SEASONAL VARIATION OF SUICIDES AND HOMICIDES IN FINLAND

With special attention to statistical techniques used in seasonality studies

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Abstract

Seasonal variations of events are apparently playing an important part in various psychiatric conditions. To study the seasonal variation of a condition appears to be one useful approach to clarify the aetiology of a mental disorder and phenomena to which mental disorders are associated. In the present study the seasonal variations of suicides during the period of 1980-95 (n=21279) and homicides during the years 1957-95 (n=4553) in Finland were analysed. In addition, the use of statistical techniques for seasonality and some important characteristics of study samples were evaluated from 44 original suicide seasonality studies published between 1970-97. Special attention was paid to statistical methods for seasonality and these were reviewed in the summary part of this dissertation.

A statistically significant spring peak of suicides was found in both genders, in all age groups (aged 39 years or below, 40-64 years, and 65 years or more) and in violent (hanging, drowning, shooting, wrist-cutting, jumping from a height) and non-violent suicides (poisoning, gas, other methods). A secondary autumn peak of suicides was present in females and also associated with non-violent methods. The rate of violent suicides had increased significantly during 1980-90 and decreased thereafter, while the non-violent suicides had kept steadily increasing over the whole 16-year study period. The seasonal variation of violent suicides had remained stable and statistically significant over the whole study period, but the seasonality in non-violent suicides has diminished over time.

The seasonal pattern of homicides showed a statistically significant peak in summer and a trough in winter. The observed rate of homicides was about 6% higher in summer and 6% lower in winter than expected under the null hypothesis of a uniform distribution. Both the crude numbers of homicide and the rate of homicides per 100 000 population increased significantly over the 39-year study period. The increasing rate of homicides in Finland was accompanied by decreasing homicide seasonality. The seasonal trends in homicides correlated significantly (positive correlation) with the seasonal trends in the violent suicides over the period of 1980-95.

The use of particular statistical techniques was specified in the majority of the 44 reviewed suicide seasonality articles. This was considered as satisfactory, although in subgroup analyses and in comparisons of the seasonal pattern of suicides with phenomena other than suicides, researchers tended to interpret their study findings without a statistical significance test. In those 37 articles, which had actually examined the seasonal pattern of suicides with a statistical test, statistical methods varied from simple standard tests like the chi-square test (14 articles, 38%) to sophisticated time series analyses such as a spectral analysis (4 articles, 11%). The calendar effect (i.e. effect due to the unequal lengths of months and leap years) was reported to have been taken into account in only 10 out of 44 (22%) reviewed studies. The lack of reporting the size of a sample (12 articles, 27%) or monthly values of suicides (17 articles, 54%) was found to be a major deficit in the reviewed studies. On the basis of these findings it is recommended to carry out further surveys, which evaluate statistical content and use of statistical methods in published medical articles. These kinds of surveys remind researchers to consider more thoroughly methodological and statistical issues in their investigations.

Keywords: statistical methods, violent suicide, non-violent suicide, time trend

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Abbreviations

5-HT	5-hydroxytryptamine
5-HIAA	5-hydroxyindoleacetic acid
[^{3}H]-IMI	[^{3}H]-imipramine binding to platelets
[^{3}H]-PAR	[^{3}H]-paroxetine binding to platelets
ANOVA	Analysis of variance
ARIMA	Autoregressive Integrated Moving Average
CSF	Cerebrospinal fluid
L-TRP	Plasma L-tryptophan concentrations
SAD	Seasonal Affective Disorder

List of original studies

This thesis is based on the following original articles:

I Hakko H, Räsänen P & Tiihonen J (1998) Seasonal variation in suicide occurrence in Finland. Acta Psychiatr Scand 98: 92-97.

II Hakko H, Räsänen P & Tiihonen J (1998) Secular trends in the rates and seasonality of violent and nonviolent suicide occurrences in Finland during 1980-95. J Aff Disord 50: 49-54.

III Tiihonen J, Räsänen P & Hakko H (1997) Seasonal variation in the occurrence of homicide in Finland. Am J Psychiatry 154: 1711-1714.

IV Hakko H, Räsänen P & Tiihonen J (1998) Increasing homicide rate in Finland accompanied by decreasing seasonality over the period 1957-95. Soc Sci Med 47: 1695-1698.

V Hakko H, Räsänen P, Tiihonen J & Nieminen P. Use of statistical techniques in studies of suicide seasonality covering the period of 1970 to 1997. Submitted for publication.

These studies are referred to in the text with the above Roman numerals.

Contents

1. Introduction

Numerous epidemiological studies have shown that cyclic clusterings, such as monthly or seasonal variations of events, occur in several psychiatric conditions. For instance, the effect of seasons on the incidence of depression, on birth rates among patients with schizophrenia, or on hospital admissions due to a mental disorder have carefully been investigated (Fossey & Shapiro 1992, Takei *et al.* 1992, Modestin *et al.* 1995, Torrey *et al.* 1997). The purpose of this kind of studies has not only been to describe a seasonal pattern of events, but above all, to seek the explanations for the phenomenon. To study the seasonal variation of psychiatric disorders is, therefore, one way to clarify the aetiology and the course of a disorder.

Suicides are a major public health problem throughout the world. The suicide mortality in Finland is one of the highest in the world. In 1997 the suicide rate per 100 000 mean population was 25.7, while, for example, in Sweden it was 14.2 (year 1996) and in the USA 11.9 (year 1995) (Statistics Finland 1999a). Intensive research in Finland has considered the aetiology of suicides from various viewpoints. A number of Finnish studies have focused on suicide victims with different types of mental disorders or studied suicides in relation to social factors (Heikkinen 1994, Isometsä 1994a, Marttunen 1994, Henriksson 1996, Heilä 1999), concentrated on suicide methods (Öhberg 1998a) and suicides in specific subpopulations, like, for instance, among physicians (Lindeman 1997).

The seasonal distribution of suicides has been of continuous interest to researchers. In both the Northern and Southern Hemisphere a consistent finding has been that cases of suicide display a significant peak in spring or early summer and a trough in winter (see, for example, Kevan 1980, Näyhä 1982, Massing & Angermeyer 1985, Chew & McCleary 1995). The seasonal distribution of suicides has been found to vary in the different subgroups of a population, for example in males and females (Meares *et al*. 1981). Furthermore, the seasonal distribution of suicides has been shown to be related to the seasonal patterns of other phenomena, like climatic variables (see, for example Maes *et al.* 1994, Preti 1997). In Finland, the latest studies on suicide seasonality were published in the early 1980s (Näyhä 1980, Näyhä 1982, Näyhä 1983, Näyhä 1984).

The number of deaths due to homicides (murders, manslaughters) and injury inflicted by other persons varies largely between countries. In Finland this rate has been one of the highest in Europe being 2.9 per 100 000 mean population in the year 1995. The rate of homicides and injury inflicted by other persons was 1.2 (year 1996) in Sweden and 8.6 (year 1995) in the United States (Statistics Finland 1999a).

The seasonal distribution of homicides has only sparsely been studied in psychiatry. Most of these studies have failed to find any statistically significant seasonality in deaths due to a homicide (Michael & Zumpe 1983, Abel *et al.* 1985, Abel *et al.* 1987, Goodman *et al.* 1989, Maes *et al.* 1993a,b). Lester (1979) reported a significant excess of homicides in July and December in the USA. In Finland, Näyhä (1980) found a significant peak in July, August or October, when studying secular trends in the seasonality of homicides over several separate time periods between 1878-1972. Thereafter, the seasonal variation in homicides in Finland has not been investigated.

A variety of statistical techniques can be used to examine a seasonal pattern of events. These techniques vary from simple descriptive techniques, such as a chi-square test (Siegel & Castellan 1988), to specific time series analyses, like a spectral analysis (Chatfield 1996). The more sophisticated the statistical method, the more methodological knowledge and experience is required from a researcher, who wants to apply it correctly. In seasonality analyses it is important to use such a statistical method, which is sensitive to a specific type of seasonal or cyclic regularity in the data (Tennebaum & Fink 1994).

One way to raise the researchers' awareness of statistical and other methodological issues in scientific research is to make surveys, whose purpose is to evaluate the quality of the data and the appropriateness of the statistical techniques used in the published articles. There are studies, which have dealt with statistical contents, statistical errors or the use of statistical techniques of published articles in psychiatric research (White 1979, DeGroot & Mezzich 1985, Hokanson *et al.* 1986, McGuigan 1995, Nieminen 1995, Everitt & Landau 1998). Although researchers have frequently raised concerns about poor statistical methods and inadequate samples found in suicide seasonality studies (Lester 1971, Lester 1979, Phillips & Wills 1987, Miccolo et al. 1989, Maes *et al.* 1993a,b, Tietjen & Kripke 1994, Ho *et al.* 1997), no one has systematically evaluated methodological and statistical features of suicide seasonality studies.

In this thesis all completed suicides in Finland during 1980-95 and all homicides that occurred in Finland during 1957-95 are investigated in terms of their seasonal variation. In addition, the use of statistical techniques and features of the data are evaluated from those studies, which have examined seasonal variations of suicides during 1970-97.

2. Review of the literature

2.1. Seasonal rhythms

2.1.1. Psychiatric epidemiology and chronobiology

Seasonal rhythms in physical and mental health have been observed to exist since at least 400 BC, when Hippocrates stated (cited by Hare 1975) that

> "*Whoever wishes to investigate medicine properly should proceed thus: In the first place to consider the seasons of the year and what effect each of them produces*".

A variety of rhythms are affecting a human's everyday life. For example, human life is greatly influenced by environmental cycles, such as day and night oscillations, tides, calendar months, lunar periodicity, and seasons of the year (Hyman 1990). The word "rhythm" is defined in many ways depending on, whether it is used to describe music, speech, rhymes, dance, and mathematical or biological functions. In all cases a rhythm may be defined to be a flow, movement or procedure characterised by a basically regular recurrence of elements or features (Pauly 1980).

There is a broad spectrum of rhythms that operates simultaneously within a human's biological processes, for example the heart rate and the menstrual cycle. These rhythms are called endogenous, because they arise from within the human organism. Simultaneously, there is a broad spectrum of external rhythms in the natural environment of a human. These rhythms are called exogenous, because they arise from outside the human organism. Many of these rhythms have specific phase relationships with each other, which means that they interact and synchronise each other (Haus *et al.* 1980, Pauly 1980).

The studies on the seasonal and other rhythmic patterns in mental disorders and their associated features are mainly based on the methodology of two scientific disciplines – psychiatric epidemiology and chronobiology. Psychiatric epidemiology has applied a variety of methods and designs of epidemiology to examine causal hypotheses relevant to the aetiology of mental disorders, whether they are social, psychological or biological

(Tango 1984, Pickles 1998). Epidemiologists have been interested in cyclical clusterings of an illness over time such as a seasonal variation, because it may suggest causality due to specific factors, usually with emphasis on environmental factors, as for example with the occurrence of certain infectious diseases (Smolensky 1987). On the other hand, biological rhythms and their mechanisms are the main topic of the science of chronobiology (Halberg 1980). To chronobiologists, the cyclical clustering of illnesses points to the possible contribution of biorhythmic phenomena in the occurrence of human diseases and/or the contribution of both exogenous and endogenous cyclic phenomena (Smolensky 1987).

Although epidemiologist have studied rhythmic patterns in human diseases, mostly in terms of the prevalence or incidence, they have been criticised for not having sufficiently well enough considered relevant biorhythmic phenomena in their pursuits (Smolensky 1987, Smolensky & D'Alonzo 1988). However, recent studies have shown that there is an increasing tendency to highlight the role of seasonally regulated environmental factors on internal biological processes in seasonality studies of mental disorders (Fossey & Shapiro 1992).

The terminology used to describe various biological rhythms in chronobiological research is different from that used in every day life for rhythmic periods. It also differs from the terminology, which researchers in psychiatry have become accustomed to use. When a psychiatrist reports "yearly and weekly variations of suicides", a chronobiologist uses the expression "circannual and circaseptan rhythms of suicides". One probable explanation for this different usage of terms may relate to differences in the customary use of statistical methods. In fact, psychiatrists have found to be fond of simple statistics and significance tests, such as the chi-square test or Student's t-test (Everitt & Landau 1998). On the other hand, chronobiologists have routinely used to utilise sophisticated statistical methods and their terminology, which might be rather mathematical and technical (Nelson *et al.* 1979, Haus *et al.* 1980).

Table 1 lists the most common terms and their definitions used in research on biological rhythms of variable periodicities. Biological rhythms with periods less than 20 hours are known as ultradian rhythms, while those with periods greater than 28 hours are called infradian rhythms. Rhythms, the lengths of which lie between 20 to 28 hours, qualify as circadian rhythms.

Table 1. The range of periods of biological rhythms of different frequency (Haus et al. 1980, Hyman 1990).

Term	Definition for rhythm	Range of period
Ultradian rhythms		< 20 hours
Circadian [a]		24 ± 4 hours
Dian	Daily rhythm (about 24 hours)	24 ± 0.2 hours
Infradian rhythms		> 28 hours
Circaseptan	Weekly rhythm (about a week)	7 ± 3 days
Circadiseptan	Rhythm about two weeks	14 ± 3 days
Circavigintan	Rhythm about three weeks	21 ± 3 days
Circatrigintan	Monthly rhythm (about a month)	30 ± 5 days
Circannual	Yearly (annual) rhythm (a solar year)	1 year ± 2 months
Circalunar	Lunar rhythm	about 29.5 days

[a] The Latin *circa* means "approximately" and *dies* means a "day" (Hyman 1990).

2.1.2. Seasonality in psychiatry

2.1.2.1. Season-of-birth effect

Several studies have proposed that the month of birth might be a predisposing factor for a psychiatric disorder. The significant season-of-birth effect observed in numerous studies has proposed to suggest the involvement of a periodicity of an environmental aetiologic agent, which, on the other hand, may act in concert with endogenous biological rhythms in the susceptibility to that agent (Fossey & Shapiro 1992).

According to Castrogiovanni *et al.* (1998), over 100 studies of the season-of-birth effect on the development of schizophrenia have been published since the time of Tramer, who first reported that the births of psychotic patients had a significant peak in winter and early spring. The majority of later studies have shown 5-10% winter/early spring excess of births of subjects later diagnosed as schizophrenics when compared with the general population (see, for example, Bradbury & Miller 1985, Boyd *et al.* 1986, Torrey *et al.* 1996, Torrey *et al.* 1997, Castrogiovanni *et al* .1998). Also, among patients with schizoaffective disorders an excess of births in the first quarter of the year has been noted (Aschauer *et al.* 1994, Torrey *et al.* 1996). However, the recent meta-analysis by McGrath and Welham (1999) using data from twelve Southern Hemisphere studies were unable to detect any significant season-of-birth effect in schizophrenia.

Studies on birth seasonality for affective disorders have mainly focused on patients with bipolar disorder. Most of those studies, which have found a statistically significant birth excess, have reported similar seasonal birth excesses during winter/spring for manic-depressive psychosis/bipolar disorder as well as for schizophrenia (Boyd *et al.* 1986, Torrey *et al.* 1997, Castrogiovanni *et al.* 1998). Births of patients with major depressions/unipolar disorder have shown to peak in spring (Torrey *et al.* 1996, Clarke *et al.* 1998b).

According to a review by Torrey *et al.* (1997), Dalen found 8.5% birth excess in March among males with personality disorders. Yet, other studies have not been able to establish any significant seasonal birth pattern among patients with personality disorders (Parker & Neilson 1976, Hare & Walter 1978, Watson *et al.* 1984). Kop (1977) found that males born in the period of April-June or July-September committed their offences (the perpetration of aggressive delinquencies) significantly more often in November-December or September-October, respectively, compared with subjects born in the other months.

The season-of-birth studies in relation to alcoholics are few. Levine and Wojcik (1999) reported a 5% difference between the 17-21 year olds and the 22-29 year olds with regard to the “half year”, in which the birth occurred. Modestin *et al.* (1995) found a significant spring/summer birth rate excess in alcoholics. Other studies have reported a lack of seasonality in births for alcoholics (Watson *et al.* 1984, Kunugi *et al.* 1998).

Seasonal birth patterns have occasionally been reported in relation to other psychiatric conditions. For example, March and August births were found to be a risk factor for the development of autistic disorders (Gillberg 1990, Fossey & Shapiro 1992, Barak *et al.* 1995). An excess of births in spring has also been reported for patients with eating disorders (Rezaul *et al.* 1996) and for the group of neuroses other than neurotic depression (Parker & Neilson 1976).

The assessment of the role of the seasonal birth pattern in connection with the aetiology of a psychiatric disorder has produced several hypotheses. A variety of theories have been proposed to explain alone or in interactions with each other the association between season-of-birth and a psychiatric disorder: nutritional deficiencies, procreational habits, genetic predisposition, pregnancy and birth complications, infectious agents, seasonal variation in biochemical functioning, seasonal variation in external toxins, or climatic and weather effects (see, for example, Bradbury & Miller 1985, Boyd *et al.* 1986, Fossey & Shapiro 1992, Modestin *et al.* 1995, Torrey *et al.* 1997, Clarke *et al.* 1998b).

In addition, explanations for season-of-birth effects have been sought by studying whether seasonal birth patterns differ in subsamples of a population. The subsamples have been selected on the basis of covariates such as gender, birth year, sociodemographic factors (race, marital status, social class, place of birth), clinical characteristics (length of hospitalisation, age at onset, subtypes of a psychiatric disorder), or level of familial risk (presence or absence of family history of psychiatric illness) (Bradbury & Miller 1985, Boyd *et al.* 1986).

Methodological problems in season-of-birth studies have raised concern among researchers and statisticians. A need for large number of subjects has been highlighted in order to detect an association between season of birth and a psychiatric disorder (Hare 1975, James 1976, Torrey *et al.* 1997). Diagnostic heterogeneity of a study sample due to changes or differences in diagnostic systems have been suggested to reduce comparability of the findings (Torrey *et al.* 1997, Clarke *et al.* 1998b). Unreliable sources of data, inadequate control populations (e.g. a control group not matched to a study sample regarding year of birth or geographical region of birth), and a lack of controlling for the seasonal distribution of the general birth population have been identified as common sources for bias in season-of-birth studies (Hare 1975, Bradbury & Miller 1985, Boyd *et al.* 1986, Torrey *et al.* 1997).

The use of more sophisticated and more appropriate statistical methods for seasonality rather than simple significance tests has been recommended for season-of-birth studies as well as that more consideration should be paid to time periods of seasonality (Shensky & Shur 1982, Bradbury *et al.* 1985, Partonen & Lönnqvist 1996, Torrey *et al.* 1997, Clarke *et al.* 1998b, Räsänen *et al.* 1999). It has also been suggested that the theory of the seasonal effects of births is misplaced and instead of focusing on explanations for periods of excessive birth-rates, more attention should be paid to deficit periods (i.e. periods with lower than average of birth-rates) (Bradbury *et al.* 1985, Eagles *et al.* 1995).

Lewis and Griffin (1981) and Lewis (1989) postulated that a statistical artefact – an age-incidence effect - explains the majority of the findings in season-of-birth studies. The age-incidence effect means that if an incidence of an illness increases with age, 40-year-olds will produce more cases than 20-year olds and, to a lesser extent 31-year-olds will produce more cases than 30-year-olds. The age-incidence effect works also within years so that subjects born at the beginning of a year have had a longer time to develop a psychiatric disorder than those born at the end of a year. However, the age-incidence effect has been disproved by several researchers (Bradbury & Miller 1985, Dalen 1990, Pulver *et al.* 1990, Torrey *et al.* 1997).

