or west of one of the time zone boundaries (Pacific–Mountain, Mountain–Central and Central–Eastern); in areas which switch from and to summer time (Giuntella and Mazzonna 2019). Both studies examined self-reported sleep duration and sleeping times.

German youngsters who live further west in the time zone sleep for a shorter time on working days (24 minutes less per day on average) (Randler 2008). There is no difference in sleep duration at weekends. Youngsters who live further west go to bed later and get up later during the weekend. This effect is not evident on weekdays. The US study shows that working adults who live to the east of a time zone boundary sleep an average of 19 minutes less than workers who live to the west of that time zone boundary (Giuntella and Mazzonna 2019). The participants who lived on the eastern side also often sleep for less than eight hours (7.8 percentage points less likely to sleep at least eight hours). This effect on sleep duration is not found in participants who do not work. Both working and non-working people who live on the eastern side of a time zone boundary go to bed later. Small effects are also visible with respect to sleep quality, with sleep quality slightly worse for people living on the eastern side of a time zone boundary. These analyses took account of a large number of demographic factors that could influence sleep.

The number of studies into the effects of longitude and time zone boundaries on sleep is limited, with only two studies having been done. However, both studies show that the relative position within the time zone does influence sleep, with a more westerly location within a time zone or living to the east of a time zone boundary being associated with shorter sleeping times, later sleeping times and lower sleep quality. The position relative to the reference, further west in a time zone or to the east of a time zone boundary, is an approximation for effects that may occur if permanent summer time were to be applied.

3.2.2 Difference in longitude (east-west): health effects and illnesses

Four studies have investigated whether a difference in longitude (east-west position) between locations in the same time zone influences health. In addition, one study has focused on health differences due to the east-west position relative to a time zone boundary and one study investigated the effect of the time of sunrise.

Obesity and self-reported health
The same American study that investigated the effects on sleep (3.2.1) also describes the relationship between the east-west position with respect to the time zone boundaries between "Pacific–Mountain", "Mountain–Central", "Central–Eastern” and overweight/obesity (n = 4,331) and self-reported health (n = 9,696) (Giuntella and Mazzonna 2019). Workers to the east of a time zone boundary are 6.9 percentage points more likely to be overweight and 5.6 percentage points more likely to be obese than those who work to the west of a time zone boundary. Also, a higher percentage of workers to the east of a time zone boundary report poor health, but these differences are not significant. These analyses adjusted for a large number of demographic factors and cultural background.

Cancer and life expectancy
Three studies have been conducted in which a link between the incidence of cancer and position in a time zone was found. Overall life expectancy was also included in one study. This study (Borisenkov 2011) investigated the influence of the position in the time zone (east-west differences) on life expectancy in the 59 regions of the European part of the Russian Federation (EPRF) and 31 regions of China. The analysis included effects on latitude and gross national product. In addition to these other influences, east-west differences caused an additional variation in life expectancy. This variation is 4% for women and 3% for men in the EPRF. In China, the variation in life expectancy due to east-west differences is 15% for women and 18% for men. The life expectancy of residents in regions in the east of a time zone is higher than in the regions in the west of a time zone. This effect was stronger in the Chinese area, which can be explained by the fact that the time zone in China is 60° latitude wide, compared to only 30° in the EPRF. The position of a region in the time zone also appears to be a predictor for the incidence and mortality of specific cancers, with higher incidences and mortality in regions on the western side of the time zone.

These results are partly confirmed in research among the US population (Gu, Xu et al. 2017). This study uses data from 4 million registered cancer diagnoses among white residents of 607 regions in eleven states in the US. The influence of east-west differences on the incidence of 23 types of cancer within a time zone was investigated. The study was performed at intervals of five degrees of latitude, which corresponds to a 20-minute difference in sunrise. The data was corrected for latitude, poverty, smoking and the state of residence. The results show that cancer is more common among residents in the western part of the time zone and that this is the case for many types of cancer.

The relationship between the incidence of cancer (hepatocellular carcinoma; HCC) and position in the time zone was investigated in 56,347 cases between 2000 and 2014 in the US (Vopham, Weaver et al. 2018). The average age of the patients was 62 years and the data in the basic analysis model was corrected for age, gender, ethnicity and year of diagnosis. The extensive analysis model also included the following factors: region, health status, lifestyle factors (alcohol, physical activity, overweight and smoking), working at night, socio-economic status, and environmental factors (including UV radiation and air pollution). For every five degrees of longitude further to the west, there is an increase in the relative risk of HCC occurring. This effect was found in people younger than 65 years.

In summary, all three studies indicate that people in the west of a time zone are more likely to contract cancer, that cancer mortality is higher and that overall life expectancy is lower than in the eastern side of a time zone.

Depression
The influence of position within a time zone on mental health is discussed in two publications. In Northern Russia, a relationship between the prevalence of winter depression and the east-west position was investigated in a group of 3,435 young people between the ages of 10 and 20 years (Borisenkov, Petrova et al. 2015), of whom 8.4% and 11.8% suffered from winter depression and sub winter depression, respectively. East-west position appeared to predict the occurrence of winter depressions to a significant extent. The relative risk of winter depression was greater in the western part of a time zone than in the eastern part. These analyses take into account age, gender, research month and latitude. Contrasting findings are reported by Olders (2003). In this study, the prevalence of depression decreased with a later sunrise, which is an approximation of summer time (Olders 2003). Two registers of depression were used for this: one in nine European cities including elderly persons, and one in adults in five US cities, with the assumption that each subgroup wakes at the same time according to the social clock. However, this research has a number of serious limitations: 1. Cultural differences may lead to differences in time of waking between regions; 2. The European cohort consisted of people over the age of 65, who would not be expected to wake up according to the social clock, unlike working people and students, but more on the basis of their biological clock; 3. No factors were integrated into the analyses in order to explain differences in depression between countries, such as

the amount of daylight and latitude. Cultural and socio-economic factors can also influence the prevalence of depression.

