

Laura Hiltunen

Completed and attempted suicides in relation to weather and daylight in Finland

Register based study from 1969 to 2010

RESEARCH



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Laura Hiltunen

**Completed and attempted
suicides
in relation to weather and
daylight in Finland**

**Register based study
from 1969 to 2010**

ACADEMIC DISSERTATION

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National Institute for Health and Welfare
Department of Mental Health and Substance Abuse Services
and
University of Helsinki, Department of Psychiatry
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Dedicated to life

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Abstract

Laura Hiltunen, Completed and attempted suicides in relation to daylight and weather in Finland, register based study from 1969 to 2010. National Institute for Health and Welfare. Research 134/2014. 70 pages. Helsinki, Finland 2014. ISBN 978-952-302-284-3 (printed); ISBN 978-952-302-285-0 (online publication)

In the Finnish suicide statistics, higher figures are seen during spring and summer months, from as early as in the 1850s. This seasonality of suicides has been shown in several countries, and it appears to be more evident the longer the distance from the equator is, on both hemispheres. For this phenomenon, recurrent patterns in social behaviour as well as in weather changes have been suggested. In this thesis, the suicide figures, as well as the numbers of attempted suicides were compared to weather variables and day length.

The suicide data were from the Finnish suicide register from 1969 to 2010. The data of attempted suicides were recorder in the hospitals in Helsinki during two periods: 1.1.1989 – 31.7.1990, and 15.1.1997 – 14.1.1998. Ambient temperature, sunshine hours, global solar radiation, atmospheric pressure, and precipitation were chosen as the possible explanatory variables. The national suicide rate was compared to the local weather variables on monthly and annual bases and in addition on a daily basis separately in the Helsinki, Jyväskylä, and Oulu regions. Furthermore, the suicide rate was compared to the changes in the length and timing of photoperiod. The numbers of attempted suicides were compared to the daily weather variables in Helsinki. Women and men were analysed in separate throughout the study.

Several statistically significant correlations were found. The correlations were more significant among men, in the Helsinki region, and especially during autumn and winter. Cumulative global solar radiation had an inverse correlation with the suicide rate especially between September and April, for both men and women. Furthermore, ambient temperature correlated with the suicide rate, especially the colder it had been, and most clearly during autumn and winter. However, the highest suicide rate was found between May 15 and July 25, and during that period no association to weather variables was found.

The number of attempted suicides correlated with atmospheric pressure, but the association was opposite between genders. The number of attempted suicides for men was higher during lower atmospheric pressure, while for women that was the case during higher atmospheric pressure.

The findings in this thesis are mostly in line with previous international results, which suggest that light and temperature may associate with the timing of suicides. However, the seasonality of suicides needs to be studied further.

Keywords: weather variables, season, local, gender, day length, time of equation

Tiivistelmä

Laura Hiltunen, Completed and attempted suicides in relation to daylight and weather in Finland, register based study from 1969 to 2010 [Itsemurhat ja itsemurhayritykset, sekä päivänvalo ja sää Suomessa, rekisteripohjainen tutkimus 1969-2010]. Terveiden ja hyvinvoinnin laitos. Tutkimus 134/2014. 70 sivua. Helsinki, Finland 2014. ISBN 978-952-302-284-3 (printed); ISBN 978-952-302-285-0 (online publication)

Suomea koskeissa itsemurhatilastoissa on 1800-luvulta lähtien nähtävissä että itsemurhakuolleisuus on ollut suurempaa kevät-kesällä muihin vuodenaikoihin verrattuna. Tämä vuosittain toistuva itsemurhakuolleisuuden vaihtelu on havaittu myös lukuisissa muissa maissa sitä selvemmin mitä kauempana päiväntasaajasta ollaan. Mahdollisia selityksiä on yritetty löytää sekä sosiaalisen kanssakäymisen että säätekijöiden vaihtelusta vuodenaikojen mukaan, mutta tulokset ovat olleet osin ristiriitaisia. Tässä väitöskirjassa tarkasteltiin itsemurhien ja itsemurhayritysten sekä sään ja päivänvalon ajallista yhteyttä Suomessa.

Väitöskirjan osajulkaisuissa käytettiin tilastotietoja Suomen itsemurhakuolleisuudesta vuodesta 1969 vuoteen 2010. Tiedot sairaalahoitoon johtaneista itsemurhayrityksistä oli kerätty Helsingin alueelta 1.1.1989 – 31.7.1990 ja 15.1.1997 – 14.1.1998. Säämuuttujina käytettiin ulkoilman lämpötilaa, auringonpaistetuntien määrää, auringon kokonaissäteilyä, ilmanpainetta ja sademäärää. Itsemurhakuolleisuutta verrattiin paikallisiin säämuuttujiin päivien, kuukausien ja vuoden pituisten jaksojen aikana koko Suomessa, sekä erikseen Helsingissä, Jyväskylässä ja Oulussa. Lisäksi tutkittiin vuorokauden valoisan ajan pituuden sekä sen ajoituksen vaihtelun yhteyttä itsemurhakuolleisuuteen. Itsemurhayritysten määrää verrattiin päivittäisiin säämuuttujiin Helsingissä. Kaikki analyysit tehtiin miehille ja naisille erikseen.

Väitöskirjan osajulkaisuissa todettiin useita tilastollisesti merkitseviä yhteyksiä säämuuttujien ja itsemurhakuolleisuuden välillä. Tilastolliset yhteydet olivat vahvempia miehillä ja paikallisesti Helsingin alueella, ja erityisesti syksyn ja talven aikana. Kumulatiivinen auringon globaalisäteilyn määrä yhdistyi käänteisesti itsemurhakuolleisuuteen syyskuun ja huhtikuun välillä, sekä miehillä että naisilla. Mitä suurempi säteilyn määrä oli, sitä vähemmän itsemurhia kertyi. Vuorokauden keskilämpötila yhdistyi itsemurhakuolleisuuteen siten, että mitä kylmempää oli, sitä pienempi oli itsemurhakuolleisuus, erityisesti syksyn ja talven aikana, miehillä ja naisilla. Korkeimman itsemurhakuolleisuuden aikana toukokuun 15. päivän ja heinäkuun 25. päivän välillä ei todettu tilastollista yhteyttä mihinkään yksittäiseen säätekijään.

Helsingin alueen sairaalahoitoon päätyneiden itsemurhayritysten ja päivittäisen keskimääräisen ilmanpaineen väliltä löytyi tilastollinen yhteys, joka oli vastakkainen sukupuolien välillä. Miesten päivittäisten itsemurhayritysten lukumäärä oli korkeampi matalapaineen aikana, mutta naisilla korkeapaineen aikana.

Väitöskirjan osajulkaisujen löydökset tukevat aiempia kansainvälisiä löydöksiä, joiden mukaan valolla ja lämpötilalla voi olla yhteys itsemurhakuoleman ajoitukseen. Itsemurhakuolleisuuden vuodenaikavaihtelun taustalla olevat tekijät vaativat kuitenkin vielä jatkotutkimuksia.

Avainsanat: säämuuttajat, alueellinen, sukupuoli, vuodenajat, päivän valoisan ajan pituus, päivän valoisan ajan rytmin vaihtelu

Sammandrag

Laura Hiltunen, Completed and attempted suicides in relation to daylight and weather in Finland, register based study from 1969 to 2010, [Sjävmord och Sjävmordsförsök i anslutning till dagsljus och väder i Finland, en studie utgående från information registrerad från 1969 till 2010]. Institutet för hälsa och välfärd. Forskning 134/2014. 70 sidor. Helsingfors, Finland 2014.

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I den finska självmordstatistiken kan man urskilja en ökning av självmordsiffrorna för vår- och sommarmånaderna redan från 1850-talet. Denna årstidsrytm har noterats i många länder, och den verkar bli mera utpräglad ju längre bort från ekvatorn man kommer. Olika rytmer i det sociala livet och till och med i vädret har föreslagits som förklaring för detta fenomen. I den här doktorsavhandlingen, har antalet självmord och antalet självmordsförsök jämförts med flera meteorologiska variabler.

Antalet självmord från 1969 till 2010 bygger på data från den Finska Statistikcentralen. Uppgifterna om antalet självmordsförsök är från sjukhus i Helsingfors under två perioder: 1.1.1989 - 31.7.1990 samt 15.1.1997 - 14.1.1998. Temperatur, antalet solskenstimmar, global solstrålning, lufttryck och nederbörd valdes som meteorologiska variabler. Antalet självmord jämfördes med lokala meteorologiska observationer för olika perioder så som en månad och ett år, på olika områden så som Helsingfors, Jyväskylä och Uleåborg. Härutöver, jämfördes antalet självmord med längden och tajmingen av dagsljus. Antalet självmordsförsök i Helsingfors jämfördes dessutom med dagliga lokala meteorologiska variabler. Alla statistiska analyser utfördes separat för kvinnor och män.

Flera statistisk signifikanta korrelationer hittades i den här doktorsavhandlingen. Korrelationerna var mera signifikanta för män, i Helsingfors-området, och speciellt under höst och vinter. Kumulativ global solstrålning korrelerade negativt med antalet självmord mellan september och april, både för kvinnor och män. Dagstemperaturen korrelerade med antalet självmord, ju kallare desto lägre dödlighet genom självmord särskilt under höstar och vintrar. Den högsta mortaliteten för självmord upptäcktes under perioden från 15 maj till 25 juli, men ingen korrelation med meteorologiska variabler hittades under denna period.

Antalet självmordsförsök i Helsingfors korrelerade med lufttryck, men med motsatt relation för kvinnor och män. Antalet självmordsförsök för män var högre under lågtryck, medan antalet försök ökade för kvinnor under högtryck.

Resultaten i denna doktorsavhandling överstämmer med tidigare internationella forskningsresultat som visar att dagsljus och utetemperatur kan påverka tidpunkten av självmord. Årstidsrytmen i självmordsmortalitet kräver ytterligare forskning.