2.1.2.2. Seasonality in hospital admissions

If the seasons of a year do not affect an incidence of a disorder, one should assume that hospital admissions were evenly distributed over a year. Naturally this depends on whether possible confounding factors are controlled when assessing a seasonal pattern. Putative changes in the availability of hospital services, for example the closing of wards during the summer vacations, will distort a true seasonal pattern of admissions if its effect is ignored. Furthermore, patients may also not be so readily admitted to hospital during their holiday periods, which may results in a backlog of admissions after these periods (Hare & Walter 1978, Oldehinkel 1998). On the other hand, patients with more severe illnesses are assumed to have an equal chance of being admitted throughout a year (Eastwood & Stiasny 1978).

Of all mental disorders, admission seasonality due to affective disorders has been studied most intensively. Among patients with bipolar affective disorder, there has been reported a summer/autumn peak in admissions (Clarke *et al.* 1998a, Oldehinkel 1998, Suhail & Cochrane 1998). Hospital admissions for depression have been found to peak in spring (Eastwood & Stiasny 1978, Parker & Walter 1982, Maes *et al.* 1993b), autumn (Eastwood & Peacocke 1976, Silverstone *et al.* 1995) or winter (Pio-Abreau 1997, Suhail & Cochrane 1998). Several studies have identified a spring/summer (Hare & Walter 1978, Myers & Davis 1978, Mawson & Smith 1981, Carney *et al.* 1988, Takei *et al.* 1992) or autumn peak (Symonds & Williams 1976, Walter 1977b,) for mania admissions, but a lack of seasonality was also found (Silverstone *et al.* 1995, Partonen & Lönnqvist 1996).

For patients with schizophrenia, admission peaks during spring or summer were noticed by Hare & Walter (1978), Takei *et al.* (1992), Takei & Murray (1993), and Clarke *et al.* 1998a), but some studies have failed to establish any admission seasonality among patients with schizophrenia (Eastwood & Peacocke 1976, Eastwood & Stiasny 1978, Partonen & Lönnqvist 1996). Seasonality studies in relation to hospital admissions for personality disorders have documented an absence of seasonality (Takei *et al.* 1992, Oldehinkel 1998), but studies on alcohol related hospital admissions have revealed a peak incidence during spring (Eastwood & Stiasny 1978) or summer months (Poikolainen 1982). Oldehinkel (1998) showed that subjects with diagnosed substance dependencies had a peak incidence in admissions during winter.

The seasonal variation in hospital admission has also been reported in relation to other psychiatric disorders; in eating disorders, for example, a significant month of admission was found to be the month of March (Gotestam *et al.* 1998). For admissions due to neurosis, peak incidences have been reported during autumn (Eastwood & Stiasny 1978, Oldehinkel 1998) or not at all (Eastwood & Peacocke 1976, Takei *et al.* 1992).

Different suggestions, depending on which mental disorder was involved, have been presented as explanations for admission seasonality. Explanations based on various environmental, social or biological factors have been put forward by earlier investigators (see, for example, Hare & Walter 1978, Fossey & Shapiro 1992).

Methodological limitations noted with regard to studies of admission seasonality are in the main similar to those found in season-of-birth studies. Critics have most commonly focused on the characteristics of a study sample, diagnostic heterogeneity and boundaries for seasons, or on the use of inappropriate statistical methods for seasonality (Fossey & Shapiro 1992, Pio-Abreau 1997, Clarke *et al.* 1998a). Particularly in admission seasonality studies of depression, it was noted that some contradictory findings might be due to the varying subtypes of the depressive disorders used in different studies (Oldehinkel 1998). Furthermore, the small number of published studies concerning admission seasonality for neurotic disorders may find its reason in the fact that hospital admissions are rare for these kinds of disorders.

Studies on admission seasonality have usually been based on data indicating first admissions, readmissions, or both combined. The time lag between onset of symptoms, referral and final admission to the hospital was found to be problematic to deal with, since the readmissions often were not distinguished from the first admissions (Parker & Walter 1982, Fossey & Shapiro 1992, Takei *et al.* 1992, Balestrieri *et al.* 1997). For example, it may have been assumed that a date of a patient’s first admission to a hospital described the onset of a disorder, although it was actually a relapse of a disorder. Therefore, if a study sample includes both subjects with a true onset of a disorder and subjects in a relapse phase of a disorder, a correct interpretation of the results may be impossible.

Takei *et al.* (1992) has criticised that most studies have not examined admission seasonality in relation to the different diagnostic subtypes, gender, or ages at onset separately. Recently, Clarke *et al.* (1998a) proposed that exploration of potential protective factors operating during time periods with the lowest incidence of admissions rather than during excess periods of admissions might be an interesting subject for future research.

2.1.2.3. Seasonality in the incidence of behavioural and other health related events

Studies examining an effect of the seasons on the incidence of psychiatric conditions have scrutinised the seasonal patterns of mortality for a wide range of reasons, for example deaths due to homicides, or traumatic events like rapes, robberies, or attempted suicides. In this chapter some examples will be given regarding these phenomena in psychiatric and epidemiological research. The seasonal pattern in suicides or homicides will be presented in subsequent chapters (suicides, see chapter 2.2.; homicides, see chapter 2.3.).

The incidence of violent crimes has been reported to peak during the summer months and to exhibit a trough period during winter months in studies from both Northern and Southern Hemisphere countries (Michael & Zumpe 1983, Anderson 1987, Schreiber *et al.* 1997). Anderson and Anderson (1984) found significant positive linear relationship between daily numbers of individual criminal assaults (homicide, rape, battery, and armed robbery) and ambient temperature. A similar significant relationship was also present in their other study sample of aggressive crimes (murders, rapes) and temperature, but not between non-aggressive crimes (robbery, arson) and temperature.

Studies occupying themselves with the seasonal pattern for attempted suicides have been published to a much lesser extent than studies on suicide seasonality. DeMaio *et al.* (1982) found a significant circannual rhythm in attempted suicides with a peak in spring or summer in both males and females, respectively. Significant seasonal findings, but only among females, were noticed also in later studies (Masterton 1991, Barker *et al.* 1994). Schreiber *et al.* (1993) observed a December peak in suicide attempts through firearms among Israeli soldiers. Recently, in a study involving over 13 centres from different countries, Jessen *et al.* (1999a) found a spring peak for attempted suicides in females. A total lack of monthly seasonality, however, has also been reported (Nakamura *et al.* 1994).

Phillips *et al.* (1999) compared the number of deaths due to various reasons having occurred in the first week of the month with the number of deaths in the last week of the preceding month, in the USA. The authors concluded that the increase in the number of deaths during the first week of the month was particularly strong for homicides, suicides, motor vehicle accidents, and for deaths involving substance use. Thus, theit hypothesis that behavioural changes at the beginning of the month (e.g. the occurrence of the salary day or discretionary income, the need to pay bills, or to collect payments) may lead to an increased risk of deaths, could be accepted.

2.1.2.4. Seasonal affective disorder

Systematic findings in studies on the seasonal variations in the incidences of mania, depression and suicide led to the definition of a seasonal affective disorder (SAD), which is described in the DSM-III-R (American Psychiatric Association 1987) as a “seasonal pattern” in mood disorders (Faedda *et al.* 1993). In the DSM-IV (American Psychiatric Association 1994) SAD is defined as a specifier of either bipolar or recurrent major depressive disorders with a seasonal pattern of major depressive episodes (Partonen &

Lönnqvist 1998). In the International Classification of Mental and Behavioural Disorders (ICD-10, World Health Organisation 1993) SAD is a form of bipolar affective of recurrent depressive disorder, with episodes of varying severity (Partonen & Lönnqvist 1998).

SAD is a pattern of major depressive episodes that occurs and remits with changes in the seasons. It was originally defined as a syndrome in which depression developed during autumn or winter and remitted in spring or summer for at least 2 successive years (Rosenthal *et al.* 1984, Partonen & Lönnqvist 1998). Winter SAD, which is more common than summer SAD, includes a recurring autumn or winter depression, while the patients with the Summer SAD feel worst in summer (Oldehinkel 1998). There is also a subsyndromal SAD (S-SAD), which is similar to SAD but the symptoms are milder and they do not affect the patient’s ability to function. SAD is believed to represent a morbid extreme of a spectrum of seasonality (Kasper *et al.* 1989, Madden *et al.* 1996).

According to Magnusson *et al.* (2000), three major approaches have been used to study the epidemiology of SAD: (a) to examine patient populations showing a clear seasonal pattern in their relapses and remission, (b) to screen populations for current symptoms at different parts of the year, and (c) to survey populations with some instrument like the Seasonal Pattern Assessment Questionnaire (SPAQ, Rosenthal *et al.* 1987). Thus, sampling and survey methodology may play an important, and sometimes overlooked role in explaining differences between separate studies (Mersch *et al.* 1999).

The fluctuations in photoperiod (i.e. changes in length of day and amount of light) over the seasons are larger closer to the poles, i.e. at high northern and southern latitudes (Suhail & Cochrane 1997). Therefore, it could be assumed that an increase in latitude should produce an increase in the prevalence of SAD. A recent review by Mersch *et al.* (1999) indeed lists several studies from North America, which document a significant positive correlation between the latitude and the prevalence of SAD. The correlation was weaker, when latitudes and prevalences of SAD from European studies were considered. Furthermore, several studies have found a negative correlation between the prevalence of SAD and climatic factors, such as hours of daylight or sunshine, and temperature (see, for example, Okawa *et al.* 1996, Suhail & Cochrane 1997).

In addition to latitude and climatic conditions, several additional factors have been considered in explaining the prevalence of SAD: gender, age, genetic loading, disturbed serotonergic activity, socio-cultural or psychological factors (Partonen & Lönnqvist 1998, Mersch *et al.* 1999, Saarijärvi *et al*. 1999). For example, Madden *et al.* (1996) reported in their twin study that genetic accounted for about 30% of the variance in seasonality in men and women. Some studies have failed to find a significant seasonal pattern, for example, a lack of seasonal mood change was observed in the Icelandic population (Magnusson *et al.* 2000) as well as among chronic pain patients (Hardt & Gerbershagen 1999).

2.2. Seasonal variation of suicides

2.2.1. Suicide research

Finland has one of the highest rates of suicide mortality in the world. While the suicide rate per 100 000 mean population was 27.2 (males and females together) in the year 1995, it was 14.2 (1996) in Sweden, 12.6 (1995) in Norway and 10.1 (1995) in Iceland. When compared with other European countries, the suicide rate was 7.5 (1994) in Great Britain, 20.8 (1994) in France and 9.8 (1995) in the Netherlands. Respectively, the rates for suicides were 16.7 (1994) in Japan, 13.5 (1995) in Canada, and 11.9 (1995) in the USA (Statistics Finland 1999a).

Statistics kept on the deaths due to suicide in Finland are considered reliable. The Finnish law requires that in every case of a violent, sudden or unexpected death, the possibility of suicide is assessed by police and medico-legal investigations involving autopsy and forensic examinations. At present, a medico-legal investigation is conducted in majority of the suicides in Finland. It is estimated that about 90% of the suicides committed in Finland are correctly classified as suicides (Karkola 1990). On the other hand, expressed in a different way, official suicide rates have been found to be underestimated by 10% (Öhberg & Lönnqvist 1998b).

Research into suicides in Finland has resulted in many scientific reports, which consider the aetiology of suicides from different viewpoints. For instance, suicides have been found to be strongly associated with mental disorders (Isometsä 1994a, Marttunen *et al.* 1991, Lönnqvist *et al.* 1995, Henriksson 1996, Heilä 1999, Lönnqvist 2000a,b) and/or alcohol and other substance abuse (Marttunen 1994, Pirkola 1999a). In addition, adverse events in the lives of suicidal persons have been found to be a common factor before the suicide (Heikkinen 1994, Marttunen 1994). These reports have originated from the National Suicide Prevention Project in Finland. The project was set up in 1986 by the Finnish National Board of Health to examine various risk factors linked with suicidal behaviour and to reduce suicide mortality in Finland by about 20% (Lönnqvist 1988, Lönnqvist *et al.* 1993, Beskow *et al.* 1999). The findings of this project have had significant implications for suicide prevention and research in Finland.

2.2.2. Suicide seasonality

The seasonal variation of suicides is a well-documented phenomenon in the medical literature. In the late 1880s, Durkheim (1970) found that the incidence of suicide was at its highest during spring or early summer and at its lowest during winter. This finding has been confirmed in numerous subsequent studies both from Northern (see for example, Kevan 1980, Massing & Angermeyer 1985, Chew & McCleary 1995, Altamura *et al.* 1999) and Southern Hemisphere countries (see, for example, Parker & Walter 1982, Flisher *et al.* 1997).

In the Southern Hemisphere countries seasons are “reversed” to those in the Northern Hemisphere. For example, at the same time, when spring begins (at about April) in the Northern Hemisphere, autumn starts in the Southern Hemisphere countries. Although the seasonal distribution of suicides has been shown to be independent of the hemisphere a country is located, Flisher *et al.* (1997) recently stated that there are still insufficient grounds to conclude that findings on seasonal trends in the Northern Hemisphere should apply directly to the Southern Hemisphere.

Researchers have been interested in several types of rhythmic patterns of suicides, for example monthly, weekly, and daily distributions of suicides. The presentation of incidence rates of suicides in terms of the seasonal and other temporal variations have usually consisted of reporting simple descriptive measures of the main properties of the data, for example peak and trough periods of suicides. Furthermore, researchers may have come up with an appropriate mathematical model for some seasonal fluctuation, like for instance the monthly distribution of suicides with a sine curve.

A statistical investigation of data, which prove that a time series of events has a seasonal pattern, is, however, only of academic interest, unless a search is made for possible reasons causing it (Bowie & Prothero 1981). Thus, explanations for the seasonal variation in the incidence of suicides have been sought for among meteorological, environmental, psychosocial and biological factors (Kevan 1980, Souetre *et al.* 1987). In addition, researchers have investigated whether the seasonal pattern of suicides is different in some subgroups of a population, for example in males and females (Meares *et al.* 1981).

2.2.3. Meteorological factors and suicide seasonality

The suggestion of an association between meteorological factors and incidence of suicides dates back to the bioclimatic theory presented in the late 1800s by Morselli. According to Kevan (1980), Morselli suggested that meteorological factors, for the most temperature and its changes during spring and early summer, were important contributing factors in the seasonality of suicides. Although Morselli highlighted the biometeorological explanation, the possible roles of social, economic, and individual psychological factors as well as human biological processes in terms of the aetiology of suicides were also pointed out in his work (Kevan 1980, Chew & McCleary 1995).

Contrary to Morselli, Durkheim (1970) explained that the seasonal patterns of suicides were due to seasonal changes in social behaviour, and, thus, were only artefacts of meteorological factors, like the duration of daylight. Later biometeorological theories emphasised changes in the general dynamics of the atmosphere or the variations of sunlight (Kevan 1980). In the 1930s, Mills considered that especially a falling barometric pressure (usually associated with storms) was an important factor in human mental instability (Kevan 1980, Dixon & Shulman 1987).

Meteorological factors can be classified according to whether they describe the quantity of a factor, for example length of day in hours or temperature in degree Celsius, or the quality of a factor, for example intensity and spectral content of sunlight (Kevan 1980). A distinction can also be made between weather and climatic factors. Weather factors include a set of specific conditions of the atmosphere at a specific time and place, for example ambient temperature, while climatic factors mean the synthesis of weather conditions extended through time, for example the tropics (Tennenbaum & Fink 1994). In seasonality studies the terms “weather“ and “climate“ have often been used as synonyms.

Many kinds of meteorological factors have been thought to exert an influence on the incidence of suicides. Table 2 lists the most commonly used variables in suicide seasonality studies.

Table 2. Variables used to describe weather and other meteorological conditions in suicide seasonality studies.

Variable	Description	Selection of articles
Acidity	Atmospheric acidity	Kok & Tsoi 1993
Air pressure	Barometric pressure, atmospheric pressure	Pokorny *et al.* 1963, Linkowski *et al.* 1992, Maes *et al.* 1994
Smoke levels	Atmospheric smoke levels	Kok & Tsoi 1993
Cloudiness	Proportion of sky cover from sunrise to sunset	Pokorny *et al.* 1963, Tietjen & Kripke 1994, Dixon & Shulman 1983
Solar radiation	Geomagnetism activity, geomagnetic index, index of solar activity	Parker & Walter 1982, Souetre *et al.* 1987, Maes *et al.* 1994
Humidity	Relative humidity/humidity grade, humidity (maximum, minimum, fluctuation)	Pokorny *et al.* 1963, Zung & Green 1974, Linkowski *et al.* 1992, Kok & Tsoi 1993, Maes *et al.* 1994, Preti 1997, Salib & Gray 1997, Dixon & Shulman 1983
Latitude	Latitude for each nation’s capital city [a]	Chew & McCleary 1995
Length of day	Daylight duration	Zung & Green 1974, Souetre *et al.* 1997, Preti 1997
Rainfall	Quantity of rain, precipitation (minimum, maximum)	Pokorny *et al.* 1963, Zung & Green 1974, Miccolo *et al.* 1988, Kok & Tsoi 1993, Maes *et al.* 1994, Preti 1997, Salib & Gary 1997
Sunlight duration	Amount of bright sunshine	Parker & Walter 1982, Souetre *et al.* 1987, Miccolo *et al.* 1988, Linkowski *et al.* 1992, Kok & Tsoi 1993, Tietjen & Kripke 1994, Maes *et al.* 1994, Salib & Gray 1997
Temperature	Ambient/air temperature (minimum, maximum, difference of maximum and minimum, departure from normal temperature)	Zung & Green 1974, Dixon & Shulman 1983, Souetre *et al.* 1987, Miccolo *et al.* 1988, Linkowski *et al.* 1992, Kok & Tsoi 1993, Maes *et al.* 1994, Tietjen & Kripke 1994, Preti 1997, Salib & Gray 1997

[a] Latitude was used as indicator of seasonal change in the length of days

In addition, the following parameters have occasionally been used to describe meteorological conditions: the presence of thunderstorms, weather frontal passages, fog, or wind direction/speed (Pokorny *et al.* 1963, Dixon & Shulman 1983, Kok & Tsoi 1993, Maes *et al.* 1994).

Several studies have suggested a significant relationship between seasonal changes in meteorological variables and the incidence of suicides. For example, the monthly rhythm of suicides has been found to correlate with higher temperature, increased daylight duration, increased sunshine hours, or decreased humidity levels (Souetre *et al.* 1987, Salib & Gray 1997, Preti 1997). Sometimes these associations have been revealed only in relation to violent suicides (Maes *et al.* 1994). A negative correlation between total monthly suicides and hours of sunlight has also been observed (Linkowski *et al.* 1992, Kok & Tsoi 1993). Chew and McCleary (1995) noted that bioclimatic factors have some effect on suicide seasonality, but the effect was conditional on sociodemographic factors. Some studies have failed to detect any significant association between suicides and weather variables (Pokorny *et al.* 1963, Zung & Green 1974, Dixon & Shulman 1983, Miccolo *et al.* 1988).

One belief has been persisted that phases of the moon are associated with suicides. Martin *et al.* (1992) reviewed eleven studies, which had investigated possible relationship between lunar phases and completed suicides. Only one study out of all reviewed studies showed a lunar association with completed suicide: new moon phase contained more incidents of completed suicide than other phases (full moon, remainder).

Researchers have proposed various explanations for the apparent seasonal distribution of suicides. The relationship between suicides and meteorological conditions, such as amount of light and light/dark cycle, have been proposed to be explained by the seasonal pattern of recurrence of some psychiatric disorders, especially affective disorders (Näyhä 1982, Eastwood & Peacocke 1976, Parker & Walter 1982, Souetre *et al.* 1987, Maes *et al.* 1993b). Meteorological factors have been suggested to act as an intermediary agent capable of interfering with yearly rhythms in human biological processes. These biological rhythms may underlie a changing susceptibility to various factors, which are known to be related to suicide, such as depressive disorders (Parker & Walter 1982, Souetre *et al.* 1987, Fossey & Shapiro 1992, Maes *et al.* 1994, Altamura *et al.* 1999).