In summary, the two studies on depression produce contradictory findings, with the study of sunrise and depression involving so many limitations that no meaningful conclusions can be drawn. The studies also use a different design and focus on different variants of depression in different groups: winter depression among young people versus various forms of clinical depression in adults and the elderly.

3.2.3 Permanent standard time or permanent summer time

There is one study that compared the three different time settings with respect to social jet lag (Borisenkov, Tserne et al. 2017). Seasonal mood disorders and school performance were also investigated. Cross-sectional data over three different time periods in Russia was used for this, with the following three different time settings being used consecutively: 2009-2010: switches between summer time and standard time; 2011-2014: permanent summer time; 2015-2016: permanent standard time. Only young people were studied (10-24 years; n = 7,968). During the period with permanent summer time, the number of young people with social jet lag was compared with permanent standard time and a system with switches between summer time and standard time. The number of young people with social jet lag of >1 hour is 6.7% higher during permanent summer time; the number of young people with a social jet lag of >2 hours is 16.3% higher compared to the other two time settings. This effect was apparent during the entire measurement period (2011-2014). Corrections were made for various factors that can influence sleep: gender, age, BMI, school start times, latitude and longitude of place of residence, size of place of residence, month and year of data collection, time of sunrise and day length. There was no difference in the average sleep duration per week. No differences in school performance were found either. The authors did find an increase in mood problems in the winter with permanent summer time compared to the other time settings. The authors show that the effect on social jet lag can be explained by young people waking later at the weekend, when they catch up on sleep during permanent summer time. However, sleep duration is not described specifically for working days or weekend days. The authors suggest that the effects may be greater, depending on the north-south position of the city, with the effect of permanent summer time on social jet lag being greater in more northerly cities; however, more research is needed in this regard. All of the cities examined in this study were located in a more northerly position than the Netherlands, making direct comparison difficult. A negative effect on mood problems in the winter has also been found. Unfortunately, the above study is the only study that has compared the three different possible time settings. The differences between the years in which switches were made between standard time and summer time twice a year and the years of permanent standard time were minimal. Overall, including all the different variables, permanent standard time seems to be slightly more beneficial for social jet lag and winter mood problems, compared to the period with switches between standard time and summer time. A direct comparison between a time setting with switches between standard time and summer time and permanent standard time is complicated by the fact that both periods were separated from each other by four years. In particular, this study indicates that permanent summer time, or a shift of time zone to the east, has negative effects on sleep and specifically the incidence of social jet lag.

3.3 Effects of commuting across a time zone boundary

In order to investigate the health effects for cross-border commuters if the Netherlands were to adopt a different time setting than neighbouring countries Germany and Belgium, the literature was searched for studies on time zone commuters, i.e. people who frequently cross a single time zone boundary, for example in order to get to work. The search strategy from this type of research yielded no relevant literature. An additional in-depth search strategy yielded no additional literature either. Based on the current research, it is therefore not possible to make any statements about the potential health effects of the adoption of a different time setting in the Netherlands compared to its neighbours.

4 Discussion

4.1 Research questions

RIVM was asked to provide an overview and explanation of the evidence presented in scientific literature regarding three research questions on the health effects of (switching between) summer time and standard time. The results will now be discussed with respect to each research question.

4.1.1 Positive and negative health effects of different time settings

The first research question concerns positive and negative health effects of the three time setting options: (1) maintaining current time setting, (2) permanent summer time and (3) permanent standard time.

4.1.1.1 Health effects of maintaining the current time setting

Maintaining the current time setting means that there is a switch between standard time and summer time twice a year. The highest number of studies were found about this time setting in the literature study (see 3.1). A few studies described multiple outcome measures within one study. Thirteen studies were found on the effects of the switches on sleep or social jet lag, nineteen on the effects on different illnesses and disorders, six on the effects on other health measures, four on cognitive functioning, four on work-related accidents and four on the effects on physical activity.

Sleep

Various aspects of sleep, such as sleep duration, sleep quality and social jet lag, were included in this study as indicators of possible health effects. The results of the literature study indicate a decrease in sleep duration immediately after the switch to summer time. It is unknown how long this effect lasts. The effects are less clear when switching to standard time. Sleeping times are also influenced by switching to and from summer time: people seem to get up later after the switch to summer time and to get up earlier after the switch to standard time. In other words, they do not adjust completely to the new clock time immediately. People’s usual sleeping patterns (chronotype and short / long sleeper) play a role in this. Effects have also been found on quality of sleep and daytime sleepiness. Sleep efficiency seems to decrease temporarily immediately after the switch to standard time, but whether there is an effect around the switch to summer time is less clear. Immediately after the switch to summer time, an increase in sleepiness is found. No conclusions can be drawn about the effect of the switches on social jet lag due to the lack of good (statistical) data and controls for seasonal effects.