Nyckelord: meteorologiska variabler, väder, lokal, kön, längden av dagsljus, tajming av dagsljus

List of original papers

- I Reija Ruuhela, Laura Hiltunen, Ari Venäläinen, Pentti Pirinen, Timo Partonen. Climate impact on suicide rates in Finland from 1971 to 2003. *International Journal of Biometeorology* (2009) 53:167-175
- II Laura Hiltunen, Kirsi Suominen, Jouko Lönnqvist, Timo Partonen. Relationship between daylight and suicide in Finland. *Journal of Circadian Rhythms* (2011) 9:10
- III Laura Hiltunen, Jari Haukka, Reija Ruuhela, Kirsi Suominen, Timo Partonen. Local daily temperatures, thermal seasons, and suicide rates in three areas across Finland from 1974 to 2010. *Environmental Health and Preventive Medicine* (2014) 19:286-294
- IV Laura Hiltunen, Reija Ruuhela, Aini Ostamo, Jouko Lönnqvist, Kirsi Suominen, Timo Partonen. Atmospheric pressure and suicide attempts in Helsinki, Finland. *International Journal of Biometeorology* (2012) 56:1045-1053

Abbreviations

G	Global solar radiation
R	Precipitation
RR	Rate ratio
S	Sunshine hours
SR	Suicide rate
ST	Solar time
T	Ambient temperature
UTC	Universal Time, Coordinated Universal Time
WHO	World Health Organization

1 Introduction

Globally the suicide mortality has increased during the last 45 years, and almost one million people (with an estimated rate of 16 per 100 000) die from suicide every year according to WHO (<http://apps.who.int/gho/data/node.main.RCODWORLD?lang=en>). In Finland the suicide rate was among the highest in the world in 1990 with 30 per 100 000 (50 per 100 000 for men and 12 per 100 000 for women), but has come down to 16.1 per 100 000 (24.6 per 100 000 for men and 7.9 per 100 000 for women) in 2012. In comparison, the overall suicide rate in the European Union is 10.1 per 100 000 (<http://www.euro.who.int/en/health-topics/noncommunicable-diseases/mental-health/data-and-statistics>). Concerning the whole population of Finland, 2% of all deaths were due to suicide in 2012 (Kuolemansyyt 2012, Suomen virallinen tilasto, Tilastokeskus).

Only attempted suicides followed by hospital treatment are registered in Finland. No complete numbers on attempted suicides are available. However, WHO has estimated that the number of suicide attempts is 10 to 40 times higher than the number of deaths from suicides (<http://www.who.int/bulletin/volumes/84/4/editorial30406html/en/#>).

Many risk factors for the suicidal process have been recognized. However, factors related to the recurrent time patterns of attempted or completed suicides have not been revealed. The suicide rate has been shown to vary according to the time of the day, day of the week and month or season of the year (Maldonado, Kraus 1991, Christodoulou et al. 2011, Hakko, Räsänen & Tiihonen 1998a, Partonen et al. 2004a). Globally the seasonality of suicides is seen both on the northern and the southern hemisphere (Christodoulou et al. 2011, Woo, Okusaga & Postolache 2012, Nader et al. 2011). The pattern seems more evident the higher the latitude is both in the northern and the southern hemisphere (Lester 1970, Lester 1986, Lawrynowicz, Baker 2005, Parker, Gao & Machin 2001, Bjorksten, Kripke & Bjerregaard 2009). However, in some areas the seasonality of suicides has been suspected to be diminishing or even to have ceased to exist altogether (Ajdacic-Gross et al. 2005). Some studies have suggested that violent methods are more seasonal than the non-violent methods, and that suicides on rural areas are more seasonal than in urban settings (Woo, Okusaga & Postolache 2012, Hakko, Räsänen & Tiihonen 1998b). Also in Finland, the seasonality of suicides has been shown since the nineteenth century, as is clearly shown in Figures 1 and 2, which are from the dissertations by

University Doctor Theodor Saelan in Helsinki in 1864 (Saelan T. 1864), and by County Doctor Fredrik Wilhelm Westerlund in Oulu in 1898 (Westerlund 1898).

Låtom oss se huru härefter förhåller sig hos oss.

Tab. V. *Sjelfmorden under de olika månaderna under åren 1851—1860.*

	1851	1852	1853	1854	1855	1856	1857	1858	1859	1860	Summa	Summa
	gymnor mån	gymnor mån	gymnor mån	gymnor mån	gymnor mån	gymnor mån	gymnor mån	gymnor mån	gymnor mån	gymnor mån	gymnor mån	gymnor mån
Januari	4 3	7 2	6 1	5 0	5 1	7 1	4 1	5 0	6 0	4 0	53 9	62
Februari	2 0	0 0	6 1	4 0	2 0	3 0	4 1	3 0	4 0	3 0	31 2	33
Mars	4 0	8 0	2 1	10 1	10 0	4 1	5 1	5 1	3 0	4 1	55 6	61
April	7 1	12 0	7 4	5 0	3 3	8 1	15 1	4 2	4 0	6 4	71 16	87
Maj	2 3	9 1	11 1	3 2	12 1	9 0	5 1	6 3	10 1	11 0	78 13	91
Juni	7 1	7 2	4 0	4 0	6 1	9 1	7 2	9 1	8 1	8 2	69 11	80
Juli	7 0	3 4	7 1	4 2	8 3	4 3	2 2	7 2	1 0	5 4	48 21	69
Augusti	7 5	4 2	6 1	6 2	6 1	7 1	10 1	6 1	5 1	10 0	67 15	82
September	6 2	3 0	4 0	10 0	7 2	7 3	4 1	4 0	9 0	7 3	61 11	72
Oktober	3 0	2 1	3 0	8 0	5 3	6 1	6 3	11 1	3 0	3 1	50 10	60
November	5 1	2 0	2 0	2 0	3 0	3 1	5 0	3 0	7 3	6 0	38 5	43
December	3 0	4 1	0 1	3 0	9 0	3 0	7 0	5 1	3 1	2 1	39 5	44
Summa summarum	73	74	69	71	91	83	88	80	70	85	660 124	784
ka. per lida =>	6,1	6,2	5,8	5,9	7,6	6,9	7,3	6,7	5,8	7,1	55 10,3	65,3

Figure 1. The monthly distribution of suicides from 1851 to 1860 in Finland, Th. Saelan, 1864

Tab. XXXIV.

**Sjelfmordens fördelning på olika månader i
Finland 1861—90.**

(Absolut antal).

År	Jan.	Febr.	Mars.	April.	Maj.	Juni.	Juli.	Aug.	Sept.	Okt.	Nov.	Dec.	Summa.
1861—65	28	23	32	38	46	50	40	29	30	23	24	21	364
1866—70	29	19	35	58	56	43	31	31	40	24	22	33	421
1871—75	13	15	26	29	36	29	43	26	19	31	23	23	313
1876—80	17	17	23	34	38	45	31	34	31	21	19	26	336
1881—85	29	30	39	33	36	49	44	46	32	36	20	20	414
1886—90	39	26	35	40	48	59	43	32	36	41	23	23	455
Summa	155	130	190	232	260	275	237	198	188	176	136	146	2323

Figure 2. F.W. Westerlund, 1898. Sjelfmorden I Finland 1861 – 1895

"Om vi bland dessa siffror uppsöka de högsta för hvarje femårsperiod, så visar sig snart en del af den märkvärdiga regelbundenhet, som utmärker själfmordens fördelning på olika tider af året. Vi finna nämligen, att under tjugo år af de trettio, tabellen framställer, hafva de flesta själfmord inträffat under juni månad. Vi kunna på samma gång nämna, att ej allenast i Sverige, Norge och Danmark, som vi straxt skola framhålla, maximum af själfmorden inträffar under samma månad, utan ock att en öfver snart sagdt alla Europas stater af Morselli utsträckt statistik konstaterar, att de flesta själfmord förekomma under den varma årstiden och oftast under maj eller juni månad."

"If we look at the highest figures during each five year period, we may notice that suicides follow a regular pattern that is related to the time of the year. Indeed, during twenty years out of the thirty that have been included in the table, the number of suicides has been the highest in June. We may also emphasize that it is not only in Sweden, Norway and Denmark, which we are about to present hereafter, where the highest numbers of suicides take place during the same month, but also according to the statistics by Morselli, in all of the countries in Europe, most of the suicides occur during the warm seasons, and most often in May or in June" (translated by the author).

An increased suicide rate during summer months has been shown also among adolescents (8 to 14 years of age) in Finland (Erkkilä 1937).

During the 20th century another smaller peak in the suicide rate around October has emerged for women (Hakko, Räsänen & Tiihonen 1998a, Näyhä 1981, Näyhä 1982).

Attempted suicides have shown similar seasonal variation to that of completed suicides with higher numbers during the spring, and a decline during the winter (Yip, Yang 2004, Zakharov, Navratil & Pelclova 2013, Haukka et al. 2008), although different seasonal patterns have been shown, too (Valtonen et al. 2006). The seasonality has been noted only for attempts by women in some studies, but no increase during the autumn has been detected, as is the case with completed suicides by women (Barker et al. 1994, Preti, Miotto 2000, Rock, Hallmayer 2008, Islambulchilar, Islambulchilar & Kargar-Maher 2009).

Weather factors have been studied in an attempt to explain the seasonal changes in suicide mortality, but with inconsistent results (Woo, Okusaga & Postolache 2012, Dexter 1904, Deisenhammer 2003). No previous long-term data on the possible correlations between weather and the timing of suicides exists so far in Finland (Partonen et al. 2004a, Partonen et al. 2004b, Partonen et al. 2004c).