Wehr and Rosenthal (1989) suggested that factors that trigger summer and winter depression might also be risk factors for suicide. However, studies, which actually have investigated either the prevalence of SAD among suicide victims or the incidence of suicides among patients with SAD, are lacking. In a follow-up study of patients diagnosed as suffering from SAD, only one patient out of 124 patients was identified to have committed a suicide (Thompson *et al.* 1995).

In the statistical research of the relationships between suicides and meteorological factors some methodological limitations must be noted. Firstly, meteorological data do not always square up regionally with the suicide data. Meteorological data may have been collected over a large area assuming that weather conditions were similar throughout the whole region (Kevan 1980, Dixon & Shulman 1983). Secondly, a real effect of seasonal weather conditions may be masked by the use of monthly data, since it is assumed that meteorological seasons begin on the first day of one month and end on the last day of another (Kevan 1980). Furthermore, the collection of meteorological variables is sparse and frequently these variables are poorly described in an article. The unit used to describe the meteorological condition may have differed between studies (e.g. monthly temperature may indicate mean, minimum, or maximum temperature, or temperature difference) so that reliable comparisons of results are impossible to make. It is also recommended that the statistical analyses of a relationship between weather and suicides should rely on sophisticated statistical techniques for time series data, like spectral analyses, and not simply on correlations or chi-square tests (Maes *et al.* 1993a).

2.2.4. Social factors and suicide seasonality

Durkheim (1970) preferred to explain the seasonal distribution of suicides in terms of the seasonal changes in the communal life and activity (socio-relational sphere), which may have been affected by meteorological factors (Kevan 1980, Preti 1997). For example, during the warmer months, social intercourse is more intensive than in the cooler months. The sociodemographic hypothesis has been the other main theory besides the meteorological theory, which has dominated discussions of the possible causes of suicide seasonality (Kevan 1980).

Several kinds of sociodemographic variables have been used to test the validity of the sociodemographic hypothesis. These variables have either described some more general characteristics of a population (e.g. unemployment rate, monthly birth rates, workforce: Souetre *et al.* 1987, Chew & McCleary 1995) or highlighted certain sociodemographic characteristics of the suicide victim (e.g. marital status, social class, occupational status: Näyhä 1982, Näyhä 1983).

Souetre *et al.* (1987) found that the seasonal pattern of suicides correlated positively with the birth rate and negatively with the unemployment rate of a population. Chew and McCleary (1995) showed that both the extent of seasonal fluctuation and the ratio of spring to winter suicides correlated positively with the proportion of national workforce engaged in agriculture. Flisher *et al.* (1997) noted that the commencement of an academic year (which occurs in summer in South Africa) with increased social activity may explain the suicide seasonality (a peak in spring/summer) among young subjects.

One way to study the effect of the intensity of social interactions on suicides is to investigate the incidence of suicides around public holidays. It has been suggested that holidays may provide some psychological and social protection against committing a suicide or they may have a delaying effect on suicides (Phillips & Wills 1987). On the other hand, major holiday periods may include many kinds of stressors, for example use or abuse of alcohol, altered sleep rhythms, increased financial burdens, family conflicts, which may be contributing factors for suicide (Jessen *et al.* 1999b). It is also proposed that although weekends, holidays, etc. are usually considered to be happy and positive periods, they may sometimes promise more than they can actually keep (Nakamura *et al.* 1994, Jessen *et al.* 1999b).

Major methodological weaknesses in these studies have been found to be small size of study population, short time series, poor statistical techniques and lack of control for extraneous factors influencing suicide rates (Kevan 1980, Souetre *et al.* 1987, Phillips &

Wills 1987). It has also been argued that the study of specific holidays alone and not the whole holiday period can introduce errors (Phillips & Wills 1987).

2.2.5. Biological factors and suicide seasonality

"One way of explaining the seasonal variation of suicides is to investigate seasonal variations of biochemical variables thought to be involved in the pathophysiology of suicide" (Brewerton 1991). It is suggested that various biological variables may be associated with suicide, suicidal behaviour or considerations, and major depression (Maes *et al.* 1995, Maes *et al.* 1996).

Several studies have indicated that the existence of seasonal variations in various peripheral and central aspects of serotonergic (5-hydroxytryptamine, 5-HT) function, for example [^{3}H]-imipramine binding to platelets ([^{3}H]-IMI), [^{3}H]-paroxetine binding to platelets ([^{3}H]-PAR), 5-hydroxyindoleacetic acid concentrations (5-HIAA) in the cerebrospinal fluid (CSF), 5-HT levels in the hypothalamus, neuroendocrine responses to 5-HT agonists, and plasma concentrations of L-tryptophan (L-TRP) all which may be involved in the seasonal variations of suicides (Brewerton 1991, Maes *et al.* 1996).

Low levels of CSF 5-HIAA have been found to be linked with a history of attempted suicides in several studies (Åsberg *et al.* 1976, Brown *et al.* 1979, Lidberg *et al.* 1985, Linnoila & Virkkunen 1992) and an increased risk for suicidal behaviour (Traskman *et al.* 1981, Van Praag 1982, Banki & Araki 1983*)*. A reduced [^{3}H]-imipramine binding capacity has been shown to occur among patients with attempted suicides (Marazziti *et al.* 1989). Pine *et al.* (1995) found seasonal fluctuation in [^{3}H]-IMI values with troughs in the late winter/early spring period among adolescents, who had attempted a suicide.

Maes and his co-workers (Maes *et al.* 1995, Maes *et al.* 1996) investigated, whether the chronograms of several biochemical, metabolic and immune variables measured from a group of healthy volunteers and the chronogram of a time series of suicides from a general population in Belgium were congruent. A significant negative correlation was observed between L-TRP values and weekly numbers of violent suicides (Maes *et al.* 1995). In a later study, significant inverse time-relationships were observed between a time series of violent suicides and those of L-TRP, total cholesterol, calcium, magnesium, and immune variables (CD4+/CD8+ T cell ratio, number of CD20+B lymphocytes), while the yearly variation of suicides was positively correlated with [3H]-paroxetine levels (Maes *et al.* 1996). In both studies, nearly all biological variables and a time series of suicides showed maximal or significant changes from the norm in the period of March-May.

Studies addressing the time-relationship between suicides and biological variables have been found to suffer from some methodological limitations, such as small samples, different techniques for biochemical analyses, lack of stringent protocol in study design and analytic assays, and attrition among subgroups of a population (DeMet *et al.* 1989, Pine *et al.* 1995, Maes *et al.* 1995). In some studies, the biological rhythms from normal controls were assumed to represent the biological rhythms from suicide-prone subjects, which, however, may not represent the true situation (Maes *et al.* 1996). Furthermore, it is suggested that the delineation of a seasonal variation of a phenomenon should not merely be based on comparisons of monthly or seasonal mean values but involve true time series analysis techniques (DeMet *et al.* 1991, Maes *et al.* 1995).

2.2.6. Suicide seasonality in relation to seasonality of other death classes

Occasionally the seasonal pattern of suicides has been related to the seasonal pattern of deaths due to causes other than suicides. One purpose of these kinds of study has been to examine whether the incidence of suicides has a specific seasonal pattern, which differs from that of other death classes. Similar seasonal patterns between two or more phenomena have also been assumed to suggest common aetiological factors. In addition, it has been postulated that some death classes other than suicides may actually be misclassified suicides (Barraclough & White 1978a, Souetre 1988, Öhberg *et al.* 1997). In Finland undetermined deaths were estimated to reduce the suicide rate by 10% (Öhberg & Lönnqvist 1998b). While 6% of all driver fatalities in Finland were actually found to be suicides, the respective figure in the official statistics was only 3% (Öhberg *et al.* 1997).

Regarding the hypothesis of "masked" suicides, Barraclough and White (1978a) concluded that since undetermined deaths did not follow the same seasonal variation as suicides it was unjustifiable to combine suicide and undetermined deaths when studying suicide seasonality. Ferreira de Castro *et al.* (1989) reported that because the seasonal pattern of controversial cases (i.e. deaths due to reasons that could not unambiguously be classified) coincided with that in suicides, these deaths included also true suicide cases. Souetre (1988) observed a negative seasonal correlation between suicides in males and deaths due to traffic accidents suggesting a possible link with impulsive behaviour, alcoholism and psychiatric disorder. Näyhä (1983) noted that the seasonal distribution of undetermined cases of violent death (suicide, accident, and homicide) was strikingly similar to the seasonal distribution of confirmed suicides.

Some investigators have examined whether a specific seasonal pattern is characteristic of suicides but not of the other death classes. It had been noted that the seasonal distribution of suicides differed from deaths due to all other causes (Lester 1971) or deaths from natural causes (Salib and Gray 1997). The lack of a similarity between the seasonal patterns of suicides and homicides has also been reported (Maes *et al.* 1993a, Maes *et al.* 1994).

2.2.7. Hospital admissions and suicide seasonality

Some studies attempted to link the seasonal trend in suicides with the seasonal variation in hospital admissions due to mental disorders in order to clarify the putative association between suicidal risk and psychiatric disorder. Zung and Green (1974) found that seasonal distribution of suicides and admissions of depressed male patients correlated significantly, but no seasonal relationship was observed between suicides or admissions of nondepressed patients. Eastwood and Peacocke (1976) observed that since the seasonal variation in hospital admissions for depressive illnesses and suicides (peaks in spring and autumn) coincided, the importance of depression, as a cause of suicide should be considered. Furthermore, Parker and Walter (1982) investigated the seasonal variation in admissions for depressive disorders and suicidal deaths assuming that depression might be recognised as a significant factor in the majority of those who commit suicide.

2.2.8. Subgroup analyses in suicide seasonality studies

The aim of subgroup analyses has been to test various theories, such as the meteorological, biological and psychosocial theories, which have frequently been proposed to explain the seasonal trends in suicides. In the early 1970s, Lester (1971) discussed that “if some measurable factor could be hypothesised as causing a phenomenon and if two groups of the population could be found to differ with respect to that variable, then the validity of that variable as an explanation of the phenomenon could be tested”. He presented as an example, that “if seasonal variations in social activity were a cause of the phenomenon, then one would not expect to find a strong seasonal variation in suicidal deaths among those permanently institutionalised, for there should be little seasonal variation in the social activity of these people”.

Subgroup analyses have shown to share some common methodological difficulties. The most serious problem may have been that the reduction in the number of events in a subgroup can lead to lack of power in statistical analyses. The use of less powerful statistical tests has been found to be particularly problematic (Miccolo *et al.* 1989).

2.2.8.1. Gender

In most countries men commit more suicides than females (Reid *et al.* 1980, Öhberg *et al.* 1996, Altamura et al. 1999). For example, in Finland the male to female suicide ratio was 3.7 in the year 1997 (Statistics Finland 1999a).

A consistent finding has been that male suicides have one peak in the spring, while female suicides have two peaks – one in spring and a secondary one in autumn (Meares *et al.* 1981, Näyhä 1982, Näyhä 1983, Massing & Angermeyer 1985, Souetre *et al.* 1987). Yet, Lester and Frank (1988) found a bimodal distribution of suicides also among men. Some studies have actually failed to find any differences in relation to gender at all (Modan 1970, Lester 1971, Souetre 1988, Maldonado & Kraus 1991).

Reasons for the sex differences in suicide seasonality are still unknown. Näyhä (1983) found that the autumn peak of suicides was most marked among married and widowed women. It has been proposed that rhythmic patterns of suicidal behaviour may have biological determinants, which are not the same for both sexes (Meares *et al.* 1981).

2.2.8.2. Age groups

It has been suggested that at certain stages of a person's life cycle, people are more inclined than usual to been thrown off balance (e.g. puberty, midlife, menopause, retirement: Massing & Angermeyer 1985). This may explain why different age groups have been found to exhibit different seasonal pattern of suicides.

Näyhä (1982) found a spring or summer peak in total suicides in age groups of 25-44, 45-64, and 65 years or more, and a secondary autumn peak among the ages of 15-24 years. Massing & Angermeyer (1985) observed significant spring or early summer peak in male suicides of all age groups (25-44, 45-64, 65-74 and 75-94 years), except in the age group of the 15-24 year-olds, and in females only in the age group of the 45-64 year-olds. Souetre *et al.* (1987) noted a bimodal distribution with peaks in spring and autumn among suicides of the under 25 year-olds, and early summer peak alone in people over 65 years of age. Maes *et al.* (1993a) reported peaks in violent suicides during March-April for younger persons (less than 65 years) and in August for elderly persons (65 years old or older). Maldonado *et al.* (1991) failed to find any differences between the age groups 10-34 and 35-64 years.

2.2.8.3. Suicide methods

Table 3 presents the codes for deaths due to suicides according to the International Classification of Diseases (ICD-9) (World Health Organization 1977).

Table 3. Codes for deaths due to suicides according to the International Classification of Diseases (ICD-9) (World Health Organization 1977).

ICD-code	Description
E950	Poisoning by solid or liquid substances
E951	Poisoning by gases in domestic use
E952	Poisoning by other gases and vapors
E953	Hanging, strangulation and suffocation
E954	Submersion (drowning)
E955	Firearms and explosives
E956	Cutting and piercing instrument
E957	Jumping from high place
E958	Other and unspecified means

There is no unique way to categorise the methods of a suicide. Two common practices have been base the categories either on the level of activity needed to commit the suicide or on the "lethality" of a suicide method (Öhberg 1998a). For example, Lester (1971) divided suicides into those committed by active (hanging, jumping, firearms, cutting) or passive methods (gas, drugs, poisons). Isometsä *et al.* (1994b) considered suicides by hanging, shooting, cutting, and jumping from a high place or in front of trains as violent, and suicides by drowning and use of gases, intoxicants, drugs or poisons as non-violent. On the other hand, Maes *et al.* (1994) defined suicides by hanging, strangulation and suffocation, submersion, firearms and explosives, cutting or piercing instruments and by jumping from high places as violent, and other methods as non-violent. In a recent study by Altamura *et al.* (1999) violent means of suicides were hanging, drowning, use of firearms, jumping from a high place, and car accidents, and non-violent means included suicides by intake of solid or liquid substances, and inhalation of gases.

Only very few researchers have analysed seasonality of suicides in relation to the suicide methods. Lester (1971) found that the monthly distribution of suicides by active methods with a peak in May as well as in October departed significantly from chance expectations, but that suicides by passive methods did not. Later, Lester (1985) examined specific suicide methods separately and noted that suicides by hanging, strangulation and suffocation, by firearms and explosives or by other methods peaked in spring or early summer, while suicides due to solids and liquids or gases displayed two peaks - one in spring and another in autumn. Furthermore, Lester and Frank (1988) have reported that monthly distributions of three separate suicide methods (poison, hanging, and firearms) did not differ significantly from chance expectation either in males or in females.

Massing and Angermeyer (1985) reported a spring peak of suicides by violent methods (hanging, strangulation and suffocation) for both sexes, and also for males in age groups over 45 (i.e. 45-64, 65-74, and 75-94-year olds). However, in suicides caused by non-violent methods (poisoning by means of solid or liquid substances) the only significant peak was found in November for total male suicides. Recently, Maes *et al.* (1993a) noticed a significant seasonal variation with a spring peak in violent but not in non-violent suicides.

Males have frequently been found to use more violent methods to commit a suicide than women (Modan *et al.* 1970, Hude *et al*. 1999). The choice of a suicide method has been reported to be dependent on nationality, geographical and sociocultural areas, and availability of method (Öhberg 1998a). Furthermore, in violent suicides a specific weather-sensitive biological factor, like serotonergic metabolism, that differs from that of non-violent suicides has been implicated (Maes *et al.* 1994). It is suggested that suicides by violent methods might be subject to greater impulsiveness than those by non-violent methods, which often require more planning (Preti 1997).

2.2.8.4. Other subgroups

Durkheim (1970) explained that the seasonal variation in the suicides was due to seasonal changes in the intensity of communal life and activity. Following this suggestion, one would expect a larger seasonal variation in the course of life in rural communities than in urban areas. Miccolo *et al.* (1991) reported that in Italy, indeed, the seasonality was greater in the rural than in the urban regions.

Mortality in a specific occupational group may reflect not only specific hazards of that occupation but also social conditions with which it is associated (Barker *et al.* 1998). On the other hand, suicides among subjects with outdoor occupations should follow a different seasonal pattern than suicides among subjects working in man-made environments. Näyhä (1982) analysed seasonal trends of suicides according to social classes (I=upper class/higher administrative, II=middle class/lower administrative, III= upper working class/skilled workers, IV=lower working class/unskilled workers, V= peasant class/farmers, VI=unknown/students). He noted that in social classes II-V (combined together) suicides peaked in spring, while the suicides in the highest and lowest social classes had a peak incidence in both spring and autumn. Furthermore, an autumn peak in suicides occurred in subjects with modern occupations (technical, scientific and social work, arts and letters, administrative and clerical work, sales work, service occupations), but subjects with 'traditional' occupations (agriculture, forestry and fishing, transport and communication work, manufacturing, industry and construction work) committed their suicides in spring or summer (Näyhä 1982).

Later Näyhä (1983) found that the seasonal pattern of suicides differed by marital status among males and females. For both genders suicides had a spring or early summer peak in all categories of marital status, but suicides of married or widowed females also exhibited a secondary autumn peak. Furthermore, for widowed or divorced males aged 15-44 years, suicides followed a unimodal distribution with a peak in autumn.

2.2.9. Secular trends in suicide seasonality

Secular trends are used to describe changes in disease frequency over decades (MacMahon & Pugh 1970). The changes over time that may take place with regard to the seasonal variations of suicides have interested some researchers. Maldonado & Kraus (1991) studied the change in the monthly variation of suicides in relation to age and sex over three time periods (1925-44, 1945-64, and 1965-83), but did not observe any change over time. Ferreira de Castro *et al.* (1989) noted that there was a lower seasonal dispersion of female suicides in 1980-83 than in 1965-69. In Finland, Näyhä (1980) studied the time trends of the unimodal seasonal distribution of suicides over several time periods. Covering six time periods (1878-1909, 1910-19, 1928-35, 1936-45, 1946-53, and 1969-72), one statistically significant peak was observed in June or July, while two time periods (1920-27, and 1954-68) showed seasonal peaks in both spring and autumn. However, no consistent reduction of the seasonal swing was observed during the time course. Later Näyhä (1983) reported that no substantial changes in the seasonal pattern of suicides have occurred over the 16-year study period of 1961-76.

2.3. Seasonal variation of homicides

2.3.1. Definition of homicides

The term "homicide" means either the act of killing of one human being by another or a person who kills another (Webster 1996). According to the International Classification of Diseases (ICD-9), the homicides are defined by the codes E960 through E968 presented in Table 4 (World Health Organisation 1977). Sometimes the codes E970-E978 (legal interventions), which include injuries inflicted by the police or other law enforcement agents in the line of duty, are also considered under the category of homicide (Fingerhut & Kleinman 1990).

When a researcher is interested in homicides, a clear definition must be presented so that no ambiguity remains as to whether she/he investigates homicide offenders or victims of a homicide. Official homicide rates usually measure the number of people killed rather than the number of people who have killed others (Holinger 1979).

Table 4. Codes for homicides according to the International Classification of Disease (ICD-9) (World Health Organisation 1977).