Health and diseases

Some of the studies on health and diseases addressed the effect of the switches to and from summer time, but others did not. The switch between summer time and standard time affects the incidence of heart attacks. The effect is greatest after the switch to summer time. Certain subgroups seem to be at greater risk, such as patients on certain cardiac medication. Some studies also show differences between men and women in the incidence of heart attacks after the switch to and from summer time, as well as between patients who are younger and older than 65 years. Whether the switch to summer time has an effect on mortality as a result of cardiovascular disease cannot be concluded with certainty. The switch to standard time has no effect on mortality due to cardiovascular disease.

There is no evidence that switching between summer time and standard time leads to higher incidence of mental illness, suicides or suicide attempts immediately after the switch. Nor were any clear effects found on (the symptoms of) brain disorders. There are also some indications in the literature that the switch to summer time has a negative effect on various aspects of health, including specific mortality rates, loss of pregnancy in cases of IVF, and feelings of well-being. However, each of these effects concern only one study, and the strength of the evidence is insufficient to draw any firm conclusions.

Physical activity
In addition to the effects on sleep and health, studies also examined whether the switches to and from summer time have an effect on people's physical activity patterns. In one study, the acute effect of the switches on physical activity was investigated; the other three studies focused on chronic effects over the whole summer time period, with seasonal effects playing a role. These studies provide insufficient evidence of any substantial effect of switching between summer time and standard time on physical activity.

Labour productivity, safety at work, performance at school
There is not enough evidence from the literature to demonstrate a relationship between young people’s school performance and the switches to and from summer time. No studies were found on adult labour productivity. The majority of the studies did not show any direct effect of the switches on accidents at work.

In summary, the current time setting, whereby we switch between summer time and standard time twice a year, is associated with disturbances in sleep immediately after these switches. However, it is unclear how long these effects last. And although adequate good-quality sleep is important for health, it is not known how significant the health effects of these disruptions are. Some acute health effects were found immediately after the switches. The increase in the incidence of heart attacks after the switch to summer time is the most obvious of these. It is unknown whether there are any cumulative health effects over the years due to the repeated switches between standard time and summer time.

4.1.1.2 Health effects of permanent standard time or summer time

Only one study was found that compared three different time settings in the same geographical area: switching between standard time and summer time, permanent standard time and permanent summer time. In this Russian study among young people, the outcome measures were social jet lag, seasonal mood problems and school performance (Borisenkov, Tserne et al. 2017) (see 3.2.3). One of the findings was that social jet lag increases with permanent summer time compared to both permanent standard time and switching between summer time and standard time. The authors also found an increase in mood problems in the winter with permanent summer time compared to the other time settings. It should be noted that although this study involved the same national population and region, it was not possible to correct for, for example, geo-political or economic changes during the period studied.

Several studies were found that were based on east-west differences within one time zone, or differences between two sides of a time zone boundary (see 1.3.3.2 and Figure 2 for explanation). These east-west differences have been investigated in different population groups, countries and for various sleep and health measures such as sleep duration and sleep quality, obesity, incidence of cancer and mortality, life expectancy and depression (see 3.2). The results of these studies show a consistent picture: in relation to these health outcomes, people benefit from living in the eastern side of the time zone rather than the western side; living on the western side is an approximation to permanent summer time. These results are therefore consistent with the findings of the Russian study mentioned previously with consecutive changes in the time setting, with permanent summer time leading to less favourable health outcomes compared to permanent standard time.

In short, public health seems to benefit the most from a relatively early sunrise within the adopted time zone. It is therefore recommended to take account of the geographical time zone in which people live, and not to adopt a standard time that belongs to a more easterly time zone. Figure 3 shows the lines of longitudes on the map of Europe, which indicate the geographical time zone borders with respect to the prime meridian at Greenwich on UTC. Geographically, the Netherlands is in the time zone of the prime meridian, but it adopted the Central European time (UTC+1) as its standard time. This means that the Netherlands is on the western side of its adopted time zone. If the Netherlands were to adopt UTC as its standard time, it would be on the eastern side of its time zone, which would be more favourable from a health perspective. Permanent summer time (UTC+2) would place the Netherlands on the extreme west of its time zone, and would therefore be strongly discouraged on the basis of the negative health effects found.