The mechanisms through which weather variables and/or daylight might increase the risk for suicidal behaviour are not known. Emile Durkheim, a French sociologist concluded in his study "Le Suicide" in 1897 that the increase in suicide rate during spring was due to the increase in social activities and interactions between people, and not due to temperature, which had been suggested by Morselli and Lombroso. Durkheim also concluded that the increase in the daylength in spring was connected

to the increase in activities (Le Suicide, Durkheim 1897, suom. Seppo Randell). Later it has been shown that daylight and temperature are important signals for the circadian rhythms (Somerén 2003, Roenneberg, Kumar & Merrow 2007), which are often disrupted during depression, an important risk factor for suicide.

In this thesis we were able to explore only the weather and daylight in relation to the timing of suicides. The aim of the thesis was to study whether the suicide rate in Finland and /or attempted suicides in Helsinki have associated with weather variables between 1969 and 2010. Furthermore, the daylength, which changes seasonally, was included as a possible explanatory variable in the study.

2 Literature review

2.1 Definitions of completed and attempted suicides

Suicide is defined as a cause of death if a deliberate action of aiming to kill one self can be shown to have happened

(http://www.who.int/violence_injury_prevention/violence/global_campaign/en/chap_7.pdf). The official diagnostic system in Finland is the WHO's classification system for diseases, the ICD-10, (<http://www.who.int/classifications/icd/en/>) which classifies suicide as a cause of death according to the ways self-harm has been inflicted. Code X69 describing an attempted or completed suicide by poisoning is often referred as the non-violent method, while codes from X70 to X84 are referred to as the violent methods. The same diagnoses are used also for other forms of self-harm, and attempted suicides where the result is not fatal.

Suicidal thoughts and plans are also symptoms of severe form of unipolar (F32) or bipolar depression (F31) in the diagnostic system of ICD-10.

2.2 Risk factors for suicides

2.2.1 Gender

The risk factors for suicides are numerous, but men complete three to four times as many suicides as do women. This ratio between sexes for completed suicides has stayed rather constant for centuries in the Western countries. In 2012, 655 men and 218 women completed suicide in Finland, and from all deaths, suicides by men composed 2, 6%, and suicides by women 0, 8%. For Eastern countries the gender ratio seems to be somewhat lower (Hee Ahn et al. 2012).

For attempted suicides the gender ratio seems to be opposite to that of completed suicides, but the difference is not as big as in completed suicides.

The explanation for the gender ratio among suicides is still unresolved. However, in relation to ambient temperature, there are physiological differences in the thermoregulation between sexes (Hanada et al. 2009, Charkoudian and Stachenfeld 2014, Silva and Boulant 1986). In addition, atmospheric pressure may influence the seasonal rhythms and overall levels of sex hormones (testosterone, luteinizing hormone, progesterone, follicle-stimulating hormone) (El-Migdadi, Nusier & Bashir 2000), as well as the levels of metabolites of monoamines in the central nervous

system (Nordin, Swedin & Zachau 1992, Eklundh, Fernstrom & Nordin 1994, Heilig, Mansson & Blennow 1996, Eklundh et al. 2000), which are involved in psychiatric disorders.

2.2.2 Psychiatric disorders

By different estimations 40 - 90% of suicide victims have had a psychiatric disorder in their life-time (Henriksson et al. 1993). The main psychiatric disorder in this respect is depression (Nordentoft 2007, Beghi et al. 2013). A higher suicide rate also associates with bipolar disorder, and schizophrenia, with a lifetime risk from 4 to 6% (Inskip, Harris & Barraclough 1998, Bostwick, Pankratz 2000, Palmer, Pankratz & Bostwick 2005). Furthermore, drug and alcohol problems, and some personality disorders associate with suicides (Harris, Barraclough 1997). In addition, suicidal behaviour is higher among people with a family history of attempted or completed suicide (Mendez-Bustos et al. 2013, Runeson, Åsberg 2003).

2.2.2.1 Disruptions in Circadian Rhythms

Several psychiatric disorders have been associated with disruptions in circadian rhythms. In non-seasonal major depression, bipolar disorder, eating disorders, alcohol dependence, and addiction, the normal circadian rhythms of body temperature, hormonal secretions and sleep seem to be disturbed (Evans, Davidson 2013, Albrecht 2013, Souetre et al. 1991, McClung 2013). Furthermore, a phase shift of the circadian clock is suggested as the main biological mechanism behind the winter depression (Lewy et al. 2006, Lewy et al. 2007).

In non-seasonal depression, the total sleep deprivation therapy rapidly improves the depressed mood, which is suspected to act through normalizing the function of the clock genes and the abnormal circadian rhythm (Bunney, Bunney 2013). Therefore, recent studies have suggested that the circadian disruptions might be primary to mood disorders (McClung 2013). Whether external cues such as weather conditions or daylight, are involved in the aforementioned circadian disruptions, is not known.

2.3 External cues for the circadian rhythms

2.3.1 Daylight and circadian rhythm

In the course of the evolution, most of the living creatures have developed several delicate and specific biological mechanisms in order to follow the circadian (“circa” = approximately, “dies” = day) rhythmicity of the light-dark cycle on earth, as well as the seasonal changes in it, in order to synchronize the energy need and breeding with the most favourable environmental circumstances (Hastings, Reddy & Maywood 2003).

In the suprachiasmatic nucleus lays the principal circadian clock, which regulates the functions of the circadian clocks in other parts of the brain, as well as in the peripheral tissues of the body. The timing of light-dark cycle is considered to serve as the primary time giver or “zeitgeber” for the principal circadian clock (Duffy, Kronauer & Czeisler 1996, Roenneberg, Kumar & Merrow 2007, Foster, Roenneberg 2008), but even small changes in the intensity of light, or temperature, seem to be involved in the circadian rhythms (Ashley et al. 2013). For example, it has been shown that the African stonechat, a tropical bird, can follow even the delicate changes in the timing of sunrises and sunsets according to the time of equation (Goymann et al. 2012). Furthermore, some animals in the polar regions, where the light-dark cycle lacks during winters and summers, are still able to maintain the circadian rhythm (van Oort et al. 2005).

The daily and seasonal changes in the 24 hour rhythm of light and dark are based on three astronomical phenomena, as follows.

First, the rotation of the earth around its axis, once in every 24 hours, is responsible for the daily change in light and dark.

Second, due to the elliptical shape of the earth's orbit around the sun and the $23,5^{\circ}$ tilt of the earth against the orbit the 24 hour period is not split equally by light and dark, but the duration of light and dark varies as the earth travels along its orbit around the sun. The calendar year has been divided into four astronomical seasons, by the length and direction of change in daylight. As Finland lies between the 60° and 70° latitudes of North, the changes in the duration of daylight are hereafter described from the perspective of the Northern hemisphere.

On the winter solstice at December 21 the astronomical autumn ends and the day length is at its minimum. As the astronomical winter begins, the day length starts to increase. It increases until the spring equinox at March 21, when the day length reaches 12 hours, and day and night are equally long all around the world. That is the starting point to the astronomical spring during which the day length continues to increase until its maximum on the summer solstice at June 21. That is the beginning of the astronomical summer. Thereafter the day length starts to decrease, and on the autumn equinox at September 22 the daylight has decreased into 12 hours again, which is the starting point to the astronomical autumn. Thereafter the day length decreases again into its minimum on December 21 (<http://ilmatieteenlaitos.fi/tahtitieteelliset-vuodenajat>).

Third, the speed the earth rotates on its orbit changes during the year. This is the main reason for the change in the timing of daylight in respect to the coordinated universal time, (UTC hereafter). The daylight, or solar time (ST hereafter) shifts

daily into an earlier or later timetable in respect to the official clock time, UTC. On November 04 the ST is approximately 16 minutes ahead of the UTC, and on February 11 the ST is 14 minutes behind the UTC. ST and UTC are synchronized on only four days: April 15, June 14, September 02, and December 25 (Figure 3). In between these four dates ST is therefore either gaining or being slow compared to the UTC. The time difference between the ST and UTC is called the equation of time. These changes follow a recurrent pattern annually (The United States Naval Observatory (USNO), <http://aa.usno.navy.mil/faq/docs/eqtime.php>).

2.3.1.1 Artificial light, social time tables, and circadian rhythm

For humans, artificial light with sufficient intensity and suitable spectral composition (Arendt 2012) may be a sufficient time-giver for the circadian clock in the lack of natural light-dark cycle during the winter. However, the possibility to change the social rhythm irrespective of the environmental light-dark cycle seems to have adverse consequences. Social shifts due to daylight saving time (DST), travelling across time zones, and working in shifts have been shown to cause disruptions in circadian physiological rhythms, which seem to cause multiple health problems, both physical as well as psychiatric symptoms (Evans, Davidson 2013, Albrecht 2013).

Originally, DST was implemented in Germany, in 1916, due to war, in an attempt to save fuel that was used for lightning. Since then, several countries worldwide have exercised DST, but currently it is in use in Europe and North America, as well as in a few countries in the southern hemisphere http://en.wikipedia.org/wiki/Daylight_saving_time_by_country. In Finland, DST has been in use since 1981. Every spring, the clock time is shifted one hour forward, so that the social rhythm is shifted one hour earlier in respect to sunrise and sunset, and accordingly the period with daylight in the evening is one hour longer. However, in countries situated at the northern latitudes such as Finland, with rapidly increasing length of daylight in the spring, the usefulness of this argument may be questioned. The DST has been shown to disturb rest-activity and sleep cycles, and the spring shift is more disturbing for the evening types, while the autumn shift is more disturbing for the morning types of persons (Lahti et al. 2008). In autumn the adjustment for the delaying of social rhythms is easier for the majority, as the principal circadian clock has the tendency to be slow in most people.

The same effect as in DST actualizes in different ends of time zones, although without abrupt artificial changes in social rhythms. In the western side of the time zone, one hour longer daylight in the evening has been associated with an increased prevalence of winter depression (Terman et al. 2008), as well as higher suicide rate in the United States (Quercioli 2012).