ICD-9 code	Description
E960	Fight, brawl, rape
E961	Assault by corrosive or caustic substance, except poisoning
E962	Poisoning
E963	Hanging and strangulation
E964	Submersion (drowning)
E965	Firearms and explosives
E966	Cutting and piercing instruments
E967	Child battering and other maltreatment
E968	Other and unspecified means

2.3.2. Homicide research

The deaths due to a homicide and other injuries inflicted by another person are a major global health problem. The rates per 100 000 mean population vary largely between countries. In Finland, the rate of homicides and injury inflicted by other persons has been one of the highest in Europe being 2.9 in the year 1995. The figure was about twice that of Sweden (1.2, 1996) or Norway (1.0, 1995) and about three times that of Great Britain (1.0, 1994) and France (1.1, 1994). In the USA, the homicide rate was high, being 8.6 in 1995. In the Southern Hemisphere country Australia, the homicide rate was 1.6 in 1995 (Statistics Finland 1999a).

In Finland, statistics kept on homicides are reliable. During 1995-98 the clearance rate of homicides has varied between 86-100% (Statistics Finland 1999b). A thorough psychiatric examination ordered by the Finnish courts of law has to be conducted on most of the subjects accused of homicides (Tiihonen *et al.* 1993). All the forensic psychiatric reports are filed by the National Board of Health and Welfare. The latter has offered a good opportunity to study reliably possible risk factors linked with homicidal behaviour in Finland.

During the last decade, men have committed about 90% of all deaths due to homicide in Finland (Eronen *et al.* 1996a, Statistics Finland 1999b). On the other hand, about 70% of deaths due to homicides and injury inflicted by other persons were suffered by male victims (Statistics Finland 1997).

Several studies from Finland, which have used methodologically valid data of homicide offenders, have shown that homicide violence is strongly associated with mental disorders - such as antisocial personality, alcoholism and schizophrenia alone or with interactions between each other (Tiihonen *et al* 1993, Tiihonen & Hakola 1994, Eronen 1995, Eronen *et al.*1996a, Eronen *et al.*1996b, Tiihonen *et al.*1996, Putkonen *et al.* 1998). A similar relationship between patients with a mental disorder and violent offences has also been suggested in studies from other countries than Finland like, for instance, in Sweden (Lindqvist & Allebeck 1990, Hodgins 1992, Modestin 1998).

2.3.3. Seasonal variation in aggressive behaviour

According to Tennenbaum and Fink (1994), it has long been assumed that there exists a relationship between crimes, particularly violent crimes and seasons. Increased violent offending has been shown to be correlated with increased temperature (Anderson & Anderson 1984, Rotton & Frey 1985, Anderson 1987). In the United States, Michael & Zumpe (1983) reported a significant summer peak in the monthly numbers of rape in 12 out of 13 separate regions and of aggravated assaults in 14 out of 16 separate regions. Recently, Schreiber *et al.* (1997) reported that individual violent crimes (i.e. sexual offences, aggravated assaults) and collective acts of hostility (i.e. wars) were characterised by a circannual rhythmicity with a summer peak and a winter trough. These rhythms were shown to correlate significantly with the duration of the daily photoperiod.

The effect of the seasons on the incidence of aggressive and impulsive behaviour has been demonstrated also with biological data. Low levels of CSF-5 HIAA have been reported to be associated with increased impulsiveness (Lidberg *et al.* 1985, Linnoila & Virkkunen 1992). It has been suggested that certain types of violence may display annual patterns that are influenced by seasonally regulated mechanisms in a human’s biological processes (Fossey & Shapiro 1992).

2.3.4. Homicide seasonality

Only a few studies in psychiatric research have dealt with the seasonal variation of homicides. Most of these studies have failed to detect any statistically significant homicide seasonality (Michael & Zumpe 1983, Abel *et al.* 1985, Abel *et al.* 1987, Ferreira de Castro *et al.* 1989, Maes *et al.* 1993a). Although Abel (1986) was unable to detect any significant seasonality, he noted that most homicides of children occurred during spring and fall. Lester (1979) reported that the significant peak months for homicides in the USA were July and December. Goodman *et al.* (1989) found a significant summer homicide peak in Oklahoma. Tennenbaum and Fink (1994) noticed significantly more homicides in July and August than in January in the USA.

It is suggested that the lack of statistical significance in homicide seasonality studies is a reflection of the methodological or statistical limitations of these studies. Many studies have used too short a time series of homicides leading to a small sample size and thus, a lack of power in statistical analyses (Lester 1979). In a long time series it is easier to distinguish the random fluctuations on the series from those that are systematic (Tennenbaum & Fink 1994). In addition, the use of inadequate and less powerful statistical methods has been a focus of criticism (Maes *et al.* 1993a).

2.3.5. Meteorological factors and homicide seasonality

Over 100 years ago, Quetelet presented the “thermic law of crime”, which stated that “crimes against the person increase, and those against property decrease, with seasonal and geographic increases in temperature” (cited by Michael & Zumpe 1983). Basically, the temperature-aggression hypothesis states that high temperatures increase aggression through several (possibly related) psychological and biological processes (Anderson 1989).

Michael and Zumpe (1983), however, were unable to demonstrate any clear association between temperature or latitude (photoperiod) and the monthly number of murders in locations differing geographically. Anderson and Anderson (1984) showed that increased temperature was significantly related to both increased number of criminal assaults (study 1: homicide, rape, battery, and armed robbery) and increased number of aggressive crimes (study 2: murder, rape). However, they did not find any time-relationship between temperature and non-aggressive crimes (study 2: robbery, arson). Maes *et al.* (1994) failed to detect any significant time-relationships between homicides and any of the weather variables studied.

2.3.6. Biological factors and homicide seasonality

Impulsive behaviour of humans has been shown to be closely related to a low concentration of the major serotonin metabolite 5-HIAA in the CSF (Brown *et al.* 1979, Linnoila *et al.* 1983, Virkkunen *et al.* 1994). Linnoila and Virkkunen (1992) suggested that there exist a “low serotonin syndrome, a disorder of impulse control afflicting a subgroup of violent offenders” and this syndrome is characterised by the early onset of impulsive violent behaviour and alcohol abuse, an increased risk of suicide and a family history of type II alcoholism. Low levels of CSF 5-HIAA have proposed to reflect a disorder of serotonin turnover that may make subjects more prone to acts of violence in states of emotional turmoil: the men, who had killed a sexual partner, were shown to have lower levels of CSF 5-HIAA than the healthy control subjects (Lidberg *et al.* 1985). Testosterone concentration in CSF has also proposed to associate with outward directed aggressiveness: mean CSF free testosterone was found to be higher in alcoholic, impulsive offenders with antisocial personality than in healthy volunteers (Virkkunen *et al.* 1994).

2.3.7. Subgroup analyses in homicide seasonality studies

Subgroup analyses of homicide seasonality are lacking, although the incidence of homicide has been shown to differ in the subgroups of a population when compared to the population as a whole. Rates of homicides have found to be higher among males and in younger age groups (Ferreira de Castro *et al.* 1991). Furthermore, the rates of homicide have found to differ in relation to the method of the homicide. For example, among young males the proportion of homicides caused by firearms was 75% in the USA, while it was 18% in Finland (Fingerhut & Kleinman 1990).

2.3.8. Time trends in homicide seasonality

Time trends in the seasonality of homicides have only been sparsely studied. Lester (1979) compared the homicides of 1973 with those of 1972 and found similar seasonal patterns with peaks in July and December. Näyhä (1980) found a significant seasonal variation of homicides in Finland over the period of 1878-1972. He observed that the month of peak incidence was October in the years 1878-89 and 1890-99, August during the years 1900-16 and 1946-53, and July in the period of 1954-72.

2.4. Methodology in seasonality studies

2.4.1. Time period

The most popular method to examine seasonal or other cyclic patterns of events has been to investigate them with data aggregates of monthly or seasonal values of events (see, for example, Kevan 1980, Chew & McCleary 1997). In addition, seasonal trends have been analysed, for example, according to the days of a week (Massing & Angermeyer 1985, Nakamura *et al.* 1994, Joukamaa 1995), times of a day (O'Donnell *et al.* 1992, Schmidtke 1994, Joukamaa 1995, Joukamaa 1997), phases of the lunar cycle (Martin *et al.* 1992), dates of birth (Baker & Lester 1986, Lester 1986) and daylight saving time changes (Shapiro *et al.* 1990). Some investigators have compared suicide rates between weekdays and weekends (Zung & Green 1974, Pirkola *et al.* 1999b) and the days of major national holidays or a period around them (Zung & Green 1974, Jones & Jones 1977, Lester 1979, Phillips & Wills 1987, Nakamura *et al.* 1994, Jessen *et al.* 1999b). Birthdays associated with the timing of an event, like a suicide, has also been examined (Nakamura *et al.* 1994). Phillips *et al.* (1999) compared the number of deaths of the first week of a month with the number of deaths in the last week of the preceding month.

A time series of events aggregated to monthly values (e.g. monthly totals or mean values) has been a common and natural way to group data gathered over a number of years. Freedman (1979) suggested that this habit could be due to the fact that exact dates of events might not be known more accurately, especially when they were extracted from official publications. Furthermore, monthly totals were seen as a convenient way to summarise data, for example with regard to graphical presentations. His last notation that for large numbers of data it would be more tiresome to work with exact dates of events rather than with monthly totals is, however, no longer valid because of the common and routine use of computerised data processing.

The monthly values are commonly summed up to seasons each including three consecutive months (winter = December to February, spring = March to May, etc). Sometimes seasons defined by the solstices and equinoxes have been preferred to those defined by calendar months (Eastwood & Stiasny 1978, Nakamura *et al.* 1994, Maes *et al.* 1996, Partonen & Lönnqvist 1996, Pio-Abreau 1997). In a study by Mawson and Smith (1981) a year was divided into thirteen 28-day period instead of calendar months.

Hare and Walter (1978) used bimonthly periods (December-January, February-March etc.) in order to eliminate the effect of winter and summer holiday periods, which were assumed to cause a delayed backlog on hospital admissions. Some researchers have also grouped months into trimesters (each including four successive months) or divided a year in half (semesters or other periods of 6 months). A year may have been divided into periods of unequal numbers of months. For example, Takei *et al.* (1992) separated a year into two periods: summer (June to August) and remaining months (September to May).

The grouping of the monthly data into periods other than a single month has aroused some methodological concerns. True seasonal patterns may disappear, when analyses are restricted to 3 month-periods (Torrey *et al.* 1997). Secondly, the definition of seasons is not unambiguous. For example, for some researchers the months from January to March represent the winter season, while others define winter to contain the months from December to February. It has occasionally been recommended to use seasons defined by solstices and equinoxes due to the natural changes of the photoperiod during those critical time intervals (Pio-Abreau 1997). Fourthly, the ignorance of calendar effects (i.e. an effect due to the unequal number of days in a month or irregular number of weekend days in each month etc.) may have led to spurious significant results (Cleveland & Devlin 1980, Walter 1994).

2.4.2. Sources for epidemiological information

Various kinds of mortality and morbidity statistics can be used for seasonal analyses. In epidemiological research the most common sources for data have been official statistics, hospital records, and clinical surveys. The data may have covered a whole country (national data), for example all homicides in Belgium (Maes *et al.* 1993a), or only specific subpopulations (sub-national data) as in the studies of suicides among Alaska natives (Kettl *et al.* 1991) or suicides in Wolverhampton in Great Britain (Scott 1994).

Official statistics are one of the most common sources for information. For example, data on the numbers and causes of deaths in a country are extracted from death certificates and gathered together by one official authority, such as Official Statistics in Finland. The reliability of these kinds of registers has been found to be generally high, since the gathering of the information into the register is strictly defined by the authorities. Official registers, however, can include incomplete information due to errors in the completion of death certificates, incorrect diagnoses of the causes of the death, or errors and omissions when the causes of death were written down (Barker *et al.* 1998).

Another important sources of data for an epidemiological study are hospital registers. These registers usually include a variety of information on the patient's clinical and sociodemographic characteristics during his/her hospitalisation. Nowadays this information is usually easily accessible thanks to the increased use of computerised data processing. However, the main purpose of these hospital registers is to assist administration of hospital services rather than serve as a source for information of a scientific research. Therefore, the reliability of the information should always be discussed and considered within the context of the utilisation of these hospital registers for the scientific project under consideration.

Occasionally, the time series data can be obtained from a special register, such as the railway (O'Donnell *et al.* 1992, Schmidtke 1994), prison (Joukamaa 1997) or army statistics (Schreiber *et al.* 1993). In that case, the reliability of the register must be evaluated separately, if the data is to be used in scientific research.

2.4.3. Type and size of a time series

An inadequate number of events is probably the most salient methodological problem in seasonality studies. A small sample size is likely to lead to a lack of power in statistical significance tests. Moreover, the sample size is one of the most important factors that determines, which statistical techniques can be employed for the seasonality analyses.

For example, Hare (1975) calculated that "in order to demonstrate, by a chi-square test and to a probability of 95 percent, an 8 percent deviation in seasonal birth distribution of the cyclic type, at least 1500 subjects will be needed when the distribution is considered by quarters of the year, and 4500 subjects when the distribution is considered by month". Even more subjects will be needed, if the seasonal deviation is less than 8%.

Some researchers have emphasised adequate sample size. Lester (1979) reported that a large sample (25137 suicides, 20500 homicides) made it possible to draw conclusions about temporal variations of violent deaths. He noted that discrepancies between previous results with small samples underscored the importance of using large samples for the study of these trends. On the other hand, MacMahon (1983) stated that the size of her data (185887 suicides) was large enough to interpret them on the basis of trends and patterns observed from the raw figures rather than on the basis of statistical tests.

2.5. Statistical techniques for seasonality

At least three study types can be distinguished in seasonality research. The first are the studies in which a researcher is interested in the seasonal distribution of a time series itself, such as the monthly or weekly pattern of suicides. The purpose of a study is usually to describe the main properties of the data, for example values for the minimum and maximum incidence of events, and/or to present a mathematical model fitted to the data. The statistical methods are mainly descriptive techniques or standard statistical methods, such as graphical presentations or a chi-square test (Siegel & Castellan 1988).

In the second type of study, the main object is to clarify whether there are differences in the seasonal patterns between subgroups of a population. For example, the seasonal patterns of events are compared between genders. The statistical methods consist mainly of techniques, which compare the seasonal distributions of events between two or more categories of a group variable, like for example, the chi-square test or one-way analysis of variance test (Armitage & Berry 1987, Siegel & Castellan 1988).

Thirdly, there are studies in which seasonal patterns of two or more time series are correlated with each other, for example the seasonal pattern of deaths due to suicides is related to the seasonal patterns of climatic variables. In that case the statistical methods are techniques, which correlate with or seek for a similar or lagged rhythmicity in two or more time series data, for example Pearson’s correlation or bivariate spectral analysis (Armitage & Berry 1987, Chatfield 1996).

The type of a study, thus, determines partly what kind of a statistical technique can be used for seasonal analyses of the data. In addition, there are features of the data, which influence the choice of an appropriate statistical method, such as the size of a sample and the type of a time clustering (e.g. whether the data is aggregated to monthly, weekly or seasonal totals of events). Researchers should always be aware of the basic assumptions required by a statistical technique, which they intend to use in their study. Otherwise, due to the inappropriate statistical method, spurious results or false negative findings are possible.

In the following chapters the most basic common statistical techniques used in seasonality studies in epidemiological research are briefly presented. Because the presentation does not include mathematical expressions of these techniques, references to the appropriate medical and statistical literature are given in the text.

2.5.1. Standard statistical techniques

2.5.1.1. Graphical techniques

"Anyone who tries to analyse a time series without plotting it first is asking for trouble" (Chatfield 1996). A graph serves two main purposes in a study. Firstly, it reveals easily the important features of a time series, such as trend, seasonal variation, outliers, and discontinuities. It also shows the possible errors and missing information. Thus, a graph presents the statistical information of a data in an aggregated and evocative way (Armitage & Berry 1987). Secondly, it serves as an aid to a statistical analysis. A graph shows the structure of a data, and suggests hypotheses (mathematical model), which may be further investigated (Marrero 1983, Haus *et al.* 1980, Chatfield 1996).

When presenting a seasonal pattern of a data-set, a simple graph may show, for example, the monthly frequencies of events in a form of simple histograms or a line diagram (Armitage & Berry 1987). A more complex graph is a periodogram obtained from a spectral analysis (Bloomfield 1976, SPSS 1994, Chatfield 1996). Plotting a graph needs careful considerations, so that a graph would not become misinterpreted. Researchers should pay attention, for example, to the choice of scales, the way that the points are plotted (e.g. as a continuous line or as separate dots), a clear title for the axes, and presentation of measurement units (Armitage & Berry 1987, Chatfield 1996).

2.5.1.2. Chi-square methods

Chi-square techniques include a variety of methods designed for different pursuits of a study. A common situation is that a researcher may want to test whether there is a statistically significant difference in the observed distribution of a variable between two or more categories of a grouping variable (Siegel & Castellan 1988). Thus, the purpose of this kind of analysis is mainly that of a significance test (Armitage & Berry 1987). Lester (1971) used the chi square test when comparing the monthly numbers of suicides between genders, methods (active, passive) and age groups (15-54 years, over 55 years). He did not find any statistically significant difference between seasonal distributions in any of these subgroups.

On the other hand, when a researcher is interested in certain forms of departure from the null hypothesis, he/she can use a chi-square goodness-of-fit test, which assesses a goodness-of-fit of an observed sample distribution in relation to a hypothesised distribution (Horn 1977, Siegel & Castellan 1988, Agresti 1990). The null hypothesis, for example, would state that the observed monthly distribution of events follows a uniform distribution over a year. If the counts, such as monthly frequencies of events, are aggregated over several years, the 12 monthly counts are independent Poisson observations with an equal intensity in each month, and it can be shown that the counts can be considered to derive from a multinomial distribution. The proportions of 1/12 should be adjusted according to the calendar effect and the effect of leap years (Cleveland & Devlin

1980, Walter 1994, Torrey *et al.* 1997). For example, a significant seasonal pattern in both suicides and homicides was revealed when Lester (1979) used large samples of suicides and homicides, and a chi-square goodness-of-fit test.

The main value of the chi-square goodness-of-fit test is not that of rejecting the null hypothesis, but rather that of a routine screening test making sure, that enough data is gathered to discern a departure from the null hypothesis. Confidence intervals are found to be a feasible way to locate the categories, like months, which actually show departures from the null hypothesis (Wonnacott & Wonnacott 1990).

The use of chi-square methods in seasonality analyses has some limitations, though. Firstly, the chi-square test does not take into account the ordered structure of the data, and it does not distinguish between irregular fluctuation and a smooth cyclical pattern (James 1976, Walter 1977a, Takei *et al.* 1992). Test is also sensitive to a variety of types of departures from the assumed distributional form (Shensky & Shur 1982, Sarmukaddam & Rao 1987, Freedman 1979). The chi-square methods, however, can be thought as "portmanteau techniques" able to assist in many different situations (Armitage & Berry 1987). Their popularity as one of the tests for seasonality may be accounted for by the simple mathematical theory behind them, which make them easy to calculate and understand. Sometimes chi-square tests have been utilised together with more sophisticated methods in order to "facilitate comparisons with previous studies" (Clarke *et al.* 1998b).

2.5.1.3. Correlation analyses

A correlation analysis is used either for significance testing or assessing the degree of a relationship. Thus, it does not only test whether two quantitative variables are associated but also estimate the extent to which two variables are related with each other (Sokal & Rohlf 1981). A correlation coefficient, however, does not indicate that the relationship is one of cause and effect (Bowie & Prothero 1981, Armitage & Berry 1987).

Two most common techniques for correlations are the Pearson's product-moment correlation and the Spearman's rank order correlation coefficient (Armitage & Berry 1987, Siegel & Castellan 1988). In seasonality studies, the Pearson's and Spearman's correlation coefficients have been used to assess the relationships between two time series data, e.g. monthly totals of suicides are correlated with the monthly mean values of ambient temperature. However, since these analyses are intended to look for a linear relationship between two variables, their use in seasonal data including possible cyclic trends (i.e. non-linear trends) might be questionable. For example, Zung and Green (1974) studied the relationship between monthly numbers of suicides and climatic variables with the Pearson's correlation, but no statistically significant correlations were observed. Preti (1997) reported that the monthly distribution of suicides correlated positively (Spearman's correlation) with the mean monthly values of maximum and minimum temperature and indicators of exposure to the sun, and negatively with mean monthly values of humidity grade and indicators of rainfall.