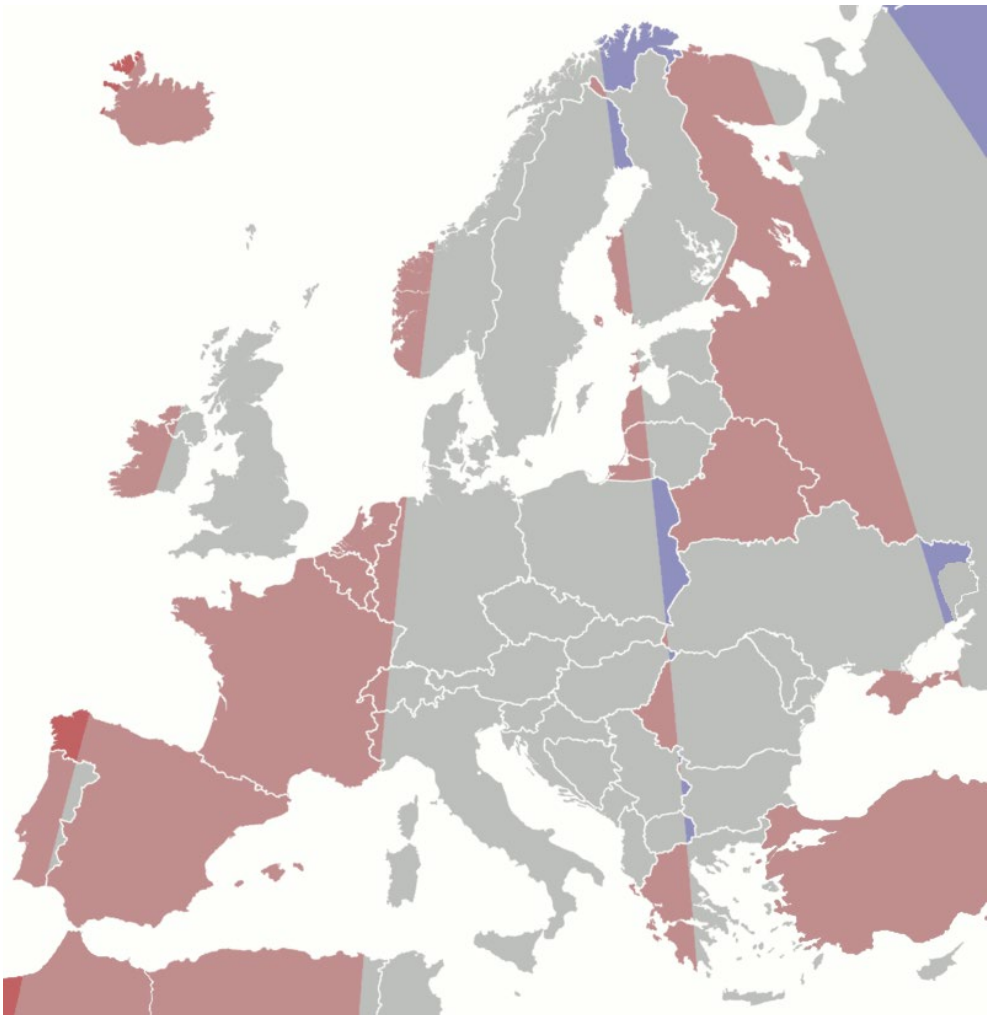

Figure 1. Geographical time zones in Europe and differences with current time settings during the winter (standard time)[14]. 1 h ± 30 min behind; 0 h ± 30 min; 1 h ± 30 min ahead; 2 h ± 30 min ahead

It is to be expected that adopting permanent standard time would benefit public health by eliminating the negative effects of switching between standard time and summer time twice a year. It is, however, important to realise that all the findings reported originate in other countries. For this reason, there remains some uncertainty regarding the specific health effects of permanent standard time in the Netherlands.

4.1.2 *Positive and negative health effects of different time settings than neighbouring countries*

The second research question addresses the positive and negative effects on health if the Netherlands were to adopt a different time setting than its neighbours Germany and Belgium.

[14] Source: https://commons.wikimedia.org/wiki/File:Tzdiff-Europe-winter.png; Version:May 18 , 2019.

In the border regions of the Netherlands, around 10,000 Dutch people travel to work in Belgium and around 11,000 Dutch people work in the German states of Lower Saxony and North Rhine-Westphalia (2014 estimate). Conversely, around 38,000 Belgians and around 34,000 Germans travel to the Netherlands to work[15]. Assuming a population of 17 million inhabitants, 0.12% of the Dutch population are cross-border commuters. If the border with Germany and/or Belgium were to become a time zone boundary, these people would become time zone commuters and have to arrange their lives based in part on the different time setting in the country where they work.

The current literature search yielded no relevant literature to describe possible health effects of such a situation. The fact that no research has been done on this subject does not mean that there are no health effects associated with time zone commuting. It is expected that time zone commuters can be identified around existing time zone boundaries in various locations around the world, and in combination with health data these could provide a source of data to investigate this research question. For the time being, this seems to be an underexplored area of research.

4.1.3 Considerations with respect to time settings in neighbouring countries

The third research question regards which effects would be more significant: the effects of the three time settings discussed under 4.1.1, or the effects that arise from adopting a different time setting to neighbouring countries (4.1.2).

Based on the existing literature, no conclusions can be drawn regarding health differences for cross-border commuters (4.1.2). For this reason, this research question cannot be answered.

4.2 Conclusion

The current practice of switching twice a year between standard time (UTC+1) and summer time (UTC+2) is associated with acute sleep disturbances and health effects, of which the increase in heart attacks is the most obvious when the clocks are put forward in the spring. The acute effects identified would disappear if a permanent time setting were chosen. In relation to such a decision, permanent standard time (UTC+1) would, from a health perspective, clearly be preferable to permanent summer time (UTC+2) and it would even be worth to consider adopting Greenwich Mean Time (UTC+0) in the Netherlands.

[15] Source CBS: https://www.cbs.nl/nl-nl/achtergrond/2017/07/factsheet-grensoverschrijdende-arbeid

5 References

Allebrandt, K. V., M. Teder-Laving, T. Kantermann, A. Peters, H. Campbell, I. Rudan, J. F. Wilson, A. Metspalu and T. Roenneberg (2014). "Chronotype and sleep duration: the influence of season of assessment." Chronobiology international **31**(5): 731-740.

Barnes, C. M. and D. T. Wagner (2009). "Changing to Daylight Saving Time Cuts Into Sleep and Increases Workplace Injuries." Journal of Applied Psychology **94**(5): 1305-1317.

Berk, M., S. Dodd, K. Hallam, L. Berk, J. Gleeson and M. Henry (2008). "Small shifts in diurnal rhythms are associated with an increase in suicide: The effect of daylight saving." Sleep and Biological Rhythms **6**(1): 22-25.

Borisenkov, M. F. (2011). "Latitude of residence and position in time zone are predictors of cancer incidence, cancer mortality, and life expectancy at birth." Chronobiology International **28**(2): 155-162.