2.3.2 Ambient temperature and circadian rhythm

Ambient temperature seems to function as a signal for the circadian clocks, as well, but it seems to have different influence on peripheral tissues as compared to the brain. Especially in the brain, temperature serves more as a mediating factor for the circadian rhythms (Sehadova et al. 2009). The main circadian clock in the suprachiasmatic nucleus regulates the cyclic changes in body temperature, which serve as time resetting signals to peripheral circadian clocks (Buhr, Yoo & Takahashi 2010), which give normally, although indirectly, feedback to the main circadian clock. Furthermore, brown adipose tissue, which is an essential part of the thermoregulatory mechanism and reacts to ambient temperature, may interact with the genes of circadian clocks through adrenergic signalling (Li et al. 2013).

In contrast to the astronomical seasons, which follow the same timetable in different parts of Finland, the timetables of thermal seasons vary clearly in the south – north axis. The classification of thermal seasons is not globally identical, and in some countries other classifications exist. The following classification is used in Finland. Thermal spring starts when the daily mean temperature (hereafter T) goes permanently above 0 degrees Celsius. Thermal summer starts when T goes above +10 degrees Celsius, thermal autumn starts when T goes below +10 degrees Celsius, and thermal winter starts when T goes below 0 degrees Celsius.

2.4 Weather and morbidity

Weather has been suspected to be involved in various health aspects since ancient times, as is shown here in the following quote from the main works of Hippocrates (460 BC -370 BC), the father of western medicine:

“ Whoever wishes to pursue properly the science of medicine must proceed thus. First he ought to consider what effects each season of the year can produce; for the seasons are not at all alike, but differ widely both in themselves and at their changes. The next point is the hot winds and the cold, especially those that are universal, but also those that are peculiar to each particular region. He must also consider the properties of the waters; for as these differ in taste and in weight, so the property of each is far different from that of any other. Therefore, on arrival at a town with which he is unfamiliar, a physician should examine its position with respect to the winds and to the risings of the sun. For a northern, a southern, an eastern, and a western aspect has each its own individual property. He must consider with the greatest care both these things and how the natives are off for water, whether they use marshy, soft waters, or such as are hard and come from rocky heights, or brackish and harsh. The soil too, whether bare and dry or wooded and watered,

hollow and hot or high and cold. The mode of life also of the inhabitants that is pleasing to them, whether they” (Jones 1868) .

In Finland, the overall mortality is highest during the winter months (Näyhä 1981) and changes in weather conditions have been related to worsening of various somatic illnesses also at present (Hassi 2013). For example, changes in humidity, temperature and light associate with physical illnesses such as asthma, atopy, cardiovascular problems, and migraine (Wang et al. 2013, Fraga et al. 2013, Nosedá et al. 2010). Furthermore, atmospheric pressure and temperature have been suggested to be involved in the pain of fibromyalgia and rheumatoid arthritis (Smedslund et al. 2013, Abasolo et al. 2013). In animal studies with rats, changes in the atmospheric pressure have increased pain-related behaviour (Sato et al. 2004, Sato et al. 2011, Messlinger et al. 2010, Funakubo et al. 2011).

Weather conditions have been associated with mental health as well. Changes in weather have been associated with changes in mood among children (Ciucci et al. 2011, Ciucci et al. 2013), and hours of sunshine have been associated with changes in cognitive performance (Kent et al. 2009). Vice versa, the sensation of thermal comfort seems to be influenced by mood, and distressed individuals may not tolerate high temperatures (Yin et al. 2012). In the brain of healthy people hours of sunshine have been shown to increase the serotonin metabolism within the same day (Lambert et al. 2002).

In psychiatric clinical settings, an increase of manic episodes has been shown during spring (Yang et al. 2013), and ambient temperature has been associated with hospital admissions due to depressive episodes of bipolar disorder (Shapira et al. 2004) as well as with those due to schizophrenia (Sung et al. 2011). Interestingly, it seems that the seasonality of symptoms is more common among depressed patients who also have short periods of hypomanic symptoms (Angst et al. 2012). Furthermore, in an international multicentre study, an earlier age of onset of bipolar disorder was linked with increased monthly sunlight (Bauer et al. 2014). Higher prevalences of seasonal affective disorder, and schizophrenia have been found on higher latitudes (Imai et al. 2003, Kegel et al. 2009, Saha et al. 2006).

Since the bright light therapy has proven an effective treatment for the seasonal affective disorder, the day length is suggested to be involved. Recurring mood disorders during other seasons, for example in summer, have been shown as well, but with lesser extent (Faedda et al. 1993, Wehr, Sack & Rosenthal 1987, Tonetti, Sahu & Natale 2012). Heat has been suggested as the explanation for some cases of summer depression (Wehr, Sack & Rosenthal 1987).

2.4.1 Weather and attempted suicides

Weather factors have been offered as an explanation for the varying time patterns among attempted suicides, but with inconsistent results. No correlation between *ambient temperature, relative humidity, rainfall or relative duration of sunshine* and attempted suicides was found in Hong Kong in 1986 (Chiu 1988). However, when all parasuicides from 1976 to 1989 in the Oxford general hospital in the United Kingdom were compared with the weather conditions, *cloud cover, minimum and maximum temperature* associated with suicide attempts of women, and *rain, cloud cover and poorer visibility* with attempted suicides by men. In addition a lagged effect of weather was found with *minimum and maximum temperature, intra-day temperature amplitude and rainfall* for women, but not for men. A change in weather by *increasing rainfall* associated with attempted suicides by men (Barker et al. 1994). In Japan, railway suicide attempts associated with *less sunlight* during the 7 preceding days between 2002 and 2006 (Kadotani, Nagai & Sozu 2013).

2.4.2 Weather and completed suicides

For completed suicides associations with weather conditions have been found as well. Annual, monthly and daily associations are presented in separate as follows.

Annual associations

Inverse correlation with annual *mean temperature* and suicide rate of women was found in Japan (35⁰N) concerning the years from 1977 to 2008, while for men the correlation was seen only in one study area, and it was not an inverse one (Inoue et al. 2012). Furthermore, in the same study, annual *sunshine hours*, as well as the *relative humidity* correlated with the suicide rate of women, and the sea level *air pressure* correlated inversely with the suicide rate of men in a few study areas. In another study from Japan in 1999, annual *total sunshine and mean temperature* associated with suicides (Terao et al. 2002), but associations in respect to genders were not reported.

Monthly and seasonal associations

Monthly *sunlight* did not associate with seasonality of suicides, but *increase in monthly temperature* associated with seasonality of suicide rate for men and women, and *rainfall* negatively with the total suicide rate of men in Taiwan (25⁰N) during the years from 1991 to 2010 (Tsai, Cho 2012). In Austria (47⁰N) the average number of monthly *sunshine hours* associated with the suicide rate of men and women with violent methods, from 1996 to 2006 (Vyssoki et al. 2011). In France (43⁰ - 50⁰N) *daylight duration, sunlight duration, and mean monthly temperature* associated with suicides from 1975 to 1982 (Souetre et al. 1987).

Daily associations

Daily *mean temperature* associated with the daily count of suicides in Korea (34⁰N-36⁰ N) from 2001 to 2005. The association was more evident among men, those > 65 years, and those with lower education (Kim, Kim & Kim 2011). In Japan daily *maximum temperature* associated with the daily suicide rate from 1972 to 1995, and especially with suicides of violent methods. (Likhvar, Honda & Ono 2011). In Finland, in the Helsinki area diurnal *temperature range and springtime maxima* associated with the suicide rate of men from 1973 to 2010 (Holopainen, Helama & Partonen 2013). Diurnal *variation in temperature on preceding days* associated with suicides also in England (53⁰N) from 1989 to 1993 (Salib, Gray 1997) and furthermore, daily *mean temperature, above 18⁰ C*, associated with daily suicide counts, and especially so with violent suicides in England and Wales from 1993 to 2003, for women the result was weaker (Page, Hajat & Kovats 2007).

The lag and duration of solar radiance associated with suicides in Greece (39⁰N) from 1992 to 2001. For men longer duration of sunshine (up until nine days before the suicide) associated with a higher suicide rate, but for women a lag period of three to four days from the sunshine associated with suicides (Papadopoulos et al. 2005). In England, *daily sunshine hours* at the day of fatal self harm, and the day before, associated with increased suicide rate from 1989 to 1993 (Salib, Gray 1997).

2.5 Weather data and meteorology in Finland

In Finland, the oldest recorded temperature observations are from Tornio in 1737. The Finnish Meteorological Institute dates back to 1838, when the magnetic observatory of Helsinki was founded for the research of magnetic and meteorological observations. The first international congress in meteorology was held in Wien in 1873, and as meteorology became more and more the main focus in research, in 1881 the magnetic observatory of Helsinki was renamed as Meteorologinen Päälaitos.

During the 20th century Finland has been one of the leading countries in the development of meteorological instruments and devices. Vilho Väisälä (1889-1969) and Erik Palmén (1898-1985) were two famous Finnish meteorological researchers, and at the 1930s Vilho Väisälä developed a radiosond that became world famous (<http://www.kansallisbiografia.fi/kb/artikkeli/5759/>). These radiosonds dramatically improved the possibility to measure and transmit on line weather data from different levels of the atmosphere (<http://ilmatieteenlaitos.fi/meteorologian-historiaa>).

At present meteorological data are collected at more than 500 weather stations scattered across Finland every year. The frequency of the observations varies depending on the weather variable, but larger synoptic weather observations are

reported regularly on a daily basis at 00, 06, 12, and 18 UTC for international broadcasting. There are 60 such synoptic weather stations in Finland. Two meteorological observatories, which are the most widely equipped, are in Sodankylä and Jokioinen. Global solar radiation (MJ/m^2) is measured in these two observatories.