2.5.1.4. Regression analyses

The purpose of a regression analysis is to describe and/or predict variation in a dependent variable with variations in one or more predictors (called also independent or explanatory variables). There has been much confusion between a correlation and a regression analysis. While a correlation analysis establishes and estimates the strength of the relationship between two variables, a regression analysis describes a functional relationship and/or predicts one in terms of the other (Sokal & Rohlf 1981, Cambell & Machin 1993).

The choice of an appropriate regression analysis depends, for example, on the statistical distribution of a dependent variable (e.g. a normal or binomial distribution), the type of independent variables (continuous, dichotomous etc.) and what kind of association is assumed to exist between dependent and independent variables (linear, non-linear etc). An ordinary regression analysis is usually concerned with the linear relationship between the mean value of one variable and the value of another variable, i.e. whether a change in a dependent variable will lead directly to a change in another dependent variable. A multiple regression analysis gives a regression model in which the dependent variable (or outcome) is expressed as a combination of the several independent variables (explanatory variables, predictors, covariates) (Armitage & Berry 1987, Tabachnick & Fidell 1989, Altman 1991, Munro 1997). A logistic regression analysis can be utilised when a dependent variable is a dichotomous variable (Kleinbaum 1994, Fleiss *et al.* 1986).

Occasionally, a regression analysis with dummy variables has been utilised in seasonality studies. For example, a regression with 11 dummy variables (one month is used as a reference month) representing the 12 months of the year has been used to test whether the events of some phenomenon is different from some months than others (Tennenbaum & Fink 1994). After adjusting for the number of days in each month Tennenbaum and Fink (1994) found that July and August were months with significantly more homicides than January. By means of regression analysis, which included dummy variables for each of the six national public holidays, Phillips and Wills (1987) noted that suicides did not increase around the holiday after adjusting for the effect of extraneous variables, such as days of the week.

Anderson & Anderson (1984) utilised an ordinary linear regression analysis in their study examining temperature-aggression relationships. A dependent variable was the daily number of criminal assaults (homicide, rape, battery, armed robbery), aggressive crimes (murder, rape) and non-aggressive crimes (robbery, arson), and the day of a week, temperature and temperature squared were used as the predictor variables. The results showed that both criminal assaults and aggressive crimes increased linearly in frequency as temperature increased, and that they were significantly associated with the day of the week. The non-aggressive crimes were unrelated to all predictors. Souetre *et al.* (1990) revealed with the regression analyses that the significant factors affecting the regional distribution of suicides were ambient temperature and sunlight duration. Wasserman and Stack (1994) noticed that people are not significantly more likely to commit a suicide near the time of their birthday than they are at other time of the year after controlling for seasonal effects (month of death), gender, marital status, ethnicity and educational level in the multivariate regression analysis.

2.5.1.5. Analysis of variance techniques

The main idea of analysis of variance techniques is to describe the characteristics of a variable under study and to compare the means of a dependent variable between categories of a grouping variable. There are many assumptions required before the analysis of variance methods can be used, all of which should be carefully taken into account (Armitage & Berry 1987, Munro 1997). However, when used in seasonality analysis, these methods only reveal whether time can be considered as a statistically significant source of variation (Haus *et al.* 1980).

Student’s t-test is used to analyse the difference between two independent group means, for example to compare the mean values of suicides between winter and summer. The one-way analysis of variance allows comparisons between two or more group means, for example to compare mean value of homicides between 12 calendar months. A two-way analysis of variance compares the mean differences simultaneously between two grouping variables, for example monthly mean values of suicides by gender. One- or two-way analyses of variance technique include the possibility to make multiple group comparisons (Sokal & Rohlf 1981, Armitage & Berry 1987).

By means of ANOVA, for example, Maes *et al.* (1993a) showed that a significantly higher number of violent suicides occurred in spring and summer than in other seasons. Meares *et al.* (1981) found with the help of the two-way analysis of variance that daily mean suicide incidence differed significantly from the equal monthly incidence and that there was a significant between the years effect also.

2.5.1.6. Non-parametric techniques

The non-parametric techniques make few, if any assumptions about the distribution of the dependent variable in the population. They are usually used as alternative statistical techniques in situations, when the statistical assumptions required by the parametric methods are not fulfilled (Siegel & Castellan 1988).

The Kolmogorov-Smirnov one-sample test is used to assess the degree of agreement between the distribution of observed and expected values determined according to some specified distribution, for example a uniform distribution. It is suitable to assess the goodness-of-fit for variables, which are measured on at least in ordinal scale. When sample sizes are small, the Kolmogorov-Smirnov test has been found to be more powerful than its alternative, the chi-square goodness-of-fit test (Siegel & Castellan 1988).

The Mann-Whitney U-test is a non-parametric alternative to Student’s t-test. Respectively, the Kruskal-Wallis test is an alternative for the parametric one-way analysis of variance test, if there are two or more independent groups to compare (Siegel & Castellan 1988). Barker *et al.* (1994), for example, found with the Kruskal-Wallis test that significant seasonal and monthly variations in mean daily frequency of suicide attempts were observed in women, but not in men. In addition, significant relationships (as assessed with the Mann-Whitney U-test) were found between female parasuicides and ‘hot’, ‘still’, ‘still/hot’ days as well as between male parasuicides and ‘windy’ days.

2.5.2. Time series methods in frequency domain

A time series data-set consists of a long series of observations, like those on daily temperature, for instance, made at successive points in time, usually at equally spaced intervals. Furthermore, it is allowed that neighbouring observations are correlated with each other over time. The latter assumption is different from most statistical methods requiring independence of observations.

The one purpose of a time series analysis is to describe the time series by a mathematical model, which provides an appropriate description of the systematic and random variation in a data-set. Furthermore, with the help of a time series analysis, a researcher may also want to predict future observations by taking into account recent changes in the series (Armitage & Berry 1987, Chatfield 1996). The time series analysis methods are appropriate for data, which include a large number of time intervals. Methods for time series analyses vary from simple graphical techniques (which are used to visualise or describe the temporal patterns in a time series data-set) to sophisticated modelling techniques, such as a spectral analysis or a Box-Jenkins analysis.

The time series analyses can be classified in two categories, namely those of the time and those of the frequency domain. These two approaches are in fact mathematically equivalent, in that one form of analysis can be derived from the other (Armitage & Berry 1987). The frequency domain approach (spectral approach) involves representing the time series data by a superposition of sinusoidal waves of different frequencies. Harmonic analysis and spectral analysis are the most popular time series methods used in the frequency domain. In the time domain approach (ARIMA or Box-Jenkins approach), the behaviour of a time series is described in terms of the way in which observations at different times are related statistically with each other. It consists of methods, which fit autoregressive and/or moving-average models to the data-set after differencing and/or seasonal adjustments (Box & Jenkins 1976, McCleary & Hay 1980, Armitage & Berry 1987, Chatfield 1996).

2.5.2.1. Harmonic analysis

Harmonic analysis methods are widely utilised in chronobiological research for biological time series exhibiting various predictable variations (Haus *et al.* 1980). These methods, which are called “rhythmometric“ methods in chronobiology, describe all aspects of a rhythm in terms of an appropriate mathematical model fitted to an entire time series (Bloomfield 1976, Nelson *et al.* 1979).

Harmonic analyses (periodic regression) include various techniques, in which the time series is decomposed into a number of periodic components of sinusoidal form. The basic idea of this type of analysis is that a time series data-set can be described in terms of some parameters, such as a mesor, amplitude and an acrophase of a series of sinusoidal curves. Before using a harmonic analysis technique, any trend in the data needs to be removed (Armitage & Berry 1987). Näyhä (1983), for example, observed a significant seasonal pattern of suicides for males and females by using a harmonic analysis and after adjusting the monthly frequencies of suicides to months of equal length. A similar approach was also followed in other studies (Näyhä 1982, Miccolo *et al.* 1989, Miccolo *et al.* 1991, Ho *et al.* 1997).

The mathematical terms used in a harmonic analysis, and also in a spectral analysis, are not as familiar to researchers in psychiatry as they are for chronobiologists (Hakko *et al.* 1999). For example, when a time series data-set is described in terms of a fitted mathematical model like a sine wave, some terms need to be clarified and described carefully in an article. The term “mesor“ means the mean value of a rhythm defined by a mathematical mode, such as a sine curve, i.e. a point midway between the lowest and highest value of a sine function. The term “amplitude“ is the distance between a mesor and the highest point defined by a mathematical model. The term “acrophase“ indicates the timing of the highest rhythms defined by a mathematical model. A period is the duration of one complete cycle in a rhythmic function (Nelson *et al.* 1979, Haus *et al.* 1980).

The most common modifications of a harmonic analysis are presented in the following sections, because these methods have frequently been used to study different types of seasonal distributions in epidemiological research.

Edwards’ test: Edwards’ model (1961) tests whether the distribution of events follows a simple harmonic curve having one peak and one trough within a single 12-month period. In Edwards’ method the data must consist of the frequencies of events grouped into appropriate time intervals, for example months of a year or days of a week. The assumptions required by the original method are that the length of the time intervals must be equal and that the events are independent. The data are presented in the form of the rim of a circle divided into sectors. For example, twelve sectors are defined when the data consists of monthly totals of events, and seven sectors when the data includes the totals by days of a week. If there were no seasonal variation in the data, the expected centre of the gravity of a time series of events would be in the centre of the circle. The position of the actual centre of gravity indicates the time period for peak incidence and its distance from the centre of the circle indicates the relative strength of the seasonal variation (Edwards 1961, MacMahon & Pugh 1970, Hewitt *et al.* 1971, Pocock 1974, Walter 1977a, Jones 1988). The efficiency of the method is dependent on the underlying model with a single peak and a single trough (MacMahon & Pugh 1970).

Although Edwards’ test is a popular method for seasonality in epidemiological research, it is only occasionally utilised in psychiatry. For example, Bazas *et al.* (1979) identified with the help of Edwards’ test a statistically significant seasonality of suicides in Greece with a June peak. Takei *et al.* (1992) revealed significant seasonality in hospital admissions for schizophrenia and affective disorders with a common peak in July for patients in England and Wales.

Edwards’ test suffers from the lack of power for small sample sizes (Hewitt *et al.* 1971, Roger 1977). It is sensitive to occasional extreme values in the data as well as cyclic variations of other forms than a simple harmonic curve (Hewitt *et al.* 1971, Wehrung & Hay 1970). Also, the assumption of the equally spaced time intervals may not be fulfilled in practice, e.g. due to the unequal lengths of the months. Edwards’ test does not take into account the size of the population at risk (Walter & Elwood 1975). Various modifications of this test have later been employed (Hewitt *et al.* 1971, Cave & Freedman 1975, Walter & Elwood 1975).

Hewitt’s test for seasonality: Hewitt *et al.* (1971) proposed a non-parametric test for seasonality as an alternative for the parametric Edwards’s test, because Edwards’ method has been noted to suffer from a lack of power in relation to small samples. In Hewitt’s method the monthly data of events was ranked from lowest to highest, and then all possible sequences of six consecutive months were examined. Hewitt’s test makes the assumption that the year is split into two equally wide intervals of 6 months each. Although no lower limits for sample size are stipulated, at least six of the 12 months must have non-zero frequencies of occurrences (Hewitt *et al.* 1971).

Rogerson’s (1996) generalised Hewitt’s test to situations in which a predetermined 3, 4 or 5-month period of raised frequencies of occurrences are hypothesised. For example, Walter (1977b) applied the non-parametric Hewitt’ test for admissions due to mania and reported a significant seasonal trend for both sexes with peak values occurring during May-October.

Hewitt’s test is criticised due to its assumption to divide a year into two 6-month periods (Rogerson 1996, Marrero 1983). Also, it does not allow estimating parameters of the simple harmonic curves even if a significant departure from the null hypothesis is indicated. When sample size is substantial large, Hewitt’s test has been found to possess a low power to detect a seasonal trend, unless it is fairly marked (Walter & Elwood 1975).

Pocock’s method: Pocock (1974) developed a method, which generalises Edwards’ approach and allows the alternative hypothesis of a seasonal pattern of arbitrary shape. In that test, the seasonal pattern is estimated by the application of a harmonic analysis to a complete time series of frequencies observed for a fixed population in equally spaced time intervals.

Under this model, the variation between the months is described as a sum of sinusoidal curves. The seasonal variation consists of those components with cycles, which repeat themselves an exact number of times per year. Or in other words, the seasonal variation is presented by the harmonics of period 1, 1/2, 1/3, 1/4, 1/5 and 1/6 of a year, and the significance of each of these and the percentage variation that each represents can be estimated (Pocock 1974, Barraclough & White 1978a,b). The sample variance could be divided into random, seasonal and non-seasonal components. In order to compare the relative importance of seasonal variation in two or more different time series, the adjusted ratio of seasonal and random components of variance can be calculated (Pocock 1974). For example, Barraclough and White (1978a) found with Pocock’s method that for suicides the harmonics with yearly period 1, 1/2, 1/4 and 1/6 were all significant, but for undetermined deaths only the harmonic with a 1/4 year period was significant.

Walter and Elwood test for seasonality: Walter and Elwood (1975) modified Edwards’ test in situations, which allow for an arbitrary pattern of variation in the population at risk and also for unequal lengths of time intervals. Different from Edwards’ test, the expected number of events (e.g. expected number of events in a month) is calculated to be proportional to the population at risk. From the test it is possible to estimate the amplitude of the seasonal variation and the time at which the maximum occurs in a postulated simple harmonic fluctuation.

The Walter and Elwood method has also been used in situations, in which the frequencies of an event of primary interest were compared directly to the frequency of another event, for example admissions with schizophrenia versus admissions with neurosis rather than all admissions (Clarke *et al.* 1998a). Because both events are assumed to being seasonally distributed, the adjustment for the comparison event is supposed to reveal the “true“ biological seasonal pattern in an event of main interest (Hare & Walter 1978).

By using the Walter and Elwood method for seasonality, Walter (1997b) found a peak incidence during August in admissions for mania after adjusting for total admissions. Hare and Walter (1978) showed a significant July peak in admissions for schizophrenia and an August peak for mania after adjusting for various comparative diagnoses. Recently, Clarke *et al.* (1998a) reported the July peak was seen in the admission patterns of schizophrenia, and the peak of admissions for bipolar disorder extended from June to August, when in both analyses the comparison event were the admissions with neurosis.

Other modifications for Edwards’ test: Cave and Freedman (1975) modified Edwards’ test (1961) for seasonality so that a sinusoidal curve with two peaks and two troughs was proposed, instead of Edwards’ hypothesis of a sinusoidal curve with only one peak and one trough during the year. St Leger (1976) advised, how Edwards’ method could be refined by using a maximum likelihood technique.

Roger (1977) presented a test statistic, which originated from the methods provided by Edwards (1961) and Walter & Elwood (1975), because according to Roger himself, these methods were “based on an intuitive approach to the seasonality problem“. Roger derived a test statistic suitable for small samples. By using Roger’s test statistic, for example, Shensky and Shur (1982) showed that both “low genetic risk” and “high genetic risk” groups of schizophrenic patients showed a significant seasonal variation in birth-rates, with peaks in October and April-May, respectively. Poikolainen (1982) found that alcohol-related hospital admissions followed a simple harmonic process with a peak incidence mainly during summer months.

Kolmogorov-Smirnov type statistic: The Kolmogorov-Smirnov type statistic is a non-parametric method that is used to test whether the distribution of an ordinal variable differs significantly between two samples (Clarke *et al.* 1998a). Freedman (1979) developed a variation of this test in a situation, when there is no particular reason to expect a specific parametric alternative, for example a sinusoidal curve, to the null hypothesis of a uniform seasonal pattern. The data can be exact dates of occurrences or, for example, grouped into months.

Clarke *et al.* (1998a) found that both schizophrenia and affective disorder had a significant seasonal variation in their monthly admissions as compared with admissions for neurosis, when Kolmogorov-Smirnov type statistic were used in the statistical analyses. In another study they found that the quarterly birth distribution of unipolar forms of affective disorder differed significantly from the general population (Clarke *et al.* 1998b).

2.5.2.2. Spectral analysis

Spectral analysis is used to find various kinds of periodic behaviour in time series. The rationale behind a spectral analysis is that a time series, which is recorded at equal time intervals, can be decomposed into a sum of trigonometric periodic functions with different frequencies, amplitudes and phases. Frequencies range from zero to the highest frequency discernible in the data. Periodicities in the series can then be examined for each frequency (Chatfield 1996, SPSS 1944, Thrall & Engelman 1990).

Spectral analysis is a modification of Fourier analysis, which is basically concerned with approximating a function by a sum of sine and cosine terms, called the Fourier series representation (Bloomfield 1976, Chatfield 1996). The difference between the spectral and harmonic analysis is, that while a harmonic analysis examines periodic fluctuations with predetermined frequencies, a spectral analysis allows the whole frequency band to be analysed simultaneously (Armitage & Berry 1987).

The spectral analysis can also be used to study pairs of series (bivariate spectral analysis). The coherence between two series can be calculated and it represents the degree of linear association between the two series in different frequency bands (Bloomfield 1976, Chatfield 1996, Thrall & Engelman 1990**).** As with many time series analysis methods, the data usually need to be prepared prior to a spectral analysis. For example the missing values in a series must be replaced and seasonal means or a linear trend must be removed (Thrall & Engelman 1990).

Various forms of a spectral analysis have been applied in seasonality studies. Torrey *et al.* (1996) showed with bivariate spectral analysis that statistically significant coherence in birth patterns among diagnostic groups were found between bipolar disorder and major depression, paranoid schizophrenia, and schizoaffective disorder, as well as between schizoaffective disorder and ‘process’ schizophrenia. The same method was used by Linkowski et al. (1992), who found that the death probabilities due to violent suicides were positively correlated to the humidity grade and negatively to the sunlight duration in both sexes.

2.5.3. Time series methods in time domain

Under the label of “time series analysis”, two correlation techniques must firstly be mentioned. The first one is a cross-correlation, which shows the correlation between two series at the same time or with each series leading by one or more lags. It should be used only on series that fulfil the criteria of stationary (i.e. mean and variance of each series stay about the same over the length of the series). Another important correlation is an autocorrelation, which measures the correlation between observations of a series at different distances apart (Box & Jenkins 1976, SPSS 1994).

ARIMA (Box-Jenkins) models are widely used time series techniques in time domain. ARIMA means AutoRegressive Integrated Moving Average, after the three components (autoregression, integration, moving averages) of the general ARIMA model (SPSS 1994). Sometimes ARIMA models are related to regression models. According to McCleary and

Hay (1980) “the only real difference between ARIMA and regression approaches to time series analysis is a practical one. Whereas regression models can be built on the basis of prior research and/or theory, ARIMA models must be built empirically from the data”. The latter condition determines quite strictly that relatively long time series are needed for ARIMA models. Otherwise, regression approaches informed by prior research and/or theory may be a more appropriate solution than ARIMA models (McCleary & Hay 1980).

ARIMA modelling is usually conducted in three stages. Firstly, a reasonable model based on patterns of autocorrelation is identified. Secondly, the parameters of the tentative model are estimated so that their values are statistically significant and consistent with assumptions of stationary. Thirdly, the adequacy of the model with its estimated parameter values is evaluated. This iterative identification/estimation/diagnosis procedure continues until an adequate and most parsimonious ARIMA model has been achieved for a given time series (Box & Jenkins 1976, McCleary & Hay 1980, Armitage & Berry 1987, Martinez-Schnell & Zaidi 1989, Tennenbaum & Fink 1994, Chatfield 1996).