Borisenkov, M. F., N. B. Petrova, V. D. Timonin, L. I. Fradkova, S. N. Kolomeichuk, A. L. Kosova and O. N. Kasyanova (2015). "Sleep characteristics, chronotype and winter depression in 10-20-year-olds in northern European Russia." J Sleep Res **24**(3): 288-295.

Borisenkov, M. F., T. A. Tserne, A. S. Panev, E. S. Kuznetsova, N. B. Petrova, V. D. Timonin, S. N. Kolomeichuk, I. A. Vinogradova, M. S. Kovyazina, N. A. Khokhlov, A. L. Kosova and O. N. Kasyanova (2017). "Seven-year survey of sleep timing in Russian children and adolescents: chronic 1-h forward transition of social clock is associated with increased social jetlag and winter pattern of mood seasonality." Biological Rhythm Research **48**(1): 3-12.

Čulić, V. (2013). "Daylight saving time transitions and acute myocardial infarction." Chronobiology International **30**(5): 662-668.

Dibner, C., U. Schibler and U. Albrecht (2010). "The mammalian circadian timing system: organization and coordination of central and peripheral clocks." Annu Rev Physiol **72**: 517-549.

Ferrazzi, E., C. Romualdi, M. Ocello, G. Frighetto, M. Turco, S. Vigolo, F. Fabris, P. Angeli, G. Vettore, R. Costa and S. Montagnese (2018). "Changes in Accident & Emergency Visits and Return Visits in Relation to the Enforcement of Daylight Saving Time and Photoperiod." J Biol Rhythms **33**(5): 555-564.

Fetter, D., R. Lefaucheur, A. Borden and D. Maltête (2014). "Parkinson's patients cope with daylight saving time." Revue Neurologique **170**(2): 124-127.

Gaski, J. F. and J. Sagarin (2011). "Detrimental effects of daylight-saving time on SAT scores." Journal of Neuroscience, Psychology, and Economics **4**(1): 44-53.

Giuntella, O. and F. Mazzonna (2019). "Sunset time and the economic effects of social jetlag: evidence from US time zone borders." J Health Econ **65**: 210-226.

Goodman, A., A. S. Page, A. R. Cooper, K. Kordas, R. Davey, R. R. Pate, J. Salmon, L. B. Andersen, K. Froberg, L. Sardinha, S. Anderssen, A. Timperio, K. F. Janz, S. Kreimler, P. Hallal, E. van Sluijs, G. P. Sutton, U. Ekelund and L. Sherar (2014). "Daylight saving time as a potential public health intervention: An observational study of evening daylight and objectively-measured physical activity among 23,000 children from 9 countries." International Journal of Behavioral Nutrition and Physical Activity **11**(1).

Grandner, M. A. (2017). "Sleep, Health, and Society." Sleep Med Clin **12**(1): 1-22.

Gu, F., S. Xu, S. S. Devesa, F. Zhang, E. B. Klerman, B. I. Graubard and N. E. Caporaso (2017). "Longitude position in a time zone and cancer risk in the United States." Cancer Epidemiology Biomarkers and Prevention **26**(8): 1306-1311.

Hansen, B. T., K. M. Sønderskhov, I. Hageman, P. T. Dinesen and S. D. Østergaarde (2017). "Daylight savings time transitions and the incidence rate of unipolar depressive episodes." Epidemiology **28**(3): 346-353.

Harrison, Y. (2013). "Individual response to the end of Daylight Saving Time is largely dependent on habitual sleep duration." Biological Rhythm Research **44**(3): 391-401.

Heboyan, V., S. Stevens and W. V. McCall (2018). "Effects of seasonality and daylight savings time on emergency department visits for mental health disorders." Am J Emerg Med.

Holland, N. H., J. (2000). "Daylight savings time changes and construction accidents." Journal of construction engineering and management: 404-406.

Holmes, A. M., G. Lindsey and C. Qiu (2009). "Ambient air conditions and variation in urban trail use." J Urban Health **86**(6): 839-849.

Janszky, I., S. Ahnve, R. Ljung, K. J. Mukamal, S. Gautam, L. Wallentin and U. Stenestrand (2012). "Daylight saving time shifts and incidence of acute myocardial infarction--Swedish Register of Information and Knowledge About Swedish Heart Intensive Care Admissions (RIKS-HIA)." Sleep Med **13**(3): 237-242.

Janszky, I. and R. Ljung (2008). "Shifts to and from daylight saving time and incidence of myocardial infarction." New England Journal of Medicine **359**(18): 1966-1968.

Jiddou, M. R., M. Pica, J. Boura, L. Qu and B. A. Franklin (2013). "Incidence of myocardial infarction with shifts to and from daylight savings time." American Journal of Cardiology **111**(5): 631-635.

Kantermann, T., M. Juda, M. Merrow and T. Roenneberg (2007). "The Human Circadian Clock's Seasonal Adjustment Is Disrupted by Daylight Saving Time." Current Biology **17**(22): 1996-2000.

Kirchberger, I., K. Wolf, M. Heier, B. Kuch, W. von Scheidt, A. Peters and C. Meisinger (2015). "Are daylight saving time transitions associated with changes in myocardial infarction incidence? Results from the German MONICA/KORA Myocardial Infarction Registry." BMC public health **15**: 778.