The weather phenomena that are the most evident in everyday life take place in the lowest 10 km of the atmosphere, that is, in the troposphere. Temperature, pressure, wind, humidity and precipitation are the basic elements of atmosphere, which interact with each other according to the laws of radiation physics and thermodynamics, and to which humans are exposed on a daily and seasonal basis. The energy and therefore the rhythm of these aforementioned interactions are derived from the sun. However, local geographical topography, and human derived actions influence the gas consistency and the humidity of the air, the way radiation of the sun is emitted or absorbed in the environment, just to give a few examples. Therefore, a great deal of annual variation in the seasonal changes of weather conditions exists locally (<http://ilmatieteenlaitos.fi/ilmakeha-ja-saailmiot>), (Oksanen 1924).

3 Study objectives

The main objective of the present study is to describe possible associations between weather conditions, and the suicide rate as well as the attempted suicides in Finland.

The specific aims of the study are:

I To find out whether global solar radiation, sunshine hours, ambient temperature, or precipitation associate with the suicide rate in Finland.

II To study possible differences in associations between weather conditions and the suicide rate across Finland in the south-north axis, as well as during different time frames.

III To explore the associations between the suicide rate and the photoperiod, including the variations in the timing of the photoperiod, due to the time of equation.

IV To find out whether weather conditions associate with attempted suicides in Helsinki.

V To assess differences between genders in respect to the associations of attempted and completed suicides to weather conditions.

4 Materials and methods

4.1 Introduction to subjects and weather data

Statistics Finland (www.stat.fi) provided the daily number of suicides in Finland from 1969 to 2003 to the first study, and updated the data up to the year 2010 for the third article. Deaths for which the cause has been indeterminate, were not included in the study. Sex, age at the date of death, and place of domicile at the time of suicide for each case was provided. In addition, Statistics Finland provided the numbers of population per year for the different study areas. In order to give an overview of the changes in suicide mortality, the populations, absolute numbers of suicides, and suicide rates in Finland, in 1971, 1990, 2003, and 2010 are presented in Tables 1 and 2, for women and men respectively.

Table 1. Female population, absolute number of suicides, and suicide rate per 100 000 in Finland from 1971 to 2010 (www.stat.fi)

Year	Population	Suicides	Suicide rate per 100 000
1971	2 391 875	222	9,3
1990	2 572 274	322	12,5
2003	2 666 839	260	9,7
2010	2 736 860	236	8,6

Table 2. Male population, absolute numbers of suicides, and suicide rate in Finland from 1971 to 2010(www.stat.fi)

Year	Population	Suicides	Suicide rate per 100 000
1971	2 234 037	781	35,0
1990	2 426 204	1 198	49,4
2003	2 552 893	815	31,9
2010	2 638 416	718	27,2

The daily numbers of attempted suicides in Helsinki during 1.1.1989 - 31.7.1990, and 15.1.1997 - 14.1.1998 were collected as a part of the World Health Organization Projects on Parasuicide (Bille-Brahe et al. 1995). These numbers include only the

attempted suicides which were hospitalized during those aforementioned periods in the hospitals of Helsinki city.

Finnish Meteorological Institute (www.fmi.fi) provided the daily weather data.

4.2 Study I: Suicide rate in relation to global solar radiation, ambient temperature and precipitation in time frames from one month to one year in Finland from 1971 to 2003

4.2.1 Subjects and weather data

The daily numbers of completed suicides from 1971 to 2003 in Finland were selected as subjects on the basis of the time period that weather data was available. Altogether 41 221 suicides (32 311 of men, 8 910 of women) were committed, and the population in Finland expanded from 4 625 912 to 5 219 732 during that period.

Finnish Meteorological institute provided the daily data on global solar radiation (MJ/m^2) at the Jokioinen weather station, daily sunshine hours, mean ambient daily temperature (degrees Celsius), and precipitation (mm). Daily values of global solar radiation have been measured at the Jokioinen weather station in south-eastern Finland since 1971, which defined the starting point for this study. Global solar radiation is measured with a pyranometer at 1 minute intervals from which the mean daily value was calculated. Sunshine hours were not used in the analysis after all due to the strong intercorrelation with global solar radiation (0.839). Temperature and precipitation are measured on weather stations across the country; they were interpolated onto a 10km x10km grid. Cumulative values of global solar radiation and precipitation were calculated as the sum of daily values, but the average of ambient temperature was calculated over the chosen time frames from one month to one year.

4.2.2 Statistics

The associations between suicide rate (suicides per 100 000) and weather variables were analysed with univariate and multivariate linear regression. In univariate linear regression the cumulative suicide rate was the dependent variable while global solar radiation (G), temperature (T), and precipitation (R) were the explanatory variables. In the multivariate model the weather variables were included stepwise in the model. The models were based on the following equation: $\text{suicide rate} = a + b (G) + c (T_{\text{avg}}) + d (R)$, where a, b, c, and d are the regression coefficients. Regression analyses were executed to aggregate data for different time periods between one month and one year.

4.3 Study II: Daily suicide rate in relation to day length, time shift in day length, and daily weather changes in Finland from 1969 to 2003

4.3.1 Subjects, astronomical data and weather changes

The daily data of all suicides committed in Finland from 1969 to 2003 were provided by Statistics Finland. Altogether 43,393 suicides, of which 33 993 men's suicides, were committed during that period.

Based on the hypothesis that the main circadian clock follows the daily changes in the light-dark cycle, the dates for the astronomical seasons, and periods by the time of equation (see for the definition 2.3.1) for each year were provided by the Almanac Office at the University of Helsinki. Each calendar year from 1969 to 2003 was divided into twelve periods according to the yearly repeating patterns concerning the increases and decreases in the day length, and the time differences between the sun time (ST) and the official local clock time (UTC) (see Table 3, and Figure 3). Astronomical seasons are periods 1-4: 1.winter, 2.spring, 3.summer, 4.autumn. Periods 5-12 are based on the time of equation.

Table 3. The numbers, dates and definitions for 12 periods used in Study II

No of period	Dates for the period	Definition by day length (DL), or the relation between ST and UTC
1	21.12-20.03	DL increasing from min to 12 h
2	21.03-20.6	DL increasing from 12 h to max
3	21.06-22.09	DL decreasing from max to 12 h
4	23.09-20.12	DL decreasing from 12 h to min
5	11.02-14.05	ST gaining compared to UTC
6	15.05-25.07	ST being slow compared to UTC
7	26.07-03.11	ST gaining compared to UTC
8	04.11-10.02	ST being slow compared to UTC
9	15.04-13.06	ST ahead of UTC
10	14.06-31.08	ST behind of UTC
11	01.09-25.12	ST ahead of UTC
12	26.12-14.04	ST behind UTC

In addition, in order to assess the possible correlation between the local daily weather changes and the daily suicide rate during these aforementioned twelve periods, Finnish Meteorological Institute provided the daily weather data on hours of sunshine and ambient temperature in Helsinki and Oulu. Suicides committed within the 25 km radius of these two cities were included in these analyses. In Helsinki

5062 suicides by men and 2160 suicides by women, and in Oulu 903 suicides by men and 278 by women were committed between 1969 and 2003.

4.3.2 Statistics

First, the daily mean of the suicide rate with 95% confidence intervals for the twelve aggregate periods over the years from 1969 to 2003 were calculated for men and women separately for Finland, Helsinki and Oulu. Second, for Helsinki and Oulu, the days within the twelve periods were divided into four subgroups according to the daily increase or decrease in the sunshine hours (S+, S-), and in the ambient mean temperature (T+, T-), compared to the previous day, ending up with four types of days (T+S+, T+S-, T-S+, T-S-). Thereafter, the daily mean of the suicide rate with 95% confidence intervals for the four types of days during the twelve periods for Helsinki and Oulu were calculated.

4.4 Study III: Suicide rates in Helsinki, Jyväskylä and Oulu in relation to daily temperatures and thermal seasons from 1974 to 2010

4.4.1 Data and subjects of study

Statistics Finland provided the daily numbers of committed suicides and the yearly populations in Helsinki, Jyväskylä, and Oulu from 1974 to 2010 for men and women separately. 7 651 suicides were committed by men, and 3151 by women.

The values of the daily mean, minimum, and maximum ambient temperature for Helsinki, Jyväskylä, and Oulu within the 25km radius of these three cities were provided by the Finnish Meteorological Institute for the same period. In addition, the dates for the thermal seasons in the three cities were provided by the Finnish Meteorological Institute.

18 weather variables were formed based on daily temperatures, astronomical and thermal seasons (Table 3 in the original paper III).

4.4.2 Statistics

Six different statistical models based on the Poisson generalized linear modelling were constructed with the selected weather variables. The statistical program R, version 2.15.0 with the packages Epi (a package for statistical analysis in epidemiology) and Ns (natural spline) were used. The statistical significance of the statistical models was assessed with chi-square tests, and p-values of < 0.05 were considered statistically significant. Changes in rate ratios (RR) of the suicide rates in respect to the statistically significant associations with weather variables were visualized.

4.5 Study IV: Suicide attempts and atmospheric pressure in Helsinki in 1989-1990, and 1997

4.5.1 Data and subjects of study

Suicide attempts were collected as a part of a multicentre study on parasuicide by World Health Organization (Bille-Brahe et al. 1995) during two separate periods; the first was from January 1, 1989 to July 31, 1990 (I) and second from January 15, 1997 to January 14, 1998 (II). All suicide attempts treated in hospitals of Helsinki during these periods were included in the study. From each individual the date and the method (violent/non-violent) of the suicide attempt, and gender were recorded. Altogether 3 945 suicide attempts were recorded during these periods, of which 2 309 during the first, and 1 636 during the second. These figures also include the repeated attempts made by the same individuals. During the first period more attempts were made by men (1198), and during the second by women (840), but the difference between the genders was not clinically significant (3,8 % (I), 2,7% (II)).

Meteorological data were provided by the Finnish Meteorological Institute from the Helsinki Kaisaniemi weather station. Daily values of minimum, mean, and maximum temperature in degrees of Celsius, precipitation in millimetres, global solar radiation in Mega joules per square meter, cumulative sunshine hours, and atmospheric pressure (included in the synoptic weather observations eight times per day) were provided. In addition, for daily temperature and global solar radiation, the deviation from the climatic normal, as compared to the period from 1971 to 2003, was calculated, in order to take into account the potential impact of acclimatization due to seasons.