For example, Tennenbaum and Fink (1994) applied ARIMA model in their data of monthly homicides occurred during 1976-89. A significant seasonality was found to homicides. After adjusting for the number of days per month, the best fitted ARIMA model was first-order autoregressive, i.e. the number of homicide in the current month was a linear function of the numbers of homicides in the previous month and the same month one year prior.

3. Purpose of the study

The purpose of the present study was to examine the seasonal variations of suicides and homicides in Finland, and to evaluate use of statistical techniques for seasonality as well as some important characteristics of the data used in previous studies of suicide seasonality.

Firstly, the seasonal variation in the incidence of deaths due to a suicide in Finland over the period of 1980-95 was analysed in order to answer the following questions (I, II):

1. Does the incidence of suicide in Finland follow a seasonal pattern?
2. Does the seasonal pattern of suicides differ according to the sex and the age group of a suicide victim?
3. Are there any differences between monthly patterns of violent and non-violent suicides?
4. Is the seasonal variation of suicides more marked in Finland compared with countries nearer to the Equator?
5. Has the rate of violent and non-violent suicides changed over time?
6. Has the extent of the seasonal variation in violent and non-violent suicides changed over the 16-year study period?

Secondly, the seasonal pattern of all homicides (murders, manslaughter) in Finland over the period of 1957-95 was investigated regarding the following questions (III, IV):

1. Does the incidence of homicide in Finland follow a seasonal pattern?
2. Are the monthly frequencies of homicides and the monthly frequencies of violent and non-violent suicides correlated to each other?
3. Have any changes over time happened in the number and rates of homicides and in the rates of homicides per 100 000 mean population in Finland?
4. Has the extent of the seasonal variation of homicides changed over the 39-year study period?

Thirdly, the use of statistical techniques and some important characteristics of study samples was evaluated from articles, which have examined the seasonal variation of suicides in a total or regional population and were published in the English language in major psychiatric journals during 1970-97. The following questions were assessed in this study (V):

1. What kinds of statistical techniques have researchers used when examining the seasonal distribution of suicides in their data?
2. Has the choice of a statistical technique remained the same over time?
3. What kinds of data have researchers utilised in their studies (e.g. size of a time series)?
4. Are there any methodological or statistical issues, which researchers should pay more attention to?

4. Material and methods

4.1. Seasonal variation of suicides

4.1.1. Material

4.1.1.1. Suicide data

The data for all suicides (I, II) in Finland over the 16-year study period of 1980-95 were obtained from official statistics of the Finnish Statistics Centre. The data included the monthly frequencies of suicides classified by year of occurrence, gender (male, female), method of suicide (drowning, gas, hanging, jumping from a height, poisoning, shooting, wrist-cutting, other methods) and age group (≤39, 40-64, ≥65 years) of a suicide victim. In subsequent analyses suicide methods were categorised as violent (hanging, drowning, shooting, wrist-cutting, jumping from a height) and non-violent (poisoning, gas, other methods).

4.1.1.2. Population data

The annual mean population values were extracted from the Yearbook of Official Statistics of Finland (Statistics Finland, 1985 and 1995) and used in calculations of annual violent and non-violent suicides per 100 000 mean population.

4.1.1.3 Data for peak-to-trough differences

In order to compare seasonal swings in suicides between studies from countries of different geographical distances from the Equator, a review was performed (II). All suicide seasonality articles published during 1966-96 were identified through a Medline-database search (keywords ”suicide” and ”season”). Only original articles, which actually reported the monthly frequencies of suicides, were included in the present study.

The following variables were extracted: origin (country) of a study sample, distance from the Equator as measured from the approximate midpoint of the country (km), total number of suicides, monthly number of suicides, length of the follow-up period (years), months of peak and trough incidences of suicides, and statistical significance for overall seasonality.

4.1.2. Statistical methods

4.1.2.1. Seasonal variation

The seasonal variation of suicides was examined by months and seasons (I, II). The winter season was defined as December, January, and February; the spring season as March, April, and May; summer as June, July and August; and autumn as September, October and November.

The seasonality of suicides (I, II) was assessed with the method described by Wonnacott and Wonnacott (1990). Firstly, the ordinary chi-square test for multinomials was used as an overall measure of deviation. The null hypothesis stated that suicides within a time interval (month, season) occur with a probability proportional to the length of that time interval.

Secondly, to locate more precisely a time interval in which there was a possible departure from the null hypothesis, a ratio and its 95% confidence interval for each time interval were calculated according to:

$$\pi / \pi_0 \pm (1.96 * \sqrt{\pi(1-\pi)/n})) / \pi_0$$

where π is the observed proportion of suicides, π_0 is the expected proportion of suicides when the null hypothesis is true, and n is the total number of suicides in a study population. If the null hypothesis was true, the value of the ratio π/π_0 had to be approximately 1.00. The null hypothesis was rejected if the 95% confidence interval of the ratio did not include the value 1.00. The calendar effect due to unequal numbers of days in time intervals (months, or seasons) and the effect of leap years were taken into account, when calculating the expected frequencies of suicides.

4.1.2.2. Subgroup analyses

The differences in monthly proportions of suicides were analysed according to gender and the age group of a suicide victim. The ordinary method of comparing the differences in two large sample proportions was chosen as a way to assess the statistical significance of differences (Wonnacott & Wonnacott 1990).

4.1.2.3. Peak-to-trough differences

The peak-to-trough difference was calculated by subtracting the ratio of trough month from the ratio of peak month. With this statistical approach it was possible to estimate the magnitude of the seasonal swing of suicides (I, II).

4.1.2.4. Time trends

Time trends in the rates of violent and non-violent suicide (II) over the years 1980-95 were assessed graphically and with an ordinary linear regression analysis. In the regression analysis, the dependent variable was the rate of suicides per 100 000 mean population and the independent variable was the year of occurrence, recoded as being time = 1 at 1980, 2 at 1981, 3 at 1983, etc., and 16 at 1995.

Time trends in the seasonal variation of violent and non-violent suicides (II) were examined separately in three non-overlapping time periods (1980-84, 1985-89, 1990-95). The statistical methods used were the chi-square test for multinomials and the ratio statistic and its 95% confidence interval (see chapter 4.1.2.1.). Furthermore, in each time period, the months for maximum and minimum ratios of suicides were identified and the peak-to-trough differences were calculated in order to find out, whether there have been any changes in these variables over a time course.

4.1.2.5. Statistical software

The statistical software SPSS 6.1 for Windows (Norusis 1995) was used in all statistical analyses.

4.2. Seasonal variation of homicides

4.2.1. Material

4.2.1.1. Homicide data

The data for all homicides (murder, manslaughter) (III, IV), which took place in Finland over the 39-year time period from 1957 to 1995, were obtained from official statistics of the Finnish Statistics Centre. This time series included the frequencies for the monthly numbers of homicides according to the year of occurrence.

4.2.1.2. Data for suicides, population and offences involving narcotics

The homicide data were compared with the suicide data (III), the mean population values (IV) and the data for offences involving narcotics (IV). Annual means of the population (IV) were drawn from the Yearbook of Official Statistics of Finland (Statistics Finland 1985 and 1995). The suicide data over the period of 1980-95 (see chapter 4.1.1.1) as well as the annual numbers of offences involving narcotics during 1980-96 (IV) were obtained from official statistics of the Finnish Statistic Centre.

4.2.2. Statistical methods

4.2.2.1. Seasonal variation

The seasonal variation of homicides (III, IV) was examined with the chi-square test for multinomials and a ratio statistic with 95% confidence intervals (see chapter 4.1.2.1).

4.2.2.2. Time trends

Time trends in the occurrence of homicide (III) were investigated graphically and with an ordinary linear regression analysis (Norusis 1995). The annual rate of homicides per 100 000 mean population was analysed against a given year of occurrence, which was recoded for the statistical analysis as being time = 1 at 1957, 2 at 1958, etc., and 39 at year 1995. Linear trends were also examined in the annual mean population values and the annual numbers of homicides without adjusting for mean population values.

Time trends in the seasonality of homicides (IV) were explored separately in eight time periods each including five consecutive years, except for the first period covering three years (1957-59) and the last covering six years (1990-95). For each time period, the statistical significance of overall seasonality was calculated as well as the ratio statistic and its 95% confidence intervals by seasons (see chapter 4.1.2.1.). The change in the peak-to-trough month difference over time was examined with a linear regression analysis.

4.2.2.3. Correlation analyses

Spearman's rank order correlation was used to examine the relationship between monthly frequencies of homicides and violent and non-violent suicides over the period of 1980-95 (III) and between the annual rates of homicides and offences involving illicit drugs over the period of 1980-96 coefficient (IV).

4.2.2.4. Statistical software

The SPSS 6.1 for Windows (Norusis 1995) was used in all statistical analyses.

4.3. Use of statistical techniques in studies of suicide seasonality

4.3.1. Material

The original articles of suicide seasonality were identified from two computerised literature databases (Medline, PsychLit). The following inclusion criteria were used: seasonal variation of suicides was one aim of the study, the article was published during 1970-97 in major psychiatric journals in the English language, and a time series of suicides included the data from a total national or regional population. Thus, those articles were excluded, which for example included seasonal analyses only in relation to poisoning, or in which only the adolescent population was considered. After locating the articles, the reference lists of these articles were thoroughly investigated in order to find those relevant articles, which might have been missed from database searches. However, no additional articles were found.

The following variables were extracted from each article: authors, publishing year, total number of authors, name of the journal, origin of data (country/region), time period for data collecting (starting year, final year), length of the time series (in years), total and annual number of suicides, time period for seasonality, name of a grouping variable in subgroup analyses, name of the phenomenon other than suicides to which suicide seasonality was related, exact name of the statistical test used to assess the statistical significance of a seasonal effect, number of references to statistical literature, reporting of the name of statistical software, and number of tables and figures concerning seasonality.

In addition, the nature of each study was determined and assigned to at least one out of three types. The first type of studies included those, in which the aim was to investigate the seasonal distribution of suicides itself. The second type of studies analysed, whether the seasonal distribution of suicides differed in some subgroups of the population, e.g. genders or age groups. In the third type, the seasonal distribution of suicides was related to a seasonal phenomenon other than suicides, e.g. temperature or deaths due to homicides.

4.3.2. Statistical methods and software

The results of the review were presented with frequency and percentage distributions. The statistical software used for the analyses of the data was the SPSS 6.1 for Windows (Norusis 1995).

5. Results

5.1. Suicide seasonality in Finland during 1980-95

5.1.1. Suicides in Finland

A total of 21279 suicides were committed during the 16-year study period of 1980-95 in Finland. Of these suicide victims, 16764 (78.8%) were males and 4515 (21.1%) females. Men were significantly younger than women at the time of death (χ^2=252.7, df=2, p<0.001) (Table 5).

Table 5. All suicides in Finland during 1980-95 by gender and age groups.

	Males		Females		Total	
Age group	%	n	%	n	%	n
≤39 years	46.4	7785	34.2	1546	43.8	9331
40-64 years	41.0	6879	46.9	2117	42.3	8996
≥65 years	12.5	2100	18.9	852	13.9	2952
Total	100	16764	100	4515	100	21279

5.1.2. Seasonal variation of suicides

The observed monthly distribution of suicides differed statistically significantly from the expected distribution of suicides (χ^2=142.5, df=11, p<0.001). Significant peak months were May (ratio 1.14, 95%CI 1.09-1.19), June (1.10, 1.05-1.15) and July (1.07, 1.03-1.12), and troughs were January (0.92, 0.88-0.96), February (0.87, 0.83-0.91), March (0.94, 0.89-0.98) and December (0.88, 0.83-0.92) (I: Tables 1 and 2).

5.1.3. Gender

A significant excess of male suicides (Figure 1) was found in April (ratio 1.05, 95%CI 1.00-1.11), May (1.14, 1.09-1.19), June (1.10, 1.05-1.15) and July (1.08, 1.02-1.13). Correspondingly, significant troughs were December (0.88, 0.84-0.93), January (0.93, 0.89-0.98), February (0.88, 0.83-0.93) and March (0.93, 0.88-0.98) (I: Tables 1 and 2).

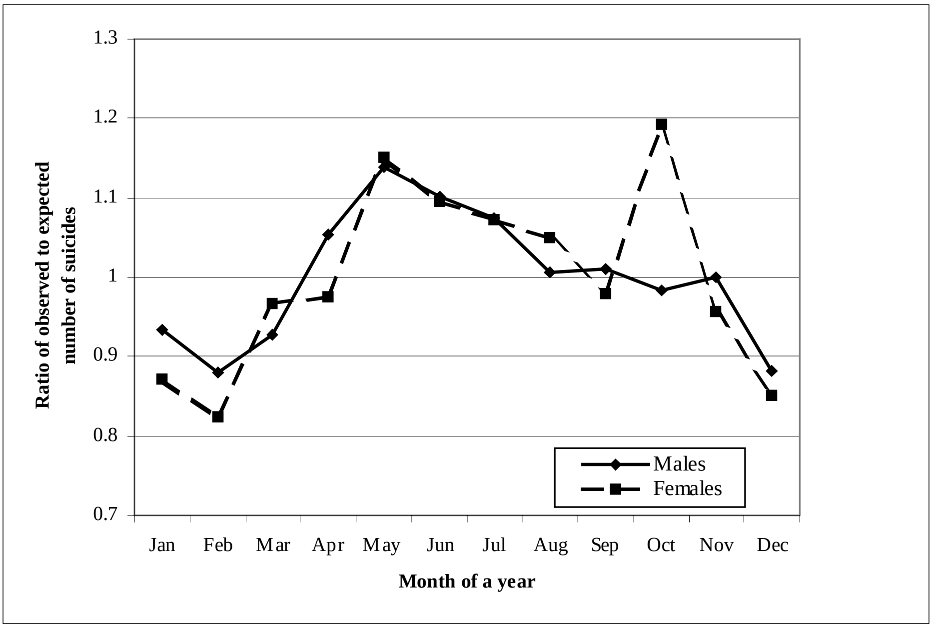

Figure 1. The monthly ratios of suicides by gender, Finland 1980-95.

The seasonal pattern of female suicides was bimodal (Figure 1). Statistically significant peak incidences were found in May (1.15, 05-1.25) and October (1.19, 1.09-1.30) and troughs were in January (0.87, 0.78-0.96), February (0.82, 0.73-0.92) and December (0.85, 0.76-0.94) (I: Tables 1 and 2).

As the unimodal distribution of male suicides and the bimodal distribution of female suicides already suggested, the monthly distribution of suicides differed significantly between gender (χ^2=27.11, df=11, p=0.004). The largest difference in the proportions of suicides between gender was found in October (difference=1.8%, 95%CI 0.81-2.76%).

5.1.4. Age groups

Among victims aged 39 years or less, statistically significant peak months for suicides were May (ratio 1.09, 95%CI 1.02-1.16) and June (1.12, 1.05-1.20), and troughs were February (0.85, 0.79-0.92) and December (0.92, 0.85-0.98) (Figure 2).

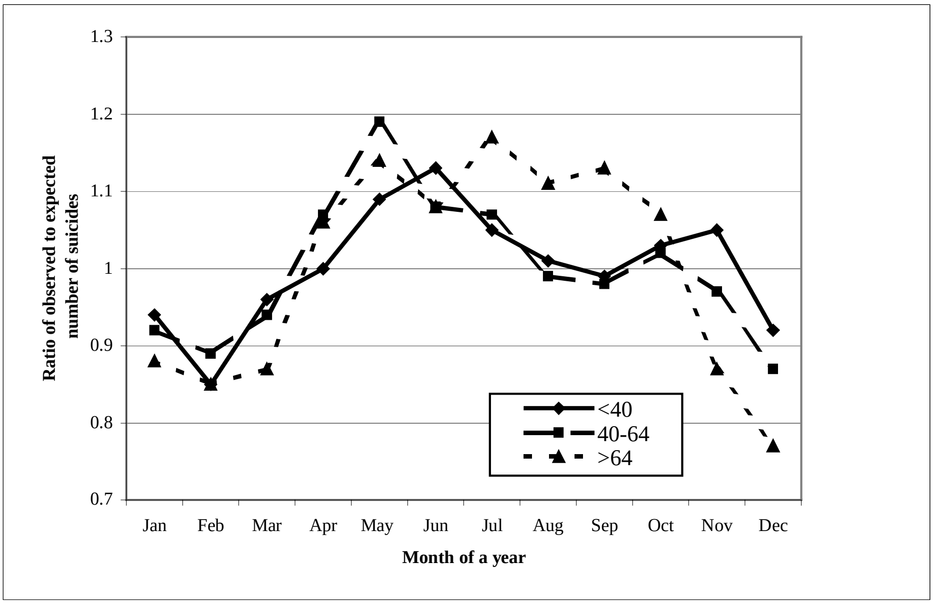

Figure 2. Monthly ratios of suicides by age groups, Finland 1980-95.

In the age group of the 40-64 year-olds, significant months for peak incidences in suicides were May (1.19, 1.12-1.27), June (1.08, 1.01-1.15) and July (1.07, 1.00-1.14). The trough months were January (0.92, 0.85-0.98), February (0.89, 0.83-0.96) and December (0.87, 0.81-0.93).

Among subjects 65 years of age or more, the significant peak months were May (1.14, 1.01-1.26) and July (1.17, 1.04-1.30). There was a trend toward a secondary autumn peak in August (1.11, 0.99-1.23) and September (1.13, 0.99-1.25). The trough months were January (0.88, 0.77-0.99), February (0.85, 0.74-0.97), March (0.87, 0.76-0.99), November (0.87, 0.66-0.87) and December (0.77, 0.66-0.87) (I: Tables 1 and 2).

A statistically significant excess in the incidence of suicides was observed in September among subjects of over 65 years of age when compared with 40-64 year olds (difference=1.2%, 95%CI 0.02-2.35%) and subjects under the age of 40 (1.1%, 0.00-2.34%). The troughs among the elderly were significantly deeper in November (1.5%, 0.37-2.55%) and in December (1.3% 0.23-2.32%) when compared with the subjects of under 40 years of age.

5.1.5. Suicide methods

Of all suicides, 14965 (70.3%) were committed by a violent method and 6315 (n=6315) by a non-violent method. There was a statistically significant difference in monthly distributions of suicides between violent and non-violent methods (χ^2=20.23, df=11, p=0.042).

In violent suicides, statistically significant peak months were May (ratio 1.16, 95%CI 1.11-1.22), June (1.12, 1.06-1.17) and July (1.11, 1.06-1.17) and troughs occurred in January (0.92, 0.87-0.97), February (0.84, 0.79-0.89), March (0.92, 0.86-0.97) and December (0.85, 0.81-0.90) (I: Figure 1). The monthly distribution of violent suicides differed significantly between males and females (χ^2=27.11, df=11, p=0.004). The proportion of male suicides exceeds the proportion of female suicides in January (difference 1.4%, 95%CI 0.3%-2.5%) and April (1.2%, 0.1%-2.3%). In October, the proportion of female suicides was greater than the proportion of male suicides (1.7%, 3.0%- 0.5%). After adjusting for age group and gender, an late summer/autumn peak was observed among the oldest age group in both genders (males in September, females in August).

In non-violent suicides, significant peak months were May (ratio=1.09, 95%CI 1.01-1.17) and October (1.08, 1.00-1.17). None of the trough months reached a statistical significance (I: Figure 1). The monthly distribution of non-violent suicides did not differ between genders (χ^2=11.26, df=11, p=0.422). However, the proportion of female non-violent suicides exceeded that of males in October (difference 1.7%, 95%CI 3.3% - 0.1%).