Koopman, A. D. M., S. P. Rauh, E. van 't Riet, L. Groeneveld, A. A. van der Heijden, P. J. Elders, J. M. Dekker, G. Nijpels, J. W. Beulens and F. Rutters (2017). "The Association between Social Jetlag, the Metabolic Syndrome, and Type 2 Diabetes Mellitus in the General Population: The New Hoorn Study." J Biol Rhythms **32**(4): 359-368.

Kountouris, Y. and K. Remoundou (2014). "About time: Daylight Saving Time transition and individual well-being." Economics Letters **122**(1): 100-103.
Lahti, T., J. Sysi-Aho, J. Haukka and T. Partonen (2011). "Work-related accidents and daylight saving time in Finland." Occupational Medicine **61**(1): 26-28.
Lahti, T. A., J. Haukka, J. Lönnqvist and T. Partonen (2008). "Daylight saving time transitions and hospital treatments due to accidents or manic episodes." BMC Public Health **8**.
Lahti, T. A., S. Leppämäki, J. Lönnqvist and T. Partonen (2006). "Transition to daylight saving time reduces sleep duration plus sleep efficiency of the deprived sleep." Neuroscience Letters **406**(3): 174-177.
Lahti, T. A., S. Leppämäki, J. Lönnqvist and T. Partonen (2008). "Transitions into and out of daylight saving time compromise sleep and the rest-activity cycles." BMC Physiology **8**(1).
Larcher, S., A. S. Gauchez, S. Lablanche, J. L. Pepin, P. Y. Benhamou and A. L. Borel (2016). "Impact of sleep behavior on glycemic control in type 1 diabetes: the role of social jetlag." Eur J Endocrinol **175**(5): 411-419.
László, K. D., S. Cnattingius and I. Janszky (2016). "Transition into and out of daylight saving time and spontaneous delivery: A population-based study." BMJ Open **6**(9).
Lindenberger, L. M., H. Ackermann and M. Parzeller (2018). "The controversial debate about daylight saving time (DST)-results of a retrospective forensic autopsy study in Frankfurt/Main (Germany) over 10 years (2006-2015)." Int J Legal Med.
Liu, C., J. A. Politch, E. Cullerton, K. Go, S. Pang and W. Kuohung (2017). "Impact of daylight savings time on spontaneous pregnancy loss in in vitro fertilization patients." Chronobiology international **34**(5): 571-577.
Lu, Y., N. Tian, J. Yin, Y. Shi and Z. Huang (2013). "Association between Sleep Duration and Cancer Risk: A Meta-Analysis of Prospective Cohort Studies." PLoS ONE **8**(9).
Manfredini, R., F. Fabbian, R. Cappadona, A. De Giorgi, F. Bravi, T. Carradori, M. E. Flacco and L. Manzoli (2019). "Daylight Saving Time and Acute Myocardial Infarction: A Meta-Analysis." J Clin Med **8**(3).
Manfredini, R., F. Fabbian, A. De Giorgi, R. Cappadona, G. Capodaglio and U. Fedeli (2019). "Daylight saving time transitions and circulatory deaths: data from the Veneto region of Italy." Intern Emerg Med.
Medina, D., M. Ebben, S. Milrad, B. Atkinson and A. C. Krieger (2015). "Adverse Effects of Daylight Saving Time on Adolescents' Sleep and Vigilance." Journal of Clinical Sleep Medicine **11**(8): 879-884.
Michelson, W. (2011). "Sleep Time: Media Hype vs. Diary Data." Social Indicators Research **101**(2): 275-280.
Monk, T. H. and L. C. Aplin (1980). "Spring and autumn daylight saving time changes: studies of adjustment in sleep timings, mood, and efficiency." Ergonomics **23**(2): 167-178.
Monk, T. H. and S. Folkard (1976). "Adjusting to the changes to and from Daylight Saving Time." Nature **261**(5562): 688-689.

Morassaei, S. and P. M. Smith (2010). "Switching to daylight saving time and work injuries in Ontario, Canada: 1993-2007." Occupational and Environmental Medicine **67**(12): 878-880.
Olders, H. (2003). "Average sunrise time predicts depression prevalence." Journal of Psychosomatic Research **55**(2): 99-105.
Randler, C. (2008). "Differences in sleep and circadian preference between Eastern and Western German adolescents." Chronobiology International **25**(4): 565-575.
Roenneberg, T., K. V. Allebrandt, M. Merrow and C. Vetter (2012). "Social jetlag and obesity." Curr Biol **22**(10): 939-943.
Rosenberg, M. and L. Wood (2010). "The power of policy to influence behaviour change: daylight saving and its effect on physical activity." Australian and New Zealand journal of public health **34**(1): 83-88.
Sandhu, A., M. Seth and H. S. Gurm (2014). "Daylight savings time and myocardial infarction." Open Heart **1**(1).
Schaffner, M., J. Sarkar, B. Torgler and U. Dulleck (2018). "The implications of daylight saving time: A quasi-natural experiment on cognitive performance and risk taking behaviour." Economic Modelling **70**: 390-400.
Scheffler, T. and C. C. M. Kyba (2016). Measuring social jetlag in Twitter data. Proceedings of the 10th International Conference on Web and Social Media, ICWSM 2016.
Schneider, A. M. and C. Randler (2009). "Daytime sleepiness during transition into daylight saving time in adolescents: Are owls higher at risk?" Sleep Medicine **10**(9): 1047-1050.
Schneider, L. D., R. E. Moss and D. M. Goldenholz (2019). "Daylight saving time transitions are not associated with increased seizure incidence." Epilepsia **60**(4): 764-773.
Shan, Z., H. Ma, M. Xie, P. Yan, Y. Guo, W. Bao, Y. Rong, C. L. Jackson, F. B. Hu and L. Liu (2015). "Sleep duration and risk of type 2 diabetes: A meta-analysis of prospective studies." Diabetes Care **38**(3): 529-537.
Shapiro, C. M., F. Blake, E. Fossey and B. Adams (1990). "Daylight saving time in psychiatric illness." Journal of Affective Disorders **19**(3): 177-181.
Sipilä, J. O. T., P. Rautava and V. Kytö (2016). "Association of daylight saving time transitions with incidence and in-hospital mortality of myocardial infarction in Finland." Annals of Medicine **48**(1-2): 10-16.
Sipilä, J. O. T., J. O. Ruuskanen, P. Rautava and V. Kytö (2016). "Changes in ischemic stroke occurrence following daylight saving time transitions." Sleep Medicine **27-28**: 20-24.
Tonetti, L., A. Erbacci, M. Fabbri, M. Martoni and V. Natale (2013). "Effects of transitions into and out of daylight saving time on the quality of the sleep/wake cycle: An actigraphic study in healthy university students." Chronobiology International **30**(10): 1218-1222.
Toro, W., R. Tigre and B. Sampaio (2015). "Daylight Saving Time and incidence of myocardial infarction: Evidence from a regression discontinuity design." Economics Letters **136**: 1-4.