4.5.2 Statistics

Descriptive synoptic weather analyses were performed for the days with clusters of suicides, and for the days without self-harm. Days with more than seven suicide attempts for either gender, or days with more than ten suicide attempts altogether were considered as cluster days. In our study, the probability for a cluster day was smaller than .01 estimated by Poisson distribution. Days without suicide attempts, and periods of two consecutive days (minimum) without self-harm were considered as days without self-harm. After the harvesting effect, or short-term mortality displacement (Huynen et al. 2001) only seven days/periods without self-harm were left for the analyses.

For the possible over-all association between the daily weather variables and suicide attempts, a Poisson regression was performed. Daily values of weather variables were considered as the independent explanatory variables, and the number of daily suicide attempts as the dependent variable. Furthermore, a separate Poisson analysis

was performed for the violent suicide attempts. Genders were analysed separately throughout the study. In order to assess the clinical meanings of the associations found, rate ratios with confidence intervals for attempted suicides were calculated per a change of one unit of each weather variable, and accordingly per a change of ten units.

5 Results

5.1 Study I: Suicide rate in relation to global solar radiation, ambient temperature and precipitation in time frames from one month to one year in Finland from 1971 to 2003

5.1.1 Annual correlations

On an annual level, the global solar radiation showed inverse correlation with the total as well as with the men's suicide rate from 1971 to 2003, when it was considered an independent variable in the regression model. The rate ratio was 0.23 for the total as well as for the men's suicide rate. Annual mean temperature and annual cumulative precipitation did not correlate with the suicide rates of either sex when included as independent variables in the regression model. However, the regression model with temperature, precipitation, and global solar radiation all included explained 32% of the variation of the total suicide rate. The same pattern was seen also in separate for men and women.

5.1.2 Monthly and seasonal correlations

In monthly aggregated data the men's suicide rate correlated with the global radiation in March (correlation coefficient = $-.004$, $p=.05$) and in September (correlation coefficient = $-.006$, $p=.015$). However, women's suicide rate correlated with the global radiation (correlation coefficient = $-.011$, $p=.026$) and ambient mean temperature (correlation coefficient = $.046$, $p=.005$) in November. The correlation of global solar radiation was an inverse one in direction for both genders.

In seasonally aggregated data the global radiation correlated with the men's suicide rate (correlation coefficient = $-.012$, $p=.022$) as well as with the women's suicide rate (correlation coefficient = $-.004$, $p=.009$) during autumn (September – November). The ambient mean temperature correlated only with the men's suicide rate (correlation coefficient = $.16$, $p=.022$) during winter (December – February).

5.1.3 Cumulative correlations

Cumulative global solar radiation from November to March correlated with men's and women's suicide rate, and for men also from November to April. After summer the correlation became significant again from November to September and November to October for both genders. The correlations were inverse ones in direction. Between November and February, and May and August the correlation was not significant.

5.2 Study II: Daily suicide rate in relation to day length , time shift in day length, and daily weather changes in Finland from 1969 to 2003

5.2.1 Day length, astronomical seasons

On the national level, the mean of the daily suicide rate of men was significantly higher during the astronomical spring and summer as compared to that of astronomical winter or autumn, when comparing the differing confidence intervals. As to women, on the national level, the mean of the daily suicide rate was lower during astronomical winter compared to the other astronomic seasons, based on the differing confidence intervals (Table 4).

In Helsinki, the results were pointing towards similar seasonal patterns in the suicide rate for men and women, but without statistical significance. Interestingly, in Oulu the time patterns seemed to be somewhat different, as the mean of the daily suicide rate was higher during astronomical summer than during astronomical spring, for men and women, but the difference was not statistically significant.

Table 4. Daily mean of men's (M) and women's (W) suicide rate by astronomical season.

Sex	Area	Astronomical season			
		Winter	Spring	Summer	Autumn
M	Finland	.099	.120*	.117	.106
		.094-.103	.115-.125	.112-.122	.101-.111
	Helsinki	.128	.138*	.135	.131
		.120-.136	.128-.148	.123-.147	.122-.140
	Oulu	.119	.141	.159*	.131
		.098-.140	.123-.160	.138-.180	.113-.150
W	Finland	.025	.031*	.029	.028
		.023-.027	.030-.032	.028-.031	.027-.030
	Helsinki	.046	.050*	.049	.048
		.042-.050	.045-.054	.045-.054	.043-.053
	Oulu	.036	.040	.042*	.039
		.029-.044	.030-.049	.032-.051	.029-.048

*= The highest daily mean suicide rate by astronomical season in each area.

The daily changes in sunshine hours and ambient temperature did not have statistically significant associations with the daily means of the suicide rates of men or women, based on the overlapping confidence intervals (Table 3 in original paper

IV). However, some similarities for weather changes with the highest suicide rate were found in Helsinki and Oulu (Table 5).

Table 5. Daily increases (+) or decreases (-) in sunshine hours (S) and/or in temperature (T) that associate with highest suicides rates (SR) of men(M) and women(W) in Helsinki and Oulu during each astronomical season.

Sex	Area	Daily weather changes with highest SR by astronomical season			
		Winter	Spring	Summer	Autumn
M	Helsinki	S+	T-	T+	T-
	Oulu	S+T-	S+T-	T+	T+
W	Helsinki	S-T-	T+	T-	S+T+
	Oulu	S+	S+T-	S-T+	S+

5.2.2 Solar time (ST) gaining or being slow in relation to UTC

On the national level, the daily mean of suicide rate was the highest for men and for women during period 6, which starts on May 15 and ends on July 25 (Table 6). During that period ST is slow compared to the UTC (for the definition of the time difference between ST and UTC, “the time of equation”, see 2.3.1 and Table 3, and Figure 3). Furthermore, the photoperiod is at its longest around this period on the northern hemisphere, as the summer solstice with the maximum day length is on June 21.

Table 6. Daily mean of men’s (M) and women’s (W) suicide rate by periods of the time of equation, with solar time (ST) gaining (5, 7) or being slow (6, 8). The time differences between ST and UTC during the periods are visualized in Figure 3.

Sex	Area	Periods by time of equation				
		5	6	7	8	
M	Finland	.109	.124*	.112	.101	Period 5: February 11 – May 14
		.105-.114	.118-.129	.107-.116	.096-.106	
	Helsinki	.131	.142*	.130	.130	Period 6: May 15 – July 25
		.121-.141	.130-.154	.122-.139	.120-.140	
	Oulu	.133	.146	.150*	.122	Period 7: July 26 – November 03
		.115-.150	.124-.167	.131-.169	.104-.140	
W	Finland	.028	.032*	.030	.025	Period 8: November 04 – February 10
		.027-.029	.030-.033	.029-.031	.024-.027	
	Helsinki	.047	.053*	.050	.043	
		.043-.051	.048-.058	.045-.054	.039-.048	
	Oulu	.038	.045*	.035	.038	
		.029-.047	.034-.057	.027-.042	.029-.047	

*= The highest daily mean suicide rate

The daily changes in sunshine hours and ambient temperature did not have statistically significant associations with the suicide rates of men or women, considering the overlapping confidence intervals (Table 4 in original paper IV). However, some similarities for weather changes with the highest suicide rate were found between Helsinki and Oulu, especially for men (Table 7).

Table 7. Daily increases (+) or decreases (-) in sunshine hours (S) and/or in temperature (T) that associate with highest suicides rates (SR) of men(M) and women (W) in Helsinki and Oulu during periods of time of equation.

Sex	Area	Daily weather changes with highest SR by periods 5-8 of time of equation			
		5	6	7	8
M	Helsinki	S+	T+S+	T-S-	S+
	Oulu	T-S+	T+S-	T+	T+S+
W	Helsinki	S+	T+	T+S+	S-
	Oulu	T-	S-	S+	T-S+

5.2.3 ST ahead or behind UTC

On the national level, the daily mean of the suicide rate was the highest for men and women during period 9, when ST stays ahead of the UTC (Table 8). However, based on the confidence intervals, the difference between the means during different periods is not statistically significant. Furthermore, the daily changes in sunshine hours and/or in temperature did not associate with the suicide rates of men and women.

Table 8. Daily mean of men's (M) and women's (W) suicide rate by periods of the time of equation with solar time (ST) ahead (9,11) and behind (10,12) the UTC. The time differences between ST and UTC during the periods are visualized in Figure 3.