5.1.6. Comparison of peak-to-trough differences between earlier studies

The correlation analysis revealed that there was no statistically significant correlation between peak-to-trough differences and distance from the Equator (Spearman correlation, r=0.25, n=9, ns). (I: Table 3). A statistically significant monthly seasonality was reported only in three out of nine studies. However, a shift of the peak month from spring to summer was noted in relation to the distance from the Equator (I: Table 3).

5.1.7. Trends in rates of violent and non-violent suicides

During the years 1980-95, there was no statistically significant linear trend in the annual rate of violent suicides per 100 000 mean population (F=1.166, p=0.20, r^2=0.28). However, from 1985 to 1990, there was an increasing trend (F=26.9, p=0.007, r^2=0.87) and after that a decreasing trend (F=42.78, p=0.007, r^2=0.93) in this rate. In the rate of non-violent suicides per 100 000 mean population, a significant increasing linear trend existed over the whole 16-year study period (F=99.04, p<0.001, r^2=0.91) (II: Figure 1).

5.1.8. Secular trends in seasonality of violent and non-violent suicides

In violent suicides, a statistically significant seasonality was found in every time interval. Significant seasons for peak incidences of suicides were spring in 1980-84 (ratio 1.09, 95%CI 1.04-1.15) and summer in all time intervals (1980-84, 1.06, 1.01-1.11; 1985-89, 1.09, 1.04-1.14; 1990-95, 1.10, 1.05-1.15). Significant trough seasons were winter in all periods (1980-84, 0.83, 0.78-0.88; 1985-89, 0.88, 0.84-0.93; 1990-95 0.89, 0.85-0.94). All time intervals included a statistically significant peak (May in 1980-84, July in 1985-89, June in 1990-95) and trough month (February in 1980-84 and 1985-89, December in 1990-95). (II: Table 1).

In non-violent suicides, a statistically significant overall seasonality was present only in 1980-84 with a peak in spring (ratio 1.12, 95%CI 1.03-1.20) and a trough in winter (0.87, 0.79-0.95). Winter was a significant trough season (0.92, 0.84-0.99) also in 1985-89. Statistically significant peak months were April in 1980-84 and June in 1990-95. No significant trough months were observed in non-violent suicides (II: Table 1).

The peak-to-trough difference decreased slightly in both violent and in non-violent suicides during the time course. The peak-to-trough differences were 46.6 (1980-84), 33.7 (1985-89) and 33.7 (1990-95) in violent suicides, and 36.6, 24.7, 28.2 in non-violent suicides, respectively (II: Table 1).

5.2. Homicide seasonality in Finland during 1957-95

5.2.1. Seasonal variation of homicides

A total of 4553 homicides were committed in Finland during 1957-95. Over this 39-year study period, the median number of homicides was 113 per year (range 55-171). The annual monthly mean number of homicides varied between 8.4-10.9 (sd 2.9-4.3).

There was a significant difference in homicide rates between the four seasons (χ^2=8.29, df=3, p=0.04). In winter, the observed frequency of homicides was about 6% lower (ratio 0.94, 95%CI 0.89-0.99) and in summer about 6% higher (1.06, 1.01-1.11) than expected under the null hypothesis. During spring and autumn, the observed frequency of homicides did not differ statistically from the expected frequency (spring 1.00, 0.95-1.05; autumn 1.00, 0.95-1.05) (III: Table 1).

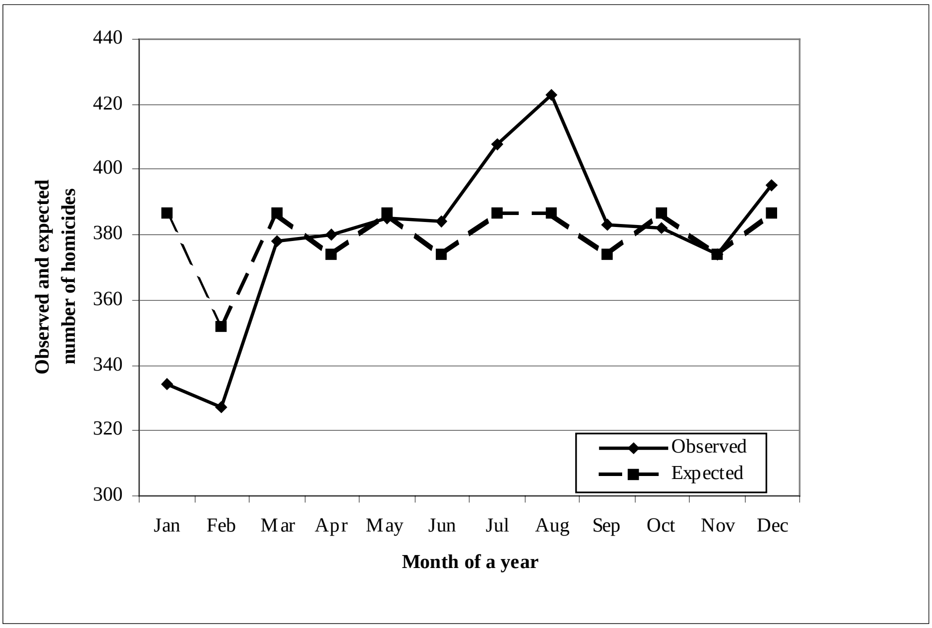

Figure 3. Observed and expected number of homicides by month, Finland 1957-95.

The monthly numbers of homicides did not differ significantly from the expected numbers (χ^2=14.56, df=11, p=0.20) (Figure 3). However, a statistically significant trough incidence was found in January (0.86, 0.78-0.95). The maximum excess of homicides was observed in August (1.10, 1.00-1.19) (III: Table 2).

Over the period of 1980-95, the monthly ratios of homicides correlated significantly with the monthly ratios of violent suicides (Spearman correlation, r=0.62, n=12, p=0.03), but not with the monthly ratios of non-violent suicides (r=0.15, n=12, p=0.63).

5.2.2. Trends in rate of homicide occurrence

From the year of 1957 to 1995 the recorded number of homicides in Finland increased by about 58%. The annual increase in homicide incidence was 1.74 homicides per year (linear regression, adjusted r^2=0.62, p<0.001). At the same time, the Finnish mean population increased by about 18%, which represented an increase of about 19 000 inhabitants per year (r^2=0.98, p<0.001).

The rate of homicides per 100 000 mean population in Finland increased by 33% (IV: Figure 1) over the whole study period. The annual increase was about 0.03 homicides per 100 000 mean population (r^2=0.46, p<0.001).

The relationship between annual homicide rates and offences involving illicit drugs was studied covering the period of 1980-96. The increase in annual homicide rates has followed the increase in offences involving illicit drugs (Spearman correlation, r=0.76, $p<0.001$).

5.2.3. Time trends in homicide seasonality

Summer was a statistically significant peak season for homicides in 1960-64 (ratio 1.21, 95%CI 1.05-1.37) and 1970-74 (1.17, 1.01-1.33), but autumn led in 1980-84 (1.19, 1.04-1.34). The only significant trough season in the incidence of homicide was winter during 1960-64 (0.76, 0.62-0.90) (IV: Table 1).

A significant overall seasonality was found only during the period of 1960-64. The peak-to-trough month difference in homicide has declined during the time course of the investigation (linear regression, r^2=0.84, $p<0.001$) (IV: Table 1).

5.3. Use of statistical techniques in studies of suicide seasonality

5.3.1. Characteristics of reviewed studies

A total of 44 studies on suicide seasonality were found trough database searches (V: Table 1). Of all articles, 21% were published in 1970-79, 39% in 1980-89 and 41% in 1990-97. The number of authors per article ranged from 1 to 6 (median 2 authors), and 33 different names of first author were found.

These reviewed articles were published in 15 different journals. Three journals published 52.5% (n=23) of all reviewed articles: British Journal of Psychiatry (9 articles, 20.5%), Acta Psychiatrica Scandinavica (8,18.2%), and Journal of Affective Disorders (6,13.6%). The rest of the articles were published in the following journals (in alphabetical order, number of articles in parenthesis): American Journal of Epidemiology (2 articles), American Journal of Psychiatry (1), Archives of General Psychiatry (1), Comprehensive Psychiatry (1), Medical Science and Law (2), Psychiatry (1), Psychological Medicine (1), Psychological Reports (2), Psychiatry Research (2), Social Science and Medicine (2), Social Psychiatry and Psychiatric Epidemiology (2), and Suicide and Life-Threatening Behaviour (4).

Of all reviewed articles, 72.7% (n=32) utilised the national and 27.3% (n=12) the regional suicide data. About half of the reviewed studies (24 articles, 54.5%) used data from European countries. Two articles originated from the Southern Hemisphere.

The length of the time series regarding suicides varied from 1 year to 59 years (median 9 years). The total number of suicides was not reported in 13 (29.5%) out of the 44 reviewed articles. Of those 31 articles, which actually reported the size of the data, the annual number of suicides ranged from 15 to 26918 (median 721).

5.3.2. Time period for seasonality

The seasonal variation of suicides was examined with monthly values of suicides in 32 articles (72.7%) and with quarter-yearly values in 10 articles (22.7%). In addition, the seasonal pattern of suicides was analysed by days of a week (8 articles, 18.2%), time of day (4, 9.1%), phases of a lunar cycle (4, 9.1%), national holidays (4, 9.1%), daylight saving time changes (1, 2.3%), the time of week in month (1, 2.3%), and day number (1-365) in year (2, 4.5%).

The number of different time periods varied from one to four periods. Most frequently researchers studied simultaneously suicide seasonality by months and days of a week (8 articles, 18.2%) or by months and seasons (7, 15.9%). However, months and/or seasons were used in 35 articles (79.6%).

The monthly values of suicides were reported as frequencies in only 9 articles. In 7 articles, they were presented in other units, such as monthly mean values or percentage deviation from chance expected numbers. When the monthly values were not reported in any way, they, however, could, roughly be estimated from graphical presentations in 9 articles.

An adjustment for calendar effects, i.e. the effect due to the unequal number of days in a month, was reported in 10 articles.

5.3.3. Seasonal distribution of a single time series

The seasonal pattern of suicides was examined with some statistical significance test in 37 articles (84.1%), although the exact name of the test could not be identified in 2 articles. In 6 articles (13.6%), no statistical method for seasonality at all was used. One article investigated suicide seasonality only with relation to other phenomena, not the seasonal distribution of suicides itself.

A chi-square method was utilised in 14 (37.8%) out of those 37 articles, which actually used some significance test for seasonality (V: Table 2). Other methods were analysis of variance methods (7, 18.9%), non-parametric methods (2, 5.4%), and log-linear modelling (1, 2.7%). Of the time series analysis methods, a harmonic analysis was used in 7 articles (18.9%) and a spectral analysis in 4 articles (10.8%). Both the Edwards' test for seasonality and Rayleigh's test for seasonality were found in one article, each.

No apparent change was observed in the choice of a statistical significance test for seasonality during 1970-97 except regarding spectral analyses, which were all performed during the 1990s.

5.3.4. Suicide seasonality in subgroups of a population

A total of 30 studies (68.2%) have considered suicide seasonality in certain subgroups of a population. Of these investigations, gender differences with regard to the seasonality of suicide were investigated in 25 articles (83.3%). Subgroup differences were also reported according to age groups (9 articles, 30.0%), suicide methods (6, 20.0%), geographical region (3, 10.0%), ethnicity (2, 6.7%), marital status (1, 3.3%), social class (1, 3.3%) and occupational status (1, 3.3%). Two studies have examined time trends in the seasonal pattern of suicides.

The number of different grouping variables per article varied from one to four (median 1 variable). Most commonly the age and gender differences were analysed simultaneously (9 articles, 30.0%).

A statistical significance test for subgroup differences was found in only 7 out of 30 articles (23.3%). The chi-square method was used in 3 articles. A Spearman correlation analysis, a cross-correlation coefficient, a two-way analysis-of-variance test, and log-linear modelling were used in one article each. The exact name of the statistical test could not be identified in two articles.

Although in 21 articles no significance test at all was used for subgroup differences in seasonal distribution of suicides, such a difference was frequently reported to exist. In those cases, conclusions were based on either the interpretation of graphical presentations or "eyeball" comparisons of results obtained from separate subgroup analyses.

5.3.5. Suicide seasonality related to seasonality of other phenomena

The seasonal distribution of suicides was related to the seasonal pattern of a phenomenon other than suicides in 19 (43.1%) out of the 44 reviewed articles. Ten (52.6%) out of these 19 studies investigated an association between suicides and various meteorological factors, such as ambient temperature, length of day, duration of sunlight or humidity.

In 9 articles (47.4%), the seasonal distribution of suicides was related to that of deaths from causes other than suicides (e.g. homicides). In one study, the suicide seasonality was associated with seasonality in sociological (e.g. unemployment rate) and biological (e.g. serotonin) factors. Eight studies (42.1%) explored a seasonal association between suicides and hospital admissions due to mental disorders, traffic accidents, attempted suicides or electroconvulsive therapy.

A total of 13 articles (68.4%) out of those 19 articles, which examined relationships between suicides and other phenomena, used some significance test. The chi-square method was used in 3 articles (15.8%), Pearson's correlation in 3 articles (15.8%), Spearman's correlation in 4 articles (21.0%) and a cross-correlation in 4 articles (21.0%). In addition, a logistic regression analysis, multiple regression analysis, a spectral analysis and the Mann-Whitney U-test were utilised in two articles (10.5%) each. In 6 articles (31.6%), researchers based their conclusions only either on the graphical interpretation of the data or results obtained from separate analyses of the studied phenomena.

5.3.6. Reporting of statistical methods, references and software

An adequate description of statistical methods – i.e. reporting of mathematical expressions, descriptions of the basic ideas of the statistical test, statistical references, or a statistical appendix - was found in 20 (45.4%) of all reviewed articles. In 17 articles (38.6%), however, the name of the statistical test without any detailed description was presented, but that was satisfactory, if a standard and well-known statistical method was used like, for instance, the ordinary chi-square goodness-of-fit test. The exact name of the statistical test could not be identified in two articles, although the p-values were reported in the text.

About half of the reviewed articles contained at least one reference to the statistical literature like a statistical textbook or a methodological article. The name of the statistical software was mentioned only in 11% of all articles.

5.3.7. Graphical presentations

At least one graph was found in 25 (56.8%) of all reviewed articles. The type of graphs were histograms (4 articles, 9.1%), “line diagrams“ or scatterplots (20, 45.5%) or a combination of these (1, 2.3%). In 12 articles (27.3%), the seasonal pattern of suicides was visualised by plotting the monthly values averaged over the study period (months on x-axis). In 6 articles (13.6%), the annual monthly values were plotted against time including (number of years) x 12 cut-off points on x-axis. For example, if the study period had been 10 years, the x-axis included 10 years x 12 months =120 monthly intervals.

In particular, gender differences in suicide seasonality studies were visualised with the help of graphs (12 articles, 27.3%). Of these 12 articles, the seasonal patterns of male and female suicides were plotted in the same figure in 7 articles (58.3%). In 5 articles (41.7%), there were separate graphs for males and females. Unequal scaling of the y-axis, which makes it difficult to compare the extent of seasonality between different graphs, was found in 3 articles.

6. Discussion

6.1. Suicide seasonality in Finland during 1980-95

6.1.1. Seasonal variation of suicides

All deaths due to a suicide in Finland during 1980-95 were investigated in terms of their seasonal distribution. A statistically significant seasonality was found exhibiting a peak period from May to July and a trough from December to March. The results agreed with earlier studies from both the Northern and Southern Hemisphere countries, of which most have reported a significant excess of suicides in spring or early summer and a trough in winter (see, for example, Lester 1971, Eastwood & Peacocke 1976, Parker & Walter 1982, Kevan 1980, Massing & Angermeyer 1985, Ho 1996). The results were also similar to those reported earlier from Finland using a time series of suicides covering the period of 1961-76 (Näyhä 1982, Näyhä 1983).

The peak incidence of suicides was in spring straight after the vernal equinox, which may be regarded as a starting point of the photoperiodicity with increasing amounts of light and temperature. The troughs of suicides occurred around the winter solstice or slightly thereafter. These findings agreed with previous studies that had reported an increased number of suicides in relation to increased amounts of daylight, higher temperature or decreased levels of humidity (Souetre *et al.* 1987, Maes *et al.* 1994, Salib & Gray 1997, Preti 1997). Thus, it is concluded that the observed seasonal variation of suicides in Finland is at least in part associated with the seasonal changes of environmental factors, such as differences in the amounts of daylight of the four seasons. It is suggested that seasonal rhythms in the environment may underlie seasonal changes of psychosocial habits and a human's biological processes, which may contribute to suicidal behaviour (Kevan 1980, Fossey & Shapiro 1992).

If the seasons of a year have an effect on the incidence of suicides, it should be seen more clearly in countries nearer the poles compared with countries closer to the Equator enjoying greater climatic continuity. Due to its northern location (between latitudes 70^{o}N 5´30´´ and 59^{o}N 48´30´´) Finland is an ideal country to study the effects of the seasonality phenomenon. The climatic factors, such as ambient temperature and daylight, vary widely between seasons in Finland (Statistics Finland 1999a).

Even between the northern and southern part of the country, there are differences in temperature and daylight duration. For example, during 1961-90 the mean temperature in winter (December to February) was –5°C in Helsinki and –14°C in Sodankylä. In summer (June to August) the mean temperatures were +16°C and +12°C, respectively (Statistics Finland 1997). Especially, the amount of daylight varies largely between the northern and southern districts. Unfortunately, regional differences in the seasonal variation of suicides could not been examined in the present study, because the data did not include that variable. This should be a subject of further research. Näyhä *et al.* (1994) have noted that mental disorders as assessed with the Cornell Medical Index questionnaire showed a seasonal variation with a spring and summer peak, which is quite similar to that of suicides in the Finnish arctic (Näyhä 1984).

6.1.2. Gender

The monthly distribution of suicides was unimodal in males and bimodal in females. These findings were consistent with previous studies from Finland and also from other countries, which have reported a spring peak of suicides in both males and females and a secondary autumn peak in females alone (Eastwood & Peacocke 1976, Kevan 1980, Meares *et al.* 1981, Näyhä 1982, Parker & Walter 1982, Näyhä 1983). In order to establish possible explanations for this apparent gender difference in the seasonal pattern of suicides in Finland, further studies are needed. For example, Meares *et al.* (1981) suggested that it might be due to some biological determinants, which are not the same for both sexes.

6.1.3. Age groups

In the present study, the spring peak of suicides among the youngest subjects (age 39 years or less) was similar to that found in earlier studies (Massing & Angermeyer 1985, Souetre *et al.* 1987), although in these studies the age categorisation (25-44 years) was slightly different. Some studies have provided evidence for a bimodal pattern of suicides (spring and autumn peaks) in subjects under the age of 25 (Näyhä 1982, Souetre *et al.* 1987), but no such pattern was revealed in this study perhaps due to the fixed age categorisation of the data.

Among suicide victims aged 40 to 64 years, a peak occurred in spring, which was in line with earlier studies of suicides in the age group of 45-64 year-olds (Näyhä 1982, Massing & Angermeyer 1985). In the oldest age group (65 years or more), a significant peak of suicide incidences was also in spring confirming earlier studies (Näyhä 1982, Massing & Angermeyer 1985, Souetre *et al.* 1987). In addition, there was a trend towards an increased number of suicides in autumn, which was not noted in other age groups. Maes *et al.* (1993a) found also an August peak in suicides by violent methods among subjects aged 65 years or more. The trough periods of the oldest age group were more pronounced and longer (November to March) compared with suicides of other age groups (troughs during December to February).