Toth Quintilham, M. C., T. Adamowicz, E. F. Pereira, M. Pedrazzoli and F. M. Louzada (2014). "Does the transition into daylight saving time really cause partial sleep deprivation?" Annals of human biology **41**(6): 554-560.

Umbach, R., A. Raine and G. Ridgeway (2017). "Aggression and sleep: a daylight saving time natural experiment on the effect of mild sleep loss and gain on assaults." Journal of Experimental Criminology **13**(4): 439-453.

Vopham, T., M. D. Weaver, C. Vetter, J. E. Hart, R. M. Tamimi, F. Laden and K. A. Bertrand (2018). "Circadian misalignment and hepatocellular carcinoma incidence in the United States." Cancer Epidemiology Biomarkers and Prevention **27**(7): 719-727.

Wagner, D. T., C. M. Barnes, V. K. Lim and D. L. Ferris (2012). "Lost sleep and cyberloafing: Evidence from the laboratory and a daylight saving time quasi-experiment." The Journal of applied psychology **97**(5): 1068-1076.

Wang, D., W. Li, X. Cui, Y. Meng, M. Zhou, L. Xiao, J. Ma, G. Yi and W. Chen (2016). "Sleep duration and risk of coronary heart disease: A systematic review and meta-analysis of prospective cohort studies." International Journal of Cardiology **219**: 231-239.

Wittmann, M., J. Dinich, M. Merrow and T. Roenneberg (2006). "Social jetlag: misalignment of biological and social time." Chronobiol Int **23**(1-2): 497-509.

Yong, M., D. Fischer, C. Germann, S. Lang, C. Vetter and C. Oberlinner (2016). "Are chronotype, social jetlag and sleep duration associated with health measured by Work Ability Index?" Chronobiol Int **33**(6): 721-729.

Zhai, L., H. Zhang and D. Zhang (2015). "Sleep duration and depression among adults: A meta-analysis of prospective studies." Depression and Anxiety **32**(9): 664-670.

Zick, C. D. (2014). "Does Daylight Savings Time encourage physical activity?" Journal of physical activity & health **11**(5): 1057-1060.

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Appendix 1 - General search strategy

PubMed
Performed on 29 April 2019

Search	Query	Items found
#19	Search (#18 AND 1989:2019[dp])	416
#18	Search (#17 AND (english[Language] OR dutch[Language]))	427
#17	Search (#1 OR #16)	462
#16	Search (#5 AND #8 AND #15)	344
#15	Search (#10 OR #11 OR #12 OR #13 OR #14)	16020504
#14	Search (sleep[ti] OR health[ti] disease*[ti] OR illness*[ti] OR risk[ti] OR time[ti] OR cancer[ti] OR oncolog*[ti] OR metastas*[ti] OR tumor*[ti] OR neoplasm*[ti] OR cardiovascular*[ti] OR mood*[ti] OR depressi*[ti] OR sport*[ti] OR social jetlag*[tiab] OR social jet lag*[tiab])	2257084
#13	Search "Leisure Activities"[Mesh]	221012
#12	Search "Public Health"[Mesh]	7320305
#11	Search "Diseases Category"[Majr]	12570141
#10	Search ("Sleep Disorders, Circadian" OR ("Sleep"[mj] AND sleep[ti]))	43250
#9	Search (#6 OR #7 OR #8)	379624
#8	Search (daylight[tiab] OR sunlight[tiab] OR summer[tiab] OR season*[tiab] OR time zone[tiab] OR time zones[tiab] OR longitude[tiab])	186650
#7	Search "Light"[mj] OR "Sunlight"[Mesh]	150845
#6	Search "Seasons"[Mesh] OR Time[mj] OR "Time Factors"[mj]	115422
#5	Search #2 OR #3 OR #4	3449
#4	Search "Circadian Rhythm/physiology"[mj] AND "Seasons"[mj]	265
#3	Search "Chronobiology Disorders"[Mesh]	3043
#2	Search circadian disrupt*[ti] OR circadian misalignment*[ti]	208
#1	Search daylight saving*[tiab]	127