Sex	Area	Periods by time of equation				
		12	9	10	11	
M	Finland	.102	.125*	.118	.107	Period 9: April 15 – June 13, Period 10: June 14 – August 31, Period 11: September 01 – December 25, Period 12: December 26 – April 14,
		.098-.107	.120-.130	.112-.123	.102-.111	
	Helsinki	.128	.146*	.135	.130	
		.121-.136	.134-.158	.122-.147	.122-.139	
	Oulu	.125	.145	.148	.139	
		.107-.144	.123-.167	.128-.168	.119-.159	
W	Finland	.026	.032*	.030	.028	
		.024-.027	.030-.034	.028-.031	.027-.030	
	Helsinki	.046	.051*	.051*	.048	
		.042-.049	.045-.056	.046-.056	.043-.053	
	Oulu	.036	.043*	.041	.038	
		.029-.044	.032-.054	.030-.053	.031-.048	

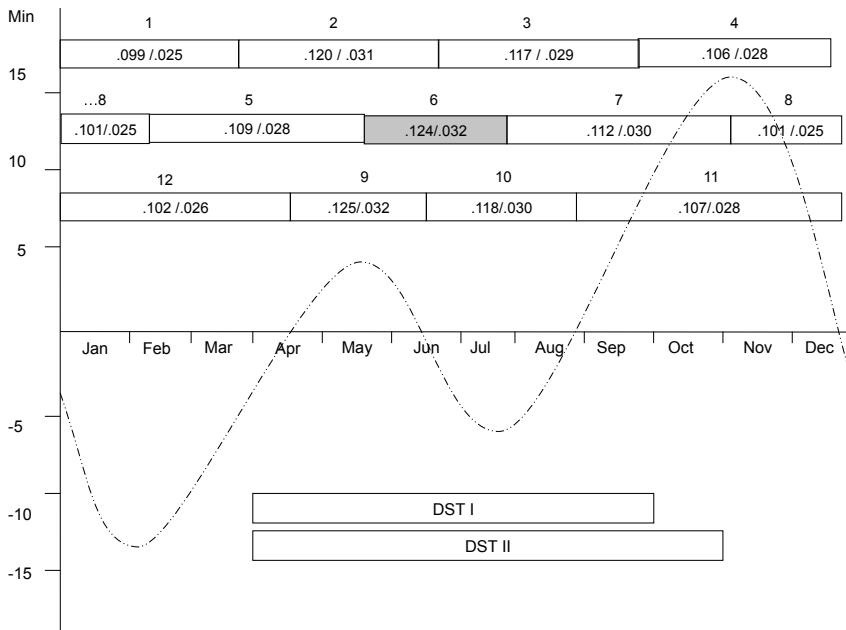


Figure 3. The mean for daily suicide rate for men and women during twelve periods by astronomical seasons and time of equation (see also Table 3). The daily suicide rate was significantly higher during the period 6 for both genders.

The dashed line visualizes the time in minutes (in y-axis) that the solar time (ST) is either ahead or behind the UTC during calendar months (x-axis). DST I = the dates for the daylight saving time from 1981 to 1994, DST II = the dates for the daylight saving time from 1995.

5.2.4 Daylight saving time

We did not find statistically significant increase or decrease in the suicide rate in Finland in relation to switching to and from the daylight saving time, neither in spring nor autumn.

5.3 Study III: Suicide rates in Helsinki, Jyväskylä and Oulu in relation to daily temperatures and thermal seasons from 1974 to 2010

5.3.1 Helsinki

Men's suicide rate correlated with the change in the daily mean temperature during five previous days ($p=0.02$). This applied especially to decreasing temperatures; the rate ratio for men's suicides was the lower the more the ambient temperature had decreased during the past five days (Figure 3, original paper III). Furthermore, the suicide rate of men in Helsinki correlated with the daily mean temperature, showing higher rate ratio with higher ambient temperature on annual basis.

5.3.2 Jyväskylä

Women's suicide rate correlated with the time (days) from the onset of thermal spring ($p=0.001$), the rate ratio increasing up to thirty days from the onset of thermal spring. Furthermore, the suicide rate of women correlated with the diurnal difference between the daily maximum and minimum temperatures ($p=0.02$) with an increasing rate ratio of 1.024 per degree of Celsius. When thermal seasons were used as categorical variables in the model, the rate ratios (RR) with 95% confidence intervals (CI) were in descending order as follows: spring (RR = 2.23, CI: 0.56-8.82), fall (RR= 0.98, CI: 0.27-3.49), and summer (RR= 0.71, CI: 0.16-3.05), winter being the reference. No statistically significant correlations were found for suicide rate of men in Jyväskylä.

5.3.3 Oulu

Men's suicide rate correlated with the daily mean temperature ($p=0.009$) (Figure 5, original paper III) showing a higher rate ratio with higher ambient temperature. In line with this, the rate ratio of men's suicides decreased with the time (days) from the onset of the thermal winter. Both of these findings are in line with the findings regarding men in Helsinki.

5.4 Study IV: Suicide attempts and atmospheric pressure in Helsinki in 1989-1990, and 1997

5.4.1 Synoptic weather analyses

5.4.1.1 Cluster days of suicide attempts

During men's cluster days it was typically cloudy, and raining or snowing, and low atmospheric pressure was dominant, except for April and May during which high pressure and sunny weather prevailed. For women high pressure was typical for the cluster days. Cluster days with more than ten suicide attempts, regardless of the sex distribution, emerged during winter with high pressure, but cloudy weather.

5.4.1.2 Days without self-harm

After the exclusion of days without self-harm due to harvesting effect, or short-term mortality displacement (Huynen et al.2001), 7 days remained suggesting that weather warmer than normal with sunshine may associate with low self-harm. For men normal atmospheric pressure seemed to be dominant on low self-harm days. However, these results should be considered with caution due to the small number of days.

5.4.2 Daily associations between weather variables and attempted suicides

Daily global solar radiation, ambient temperature, and precipitation did not correlate with the daily number of suicide attempts for either sex, analysed by Poisson regression, but for atmospheric pressure opposite correlations for men and women were found. The daily number of women's suicide attempts correlated positively with the atmospheric pressure of the day of the attempts (RR =1.005, $p=.026$), as well as with the mean atmospheric pressure one and two days before the attempts (RR=1.005, $p=.027$, and RR 1.006, $p=.011$). For men the correlation was inverse (RR=.995, $p=.016$) and applied also for the day before (RR=.996, $p=.040$). For suicide attempts of men by violent methods, that is hanging, jumping from high places, and shooting, the correlation was more significant and applied also for the two previous days (RR=.983, $p<.001$) (Table 5, original paper IV).

6 Discussion

6.1 Main findings

In this thesis the register based suicide rates from 1969 to 2010 in Finland were compared to the day length, the timing of daylight in respect to the UTC, the hours of sunshine, global solar radiation, ambient temperature, and precipitation during different time frames. In addition, a sample of attempted suicides, based on hospital treatment during two separate periods in the Helsinki region, was compared to the daily weather data.

Suicide rate associated differently with the day length, global solar radiation, and ambient temperature depending on location, gender, and the time frame that was assessed. Furthermore, we found that attempted suicides in Helsinki associated with atmospheric pressure.

On the national level, the highest suicide rate was from May 15 to July 25, when the day length is at its highest. None of the weather variables associated with the suicide rate during that period. However, on yearly assessment ambient temperature associated with the national suicide rate of men and women, as well as with the suicide rate of men in Helsinki and Oulu.

6.2 Completed suicides and weather

6.2.1 Global solar radiation

Our findings are opposite compared to the two previous studies on global solar radiation and the suicide rate, which were conducted in Greece and Germany (Papadopoulos et al. 2005, Muller et al. 2011). We found that global solar radiation seems to have an inverse association with the suicide rate. Cumulative inverse association was found from November to March for both genders, and again from November to September and October, but monthly associations were different for men (March, September) and women (November). During autumn the association applied to both genders. The lack of association during the light period suggests that during the darker period of the year, global solar radiation may have a protective effect against the suicides, but that the increase in the suicide rate during the summer is due to some other reasons. The positive associations between the suicide rate and global solar radiation in Greece and Germany were found on shorter periods of time, from a few days up to nine days. Furthermore, the number of suicides was much smaller (3717, and 2987 including attempted suicides) in both studies. Therefore the

comparison of the results to our findings is somewhat difficult, not to mention the absolute differences in climates between these three countries. In Finland the amount of global solar radiation changes significantly between seasons, with ten time higher values measured during summer compared to those in winter. It includes the direct radiation from the sun as well as the indirect radiation emitted from the cloud cover, and snow. Therefore it is a more reliable measurement for the actual luminosity circumstances than just the sunshine hours.

6.2.2 Sunshine hours

The number of sunshine hours, or more precisely, the change in the number of sunshine hours compared to the previous day of the completed suicide, was assessed in Study II in connection to the day length in two areas in Finland, Oulu and Helsinki. Statistically significant correlations between the suicide rate and changes in daily sunshine hours as well as temperature were not found. This was not what we expected, since positive associations have been found between sunshine hours and suicide rate in England, Greece and Japan (for women only) (Salib, Gray 1997, Papadopoulos et al. 2005, Inoue et al. 2012). However, different time frames may be responsible for the different results. In Greece, the time frame for the association was between one and nine days, and in Japan one year, and in England the sunshine hours at the day of fatal self harm associated with suicides. In addition, different climates may, again, partly explain the different findings. Furthermore, the relatively small numbers of suicides in Helsinki and Oulu may not have had enough statistical power. However, in Tables 5 and 7 (in Chapter 5.2.1) it is tempting to see some patterns in the daily changes of sunshine hours and temperature that associate with the highest suicide rates.

6.2.3 Ambient temperature

Ambient temperature associated with the suicide rate of men in Finland on an annual level between 1971 and 1990; the higher the ambient temperature, the higher the suicide rate, or the lower the temperature the lower the suicide rate. Our finding was in line with that concerning men's suicide rate in Japan from 1977 to 2008 (Inoue et al. 2012). However, on a seasonal level the association existed for men only during winter, and not during the warmer part of the year. In line with this, the monthly mean temperature associated with the suicide rate of women only in November. In Study III, associations between the suicide rates and temperature on a daily level showed also the most pronounced associations in the lower temperatures, and during the increase in temperature during the thermal spring, when the mean ambient temperature is between 0°C and $+10^{\circ}\text{C}$, by definition.

6.3 Completed suicides and daylight

In an attempt to assess the possible involvement of the circadian clock in the seasonal variation of suicides, in Study II we studied the changes in the suicide rate in respect to the astronomical seasons, which reflect the rhythm by which the day length increases or decreases. Furthermore, we studied the changes in the suicide rate in respect to the time of equation, which reflects the alterations in the timing of dawns and dusk in respect to the official UTC time. We hypothesized that especially the shifting of dawn into an earlier timetable in connection to the increasing day length, between February 11 and May 14, might be harmful for the circadian clock. Against our expectations, no association with that aforementioned period was found, but the daily mean of suicide rate was the highest between May 15 and July 24, (period 6, Table 3) for men and women. During that period the dawn first shifts into a later time table, and later its starts to go into an earlier timetable again, but the absolute time difference between the solar time and the UTC is approximately only five minutes. However, during this period from May 15 to July 24 the daylight reaches its maximum as the summer solstice is on June 21.

Based on our finding it may be tempting to think that the highest suicide rate is explained by the length of photoperiod. However, the highest daily mean in the suicide rate in Oulu seems to be somewhat postponed for men, compared to the national timetable. In addition, the decline in the suicide rate is not during the shortest photoperiod around winter solstice, but in January or February (Hakko, Räsänen & Tiihonen 1998a). Furthermore, the day length does not give an explanation to the inter-annual variability in the spring - summer peak of the suicide rate, nor to the elevated suicide rate two months before (April 15 - June 13, statistically not significant), but not two months after the period 6, Therefore, although the impact of the day length to suicide seasonality cannot be totally ruled out, some other explanations are needed as well. Whether it is related to the ambient temperature or whether Emile Durkheim was on the right track in his conclusion, that it is the increase in social activities during spring and summer that is responsible for the increase in suicide rate, should be further studied.

6.4 Attempted suicides and weather

The interactions between attempted suicides and weather phenomena have been studied far less than the completed suicides. We only had the data of attempted suicides during two relatively short separate periods in Helsinki, but since attempted suicides are much more common than completed suicides, almost 4000 suicide attempts were included in the analyses. Although in previous studies several weather variables have associated with attempted suicides, we found a statistically significant association only between the mean daily atmospheric pressure and the daily number of attempted suicides. Global solar radiation (proportion to the normal),

ambient temperature (deviation from the normal), and precipitation did not associate with attempted suicides as independent variables. For men the association was an inverse one in direction, and even stronger for the attempts by violent methods. According to the cluster day analyses the pattern was the same, except in April and May, when the cluster days for men occurred more often on days with high pressure.

It is interesting that pressure changes have been associated with pain related behaviour in rats, as well as with changes in sex-hormones in humans. The biological mechanisms related to pain may not be that far away from depression, since antidepressants are also used for the treatment of chronic pain (Dharmshaktu et al. 2012). It would be most interesting to study the hormonal reactivity towards pressure changes among individuals with suicidal behaviour.

6.5 Gender and weather

Our findings for men and women were different in part. However, concerning global solar radiation and temperature in relation to completed suicides, the results seem to point towards the same direction. Therefore, the differences in single separate analyses may be simply due to the far smaller sample size of women's suicides. However, another hypothetical explanation for the differences between sexes concerning associations to ambient temperature may stem from possible variations in the biological mechanisms that are involved in thermoregulation. For example, in rats the receptor-activator of NF- κ B-ligand (TNFSF11 or RANKL) and its tumour necrosis factor-family receptor RANK, both involved in the thermoregulation in the central nervous system, seem to interact with the ovarian sex hormones of the females (Hanada et al. 2009).

The opposite finding between men and women in respect to the atmospheric pressure and attempted suicides is interesting, but needs to be replicated before any further conclusions. No biological theory exists explaining this difference between the two sexes.

6.6 Methodological considerations

6.6.1 Variables

Suicides and attempted suicides

The suicide statistics from the study period may be considered relatively reliable and consistent, since the inquest procedure has not legally changed during the study period, and no major societal change, such as war, has taken place in Finland since 1969. A medico-legal investigation by the Police is required by law to all deaths that are, or are suspected to be, suicides. In addition to the investigations at the place of death and a thorough investigation concerning the way the individual has lived

before the death, the Police can order an autopsy to be conducted, which is often the case. All possible information from the relatives, friends and health care professionals are assessed in order to conclude whether the death was due to suicide or due to other causes. Suicide has not been considered a crime since 1894 in Finland, and already from the 1840s the legal consequences were not fully implemented. However, the stigma towards suicide has not completely vanished. In some cases relatives have asked the police to change the cause of death from suicide to something else (oral notification by the police), and information told to the police may be distorted by friends and relatives. Furthermore, involvement of alcohol or other drugs makes the assessment challenging.

Registers or statistics of attempted suicides do not exist in Finland. Only the numbers of attempted suicides which are treated in hospitals are registered. In this thesis, the study of attempted suicides was limited to two rather short periods of time in the Helsinki region, which impairs the generalization of our results to other parts of Finland as such.

Weather

The values of the chosen weather variables can be considered very reliable, due to the quality assurance that is being regularly done on the weather stations in Finland. Furthermore, the weather stations that provided the daily weather data were located within the radius of 25 km in respect to the place of residence of the individuals that attempted or completed suicide. Only for global solar radiation the distance was longer, since global radiation is measured only in Jokioinen in the south-western part of Finland, which can be considered as a limitation to our study. Another limitation is the fact that we did not assess the daily associations for global solar radiation, which may in part explain our opposite findings in respect to the previous studies. However, since we had the data of global solar radiation only from one weather station, daily values may not have been representative enough due to local variations. Therefore, our longer time frames may be well argued.

This thesis is based on daily register data both on completed suicides and local weather. Therefore, since the exact time of the suicides or the attempts was not available, some discrepancy may exist between the daily weather data and the numbers of suicides. Furthermore, individual exposure to the weather prior to the attempts and suicides could not be taken into account. In respect to the lightning exposure, the outdoor light - dark transitions and global solar radiation, may not give a complete picture, due to the electricity available to almost anyone nowadays. The same may apply to thermal exposure as well, but since air condition is not very common in Finnish houses, the outside temperature may have a marked impact on temperature indoors. During the colder part of the year, it is more probable that also the indoor temperatures are lower than during summer. Therefore, escaping from the

heat is much more difficult during summer than it is during winter. Data on sauna customs of the suicidal individuals would be most interesting in this respect.

Confounding factors

We had no data of socio-economic risk factors nor possible psychiatric illnesses or treatments including medications of the suicide victims. For attempted suicides we had the psychiatric diagnoses, but due to the small numbers we decided not to use them. For the same reason, in order to retain statistical power, differences between age-groups were not assessed.

6.6.2 Statistical methods

Due to the limited availability of synoptic weather data, the weather variables were mainly analysed in separate, which may be considered a limitation that should be addressed in future studies. No golden standard has yet evolved for the statistical methods and analyses in this field of suicide research, which makes the interpretations of the results between different studies challenging. However, the continuous development in the statistical techniques and programs may improve the analyses of more and more complex interactions to be taken into account in epidemiological studies.

7 Conclusions and future implications

7.1 Conclusions

This thesis was the first to assess the possible associations between weather variables and the suicide rate, as well as attempted suicides, in Finland. The main stimulus for this thesis has been the recurrent pattern of a higher suicide rate during spring and early summer, which has been shown in previous studies in Finland since the 1850s. The studies for this thesis were based on register data both on numbers of suicides, as well as local weather data, which can be considered rather reliable internationally. However, they provide only a rough estimate of the possible weather exposure of each individual, because no data of the outdoors behaviour on the individuals was available. Furthermore, since no data on psychiatric morbidity or socioeconomic risk factors were available, it is not possible to estimate what is the input of weather factors in respect to other risk factors for suicide.

This thesis showed associations between ambient temperature and the suicide rate especially during the colder and darker seasons of the year, although temperature seemed to associate with the suicide rate also on an annual basis. Furthermore, surprisingly, global solar radiation, which measures the luminosity better than sunshine hours, showed inverse association with the suicide rate, but especially during the darker part of the year. Therefore, it is tempting to suggest that temperature may be a candidate explaining the increase of the suicide rate during spring and summer. Whether it also explains the other smaller peak in the number of suicides by women in autumn, remains to be revealed. In addition, the finding that the highest mean in the daily suicide rate seems to be later in summer in Oulu compared to that in Helsinki may support the association of temperature with the higher suicide rate in summer. However, further studies are needed on the seasonality of suicides.

The finding of opposite associations between sexes in respect to atmospheric pressure and attempted suicide was new, and needs to be replicated before any further conclusions can be drawn.

7.2 Research implications

Based on this thesis it seems that cold weather might be protective against completed suicides for men and women, especially so between autumn and spring equinoxes. Although precipitation did not have a statistically significant association with the suicide rate by itself in our study, it improved the statistical model, suggesting that the more there is precipitation the less there are suicides. This is in line with the old finding from London in 1874, where they found that a higher incidence for suicides was associated with warm and dry weather (Mitchell and Buchan, *Nature* July 16, 1874). Therefore, a more synoptic view of the weather conditions in future studies should be considered, in order to have a more comprehensive understanding of our findings.

The mechanisms, biological or social, behind these correlations we found between weather factors and suicide rates, remain to be revealed. Especially the functions of circadian clocks, as well as brown adipose tissue should be most interesting in this respect. Furthermore, hypothalamic-pituitary-adrenal axis has been suggested to interact with the circadian system (Nicolaides et al. 2014). Serotonin transporter gene has been associated with vulnerability for SAD (Sher et al. 2000), but whether this is also related to an over-all sensitivity to weather changes, should be studied further. The underlying mechanisms that explain why the female gender has been linked with seasonal mood variability, should be studied more as well (Oginska and Oginska-Bruchal 2014).

Since 10-20% of suicide attempters end up completing a suicide (Isometsä 2014), more detailed data on attempted suicides, including the visits in health centres, would be needed. However, registers on health matters are always delicate, and this issue may be ethically questioned.

7.3 Clinical implications

In clinical psychiatric settings, the awareness of the elevated suicide risk in spring and around the summer solstice, and again around October (women), should be increased, so that the limited resources in health care would be most efficiently available. Furthermore, factors that may impair the thermoregulation of psychiatric patients should not be overlooked.

A suicide attempt is the most important single risk factor for a completed suicide, and therefore, it should be considered with adequate attention every time, regardless of any weather conditions or other thereby minor factors.

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* * *

Even if I had all the time and money and premises in the world, but I hadn't had my patients, I would probably not have accomplished this. Thank you all. I wish I can be there for you.

August 11, 2014, in Helsinki

Laura Hiltunen

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