Scopus
Performed on 29 April 2019

TITLE-ABS-KEY ((daylight W/3 sav*) OR (day-light W/3 sav*)) AND TITLE-ABS-KEY (health OR disease* OR illness* OR cancer OR oncolog* OR metastas* OR tumor OR neoplasm* OR cardiovascular* OR mood* OR depress* OR time-zone* OR (time W/3 factor*) OR longitude* OR risk OR sleep* OR social-jetlag* OR social-jetlag*) AND PUBYEAR > 1988 AND LANGUAGE (english OR dutch)

154 document results

Embase
Performed on 25 April 2019

Query	Results	No.
#40	#39 AND ('article'/it OR 'editorial'/it OR 'letter'/it OR 'review'/it)	835
#39	(#35 OR #37) AND ([dutch]/lim OR [english]/lim) AND [1989-2019]/py	1,031
#38	#35 OR #37	1,295
#37	#34 NOT #36	1,217
#36	#34 AND [animals]/lim	418
#35	#34 AND [humans]/lim	1,174
#34	#2 OR #18 OR #22 OR #27 OR #31 OR #33	1,635
#33	#24 AND #32	175
#32	sun:ti OR sunlight:ti OR winter:ti OR summer:ti OR daylight:ti	23,860
#31	#29 AND #30	512
#30	'circadian*':ti	26,562
#29	#26 AND #28	1,634
#28	'biological rhythm'/exp/mj	47,866
#27	#24 AND #26 AND 'review'/it	187
#26	#8 OR #9 OR #10 OR #25	116,806
#25	'time zone*':ti OR 'longitude'/exp/mj OR 'longitude':ti	172
#24	#23 AND (#8 OR #9 OR #10 OR #11 OR #12 OR #13 OR #16)	6,913
#23	'chronobiology'/exp/mj	59,477
#22	(#1 OR #3 OR #4 OR #7 OR #21 OR 'time zone*':ti OR 'longitude'/exp/mj OR 'longitude':ti) AND (#8 OR #9 OR #10 OR #11 OR #12 OR #13 OR #16)	826
#21	#5 AND (#19 OR #20)	3,495
#20	'sleep disorder'/exp/mj	93,263
#19	'sleep'/exp/mj	89,028
#18	#5 AND #17	76
#17	'oncological parameters'/exp/mj	268,892
#16	#14 AND #15	150,513
#15	'danger, risk, safety and related phenomena'/exp	2,820,568
#14	'medical parameters'/exp/mj	1,307,323
#13	'occupational health'/exp OR 'occupational disease'/exp OR 'occupation and occupation related phenomena'/exp/mj	513,307
#12	'diseases'/exp/mj/dm_ep,dm_et	2,601,074
#11	'physical activity, capacity and performance'/exp/mj OR 'social jetlag'	310,722
#10	'seasonal variation'/exp OR 'season'/mj	67,357
#9	'winter'/exp OR 'summer'/exp	47,617
#8	'sunlight'/exp	16,179
#7	#5 AND #6	172
#6	'sleep pattern'/exp/mj	3,060
#5	'circadian rhythm'/exp/mj OR 'photoperiodicity'/mj	44,688
#4	'circadian disrupt*':ti	195
#3	'circadian misalignment*':ti	95
#2	'daylight saving time'/exp OR ((daylight NEAR/3 sav*):ti)	119
#1	(daylight* NEAR/3 sav*):ti,ab	173

Appendix 2 - Specific search strategy for living and working situations around time zone boundaries

Embase
Performed on 14 July, 2019

Query	Results	No.
#17	#10 OR #11 OR #14 OR #16	229
#16	#12 AND #15	116
#15	work*:ti,ab OR 'health':ti,ab	3,627,024
#14	#12 AND #13	1
#13	'border':ti,ab OR 'frontier':ti,ab OR migra*:ti,ab	496,434
#12	#10 NOT #11	194
#11	('time zone*':ti OR 'longitude'/exp/mj OR 'longitude':ti) AND (#1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #9)	36
#10	('time zone*':ti,ab OR 'longitude'/exp/mj OR 'longitude':ti) AND (#1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #9)	230
#9	#7 AND #8	150,513
#8	'danger, risk, safety and related phenomena'/exp	2,820,568
#7	'medical parameters'/exp/mj	1,307,323
#6	'occupational health'/exp OR 'occupational disease'/exp OR 'occupation and occupation related phenomena'/exp/mj	513,307
#5	'diseases'/exp/mj/dm_ep,dm_et	2,601,074
#4	'physical activity, capacity and performance'/exp/mj OR 'social jetlag'	310,722
#3	'seasonal variation'/exp OR 'season'/mj	67,357
#2	'winter'/exp OR 'summer'/exp	47,617
#1	'sunlight'/exp	16,179

Scopus
Performed on 14 July, 2019

TITLE-ABS-KEY (time-zone-border)
2 document results

(TITLE-ABS-KEY (time-zone)) AND (TITLE-ABS-KEY (health OR sleep*)) AND TITLE-ABS-KEY (occupation* OR work*)
215 document results

TITLE-ABS-KEY (time-zone W/3 (occupation* OR work*))
130 document results

TITLE-ABS-KEY (time-zone*) AND TITLE-ABS-KEY (border*)
44 document results

TITLE (time-zone* OR longitude*) AND TITLE-ABS-KEY (occupation* OR work* OR social-jetlag OR health OR sleep*)
168 document results

TITLE (time-zone* OR longitude*) AND TITLE-ABS-KEY (border OR migra* OR frontier)
30 document results

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