The variability of the age categorisation of the suicide victims makes it difficult to compare the seasonal trends between different earlier studies. The purpose of the age categorisation has usually been to describe a group of people at a certain stage of their life. It is well known that in certain periods of their lives people are more vulnerable than usual, for example in puberty, midlife, menopause, retirement (Massing & Angermeyer 1985). There are, however, differences in the “timing” of some life stages between subjects. Instead of examining the chronological age of a subject in seasonality analyses, further research should also pay attention to the age at time points during which some “critical” life stage actually begins. If this information were possible to gather, then the statistical analysis would give a purer view of the effect of “age” on the seasonal variation of suicides.

6.1.4. Suicide methods

About 70% of all suicides in Finland were committed by a violent method. Of these violent suicides, about 83% of the victims were males. The seasonal distribution of the violent suicides followed a unimodal pattern with a peak in spring or summer, which was consistent with previous studies (Meares *et al.* 1981, Lester 1985, Maes *et al.* 1993a).

For non-violent suicides the seasonal distribution of suicides was bimodal with a peak both in spring and autumn. This differed from Maes *et al.* (1993a), who did not find any statistically significant seasonality in non-violent suicides. The bimodality of the non-violent suicides observed in the present study might explain why female suicides accounted for 32% of the non-violent suicides, while the respective proportion was about 17% for violent suicides. The seasonal pattern of female suicides was found to have a peak in spring as well as autumn (Meares *et al.* 1981, Näyhä 1982). It has also been suggested that seasonal trends in suicides may be linked with seasonal changes in a human’s biological functions, and that that link might be different in violent and non-violent suicides (Fossey & Shapiro 1992, Maes *et al.* 1994).

The present investigation was the first Finnish study, which addressed the seasonal variation of violent and non-violent suicides. The categorisation of the suicide methods was based on that used in the work-group of Maes *et al.* (1993a,b, 1994). Different categorisations have been used in other studies. For example, in a Finnish study by Isometsä *et al.* (1994b), suicides by drowning were defined as non-violent suicides, while in the present study they were defined as violent suicides. There are, however, no common rules for the categorisation of suicide methods, although the levels of the activity needed to commit a suicide or the lethality of a suicide method have been used for this purpose (Öhberg 1998a). The variability in the categorisation of the suicide methods makes comparisons of the results between different studies problematic.

Only a few studies have examined the seasonal variation of suicides on the basis of a single suicide method (Lester 1985, Massing & Angermeyer 1985, Lester & Frank 1988). The small number of studies is probably due to the lack of statistical power, which occurs easily when the data is divided into subgroups. When combining specific suicide methods under the same category, it is assumed that the seasonal pattern is similar between these methods. If it is not, it can happen that the seasonal pattern of different suicide methods cancel each other out. Further studies are needed which investigate the seasonal variation of specific suicide methods in a detailed manner. These studies might also be of help, for example, when determining which of the methods are actually violent and which are non-violent.

The incidence of a specific suicide method is dependent not only on the availability but also the lethality of a method (Öhberg 1998a). For example, the seasonal peak in suicides by drowning in Finland can be assumed to occur during the periods of a year when the lakes are not covered by ice. On the other hand, suicides by shooting have usually a fatal outcome, while the suicide attempts due to poisoning may result in survivals. Thus far, no one seems to have examined, to what extent the seasonality of a specific suicide method can be explained by the availability or the lethality of that method.

6.1.5. Comparison of peak-to-trough differences between earlier studies

When comparing the extent of the seasonal variation of suicides between studies from different countries, a statistically significant overall seasonality was observed in only four out of nine studies. The results also demonstrated that there was a trend towards significance levels in the relationship between the extent of a seasonal variation and geographic latitude. Meares *et al.* (1981) has suggested that there is a decreasing trend in the seasonality of suicides.

6.1.6. Trends in rates of violent and non-violent suicides

Time trends in the rate of violent and non-violent suicides were studied for the first time in Finland. Over the period of 1980-90, there was an increasing trend in the rates of violent suicides. Öhberg *et al.* (1995) have noted a similar increasing trend in all suicides (suicide methods were not distinguished) over the period of 1947-90 in Finland. After the year 1990, the rate of violent suicides has begun to decrease smoothly. In 1986, the Finnish National Board of Health set up the National Suicide Prevention Project in Finland and the observed decrease might be a positive consequence of its efforts to reduce the suicide mortality in Finland (Lönnqvist 1988, Lönnqvist *et al.* 1993, Beskow *et al.* 1999).

The rate of non-violent suicides in Finland during 1980-95 showed an upward trend. Possible explanations for this might be the increased availability of tricyclic antidepressants and neuroleptics between 1982-92 (Öhberg *et al.* 1995), because it is well known that most of the non-violent suicides were achieved via drug overdoses.

6.1.7. Secular trends in seasonality of violent and non-violent suicides

A statistically significant seasonality of violent suicides was revealed for every time period (1980-84, 1985-89, and 1990-95), but regarding non-violent suicides only during 1980-84. The extent of the seasonal variation showed a slight decrease over time in both violent and non-violent suicides. These findings were consistent with earlier studies, in which the seasonal variation of suicide rates was found to be significant only in violent, but not in non-violent suicides (Maes *et al.* 1993a). Based on these findings and the suggestion made by Meares *et al.* (1981), that the amplitude seasonal variation of suicides is declining, a more comprehensive study should be carried out, in which secular trends in the seasonal variation of suicides are compared over several time periods between several countries with different locations from the Equator.

6.1.8. Methodological concerns

6.1.8.1. Reliability of suicide statistics

The statistics kept on the deaths due to suicides in Finland have been found to be reliable. Karkola (1990) has estimated that about 90% of all suicides in Finland are correctly classified as suicides. It is generally accepted that official suicide statistics tend to underestimate rather than overestimate suicide numbers (Holinger 1979, Maes et al. 1993a). Due to changes in the diagnostic systems and differences in the processes of determining a death as a suicide, it was found to be somewhat problematic to make reliable international comparisons of suicide statistics (Phillips & Ruth 1993, Öhberg 1998a). These factors, however, may only have an effect when analysing a time trend in extremely long time-series but not when analysing a seasonal pattern of events. It is unlikely that possible changes in the determination of a death as a suicide might happen unevenly over a year so that it would impact on suicide rates in some months but not in others (Maldonado & Kraus 1991, Maes et al. 1993a).

6.1.8.2. Limitations of the study

A limitation of the study was that the monthly suicide data were available only from the period of 1980-95. Although Näyhä (1982, 1983) has examined suicide seasonality over the period of 1961-76, he did not investigate it with regard to the method of a suicide. If, however, longer time series were available, changes of the incidence of a phenomenon might merely be related to changes in the diagnostic techniques or the reporting accuracy over the time course or some circumstance other than a true change of the incidence (MacMahon & Pugh 1970).

Another limitation was that the seasonal trend in suicides was explored on its own, but not in relation to some other phenomenon, which was found to increase the risk for a suicide. Previous studies have indicated that seasonal changes in psychosocial and sociocultural factors and social habits as well as seasonal changes in a human's biological processes may contribute to suicidal behaviour (Fossey & Shapiro 1992, Maes *et al.* 1994, Chew & McCleary 1995).

6.1.8.3. Statistical methods

In this study, the seasonal pattern of suicides was examined with the chi-square goodness-of-fit test for multinomials. That method has been found to be valid for assessing a goodness-of-fit of an observed distribution of events in relation to a hypothesised distribution (Agresti 1990). In addition, the ratio of observed to expected number of suicides and its 95% confidence intervals were calculated in order to display the time periods (months, seasons), which actually deviated significantly from the null hypothesis of the uniform distribution of events (Wonnacott & Wonnacott 1990). The adjustment for the calendar effect and the effect of leap years was performed, so that spurious results due to the unequal lengths of the months would have been avoided (Walter 1994).

After the graphical investigation of the data, the annual trend in suicides over time was analysed with a linear regression analysis. This is the most frequently used method for this kind of an analysis due to its convenient way to describe a linear relationship of a variable against time. If the data is not linearly dependent on time, other methods, such as non-linear regression analysis should be used. Since the time series of violent suicides changed direction in 1990 according to the present study, separate linear regression analyses were performed in relation to the period of 1980-90 and 1991-1995.

6.2. Homicide seasonality in Finland 1957-95

6.2.1. Seasonal variation of homicides

The seasonal variation of homicides was studied with the data covering all homicides (murders, manslaughters) which occurred in Finland during 1957-95. A statistically significant seasonality was found with a peak in summer and a trough in winter. Lester (1979) had earlier found significant excess of homicides in July and December based on a large US data-set. Goodman *et al.* (1989) noted a summer peak in homicides, although it was statistically non-significant. Other studies with rather small samples have failed to observe any clear seasonal pattern of homicides (Michael & Zumpe 1983, Abel *et al.* 1985, Abel *et al.* 1987, Maes *et al.* 1993a). There was also a significant correlation between homicides and violent suicides in Finland, but not between homicides and non-violent suicides. Maes *et al.* (1993a) could not show any significant correlation between homicides and violent or non-violent suicides.

A large proportion of the Finnish offenders is found to suffer from impulsive antisocial alcoholism (Tiihonen *et al.* 1993, Tiihonen & Hakola 1994, Eronen *et al.* 1996a). Increased impulsiveness and aggression have been shown to correlate with low levels of 5-HIAA in the CSF and platelet paroxetine binding (Brown *et al.* 1979, Linnoila *et al.* 1983, Virkkunen *et al.* 1994, Coccaro *et al.* 1996). Studies on plasma L-tryptophan levels have shown that the levels are highest in winter and lowest in spring (Maes *et al.* 1995, Maes *et al.* 1996). Peaks of platelet imipramine binding have been noticed in February and troughs in August (DeMet *et al.* 1989, DeMet *et al.* 1991). There are grounds to suspect that seasonality of dysfunctional central 5-HT neurotransmission is related to both internally and externally directed violent behaviour (Linnoila & Virkkunen 1992). Maes *et al.* (1995) found a significant inverse relationship in Belgium between the seasonal pattern in L-tryptophan levels obtained from healthy volunteers and the occurrence of violent suicides. It is suggested that the observed seasonal variation of homicides in Finland with a peak in summer and a trough in winter is at least in part associated with the circannual rhythm of serotonin transmission. On the other hand, high concentration of free testosterone in the CSF has been found to be associated with aggressiveness or interpersonal violence (Virkkunen *et al.* 1994), which might also contribute to the seasonal variation of homicides.

There are methodological differences between previous studies on homicide seasonality. Firstly, the absence of homicide seasonality may be the result of the small size of the data. A true seasonal variation in homicides might be so small that very large data gathered over long periods are needed to reveal the phenomenon (Tennenbaum & Fink 1994). Secondly, several studies have shown that latitude and climatic conditions may affect a human's mood or impulsive behaviour (Souetre *et al.* 1987, Rosen *et al.* 1990, Okawa *et al.* 1996). While Finland is located in the extreme north (geographical co-ordinates between 60^{o} and 70^{o}), it is probable that an effect of the seasons on violent offences might be more noticeable in Finland with its great variations between the seasons than in countries nearer the Equator.

6.2.2. Time trends in the rate of homicides

The deaths due to a homicide increased significantly over the 39-year study period of 1957-95, which is a finding that is in agreement with the global trend (Gottlieb *et al.* 1988, Gudjonsson & Petturson 1990, Milroy & Ranson 1997). In the United States, the overall rate of homicides increased significantly during 1985-91; nonfirearm-related homicide rates remained stable, but firearm-related homicides increased significantly. However, during 1992-94 the overall rate of homicides decreased significantly; nonfirearm-related homicide rates declined significantly and firearm-related homicide rates stabilised (MMWR 1996).

The time trend in homicide could not be studied in relation to the method of the homicide, because the data did not include information on that detail. It is a subject of further research to examine, whether the rate of firearm-related and non-firearm related homicides in Finland follow similar trends to those in the US data.

6.2.3. Time trends in homicide seasonality

The seasonal pattern of homicide in Finland did not change intrinsically during 1957-95, although the amplitude of the seasonal variation decreased significantly. In comparisons of different time periods, peak incidences occurred mainly during summer and troughs during winter.

It is likely that there are some additional factors, which may also be associated with time trends in homicide seasonality. These might be changes in alcohol consumption or presence of more extensive luminous environmental conditions over a time course. The decreasing trend in homicide seasonality might also be explained by the progressive socio-economic inequality due to economic depression and long-term unemployment in Finland during recent years, factors that may have been diluting previous seasonal effects.

6.2.4. Methodological concerns

6.2.4.1. Reliability of homicide data

The violent behaviours that society identifies as crimes are usually counted more completely and classified more accurately than those that are not violent (Reiss & Roth 1993). Thus, the statistics kept on homicides can be considered more reliable, for example, than those kept on assaults. In Finland the registers of homicides are reliable, because only a small number of homicides remains unsolved. For example, in the period of 1991-97 the clearance rate of homicide offences known to the police varied between 86-97% (Statistics Finland 1999b).

6.2.4.2. Limitations of the study

A limitation of the study was that the time series of homicides did not include information on the gender of the homicide offenders. In 1998 males accounted for about 90% of all homicide offenders (Statistics Finland 1999b). Thus, the results can be generalised only with regard to the male population of homicide offenders. Secondly, the age of the homicide offender was not available. Because both age and gender of homicide offender are known to be important characteristics linked with the risk of homicide offending (Reiss & Roth 1993), this information could produce a deeper understanding of the seasonal trends in homicides.

On the other hand, the annual homicide rates in Finland are relatively low. Despite the long 39-year time series of homicides used in the present study, if data were divided into smaller sub-groups, it would probably have decreased the power of statistical analyses.

6.3. Use of statistical techniques in studies of suicide seasonality

6.3.1. Frequency in the use of statistical tests

The use of statistical tests was revealed in the majority of the reviewed studies, which had examined the seasonal variations of suicides during 1970-97 in a national or regional population. This was different from Lester (1971) who was concerned that researchers frequently omitted to carry out statistical tests for seasonality. It is suggested that the results reflect the general trend in scientific research that statistical tests play an essential role when presenting and interpreting study findings.

A variety of statistical methods were used to assess the seasonal pattern of suicides. These tests ranged from simple standard methods such as a chi-square test to sophisticated time series analysis methods like a spectral analysis. The choice of a specific method was rarely presented in an article. When analysing the seasonal distribution of a time series, it is essential to choose a technique, which is sensitive to a specific type of seasonal or cyclical regularity in a time series (Tennenbaum & Fink 1994). Inappropriate and/or incorrectly applied statistical methods are likely to lead to spurious study findings (White 1979).

6.3.2. Statistical techniques in a single time series

The chi-square test was the most frequently applied method for detecting a seasonal pattern in a time series of suicides. The form of the chi-square test was usually the goodness-of-fit type, which tests whether an observed sample distribution of events follows the hypothesised distribution, like, for instance, a uniform distribution (Horn 1977, Siegel & Castellan 1988). Because different types of hypotheses can be tested with a chi-square test, the description of the null hypothesis should indicate precisely which of them was used in an article. Unfortunately, this was not found in or could not be deduced from all reviewed articles.

Analysis of variance techniques, such as Student's t-test, were also applied in seasonal analyses. The purpose of these methods, however, is only to test statistical significance of differences in mean values of a variable according to a grouping variable, but not to quantify the circannual rhythms (Maes *et al.* 1993a). Researchers, on the whole, did not present in their articles, whether the assumptions required by these kinds of parametric methods were fulfilled.

The results showed that there was an increasing tendency to use time series analyses techniques. The time series analyses are sophisticated and multivariate methods, which require, not only a long time series data-base, but also deeper statistical skills and experience from researchers, in order to be adequately applied (Chatfield 1996). The spectral analysis technique arose as one popular method during the 1990s, while earlier harmonic analyses were commonly used. While a harmonic analysis requires researchers to predetermine the frequencies of a cyclic variation, a spectral analysis method allows all frequencies to be analysed simultaneously (Bloomfield 1976, Chatfield 1996, Armitage &

Berry 1987). That is why, for example, Maes *et al.* (1993a, b) preferred a spectral analysis technique to a harmonic analysis.

Edwards' test (1961) for seasonality was used only in one suicide seasonality study, although it has widely been utilised in epidemiological research. The Edwards' test is preferred to the chi-square test, because it takes into account the ordered structure of the data (Walter 1977a, Rogerson 1996). Various modifications of the Edwards' test have been developed for several kinds of seasonal distribution, such as a bimodal distribution, and different types of data like varying base populations or unequal time intervals (Walter & Elwood 1975, Roger 1977). One explanation why the Edwards' test has not been applied widely in psychiatry may be due to the geometric basis of the test, which can be rather tedious to understand (Walter 1982). This agrees with what DeGroot and Mezzich (1985) have noted, namely that psychiatrists prefer to use simple significance tests and their associated ubiquitous p-values.

6.3.3. Seasonality in subgroups of a population

In about 70% of all reviewed articles, the seasonal pattern of suicides was compared between some subgroups of a population. The two most common grouping variables were the gender and the age of a suicide victim. An odd finding was that only one quarter of the articles examining subgroups had used some statistical test for significance. Usually, this test was either a chi-square test or a correlation analysis. Most of those articles, which ignored a statistical significance test, reported, however, that there was a difference in the seasonal patterns between some subgroups. In those cases, the conclusions were based either an interpretations of graphical presentations or comparisons of results obtained form seasonality analyses, which were performed separately in each subgroup of a variable. Sensible or acceptable reasons for leaving out statistical significance tests were or could not be presented.

6.3.4. Suicide seasonality related to seasonality in other phenomena

The seasonal distribution of suicides was most commonly related to the seasonal pattern of meteorological factors such as temperature and length of day. In the late 1800s Morselli already suggested that climatic changes might cause changes in psychosocial habits among people or changes in a human's biological processes, which may predispose a person to suicidal behaviour (Kevan 1980).

In some of the reviewed articles, the seasonal trend in suicides was related to that of deaths due to causes other than suicides, for example accidental deaths, undetermined deaths or homicides. The purposes of these kinds of studies were to find out whether two or more phenomena share some common aetiological factors or whether, for example, there are masked suicides among accidental or undetermined deaths.

The relationship between a seasonal pattern of two phenomena was commonly assessed with a Pearson or Spearman's correlation coefficient. These techniques, however, describe only the extent of an association, not that the relationship is one of cause and effect (Bowie & Prothero 1981, Armitage & Berry 1987). The better choice for a correlation analysis would have been a cross-correlation, which was used in one article only. It is a true time series technique, which investigates the relationship between two time series at the same time or with each series leading by one or more lags (Bowie & Prothero 1981).

6.3.5. Characteristics of the data

6.3.5.1. Size and length of a time series

The total number of suicides was missing or could not be deduced in one third of all reviewed articles. This is a rather peculiar finding, because the size of a sample is one of the basic statistics, which should always be reported in an article. It allows a reader not only to evaluate the appropriateness of the statistical methods used in the study but also to make reliable comparisons of the results of a study with previous studies.

The longer a time period, the greater the number of events in a time series. In statistical analyses against time, a long time series is usually needed so that random fluctuations could be easier to distinguish from systematic fluctuations (Tennebaum & Fink 1994). This was noticed in some suicide seasonality studies (Lester 1979, MacMahon 1983, Miccolo *et al.* 1989). On the other hand, when a sample is very large, extremely small p-values may be produced with only moderate effect sizes (Walter 1994). That is why MacMahon (1983) based the interpretation of her data (N=185887) on the graphical presentations rather than on statistical testing. Also Näyhä (1982) noted that because of a large sample (N=16312), significance tests were not necessarily needed, although they were useful in subgroup analyses of the data.

6.3.5.2. Time period for seasonality

About 80% of the reviewed articles used suicide data aggregated to monthly or quarter-yearly totals. When analysing the seasonal pattern of events by using monthly data, it is assumed that the data do not have a long-term trend. Freedman (1979) has presented three reasons for the custom of grouping data into months. Firstly, the exact dates are not known, for example, when the data is extracted from official publications. Secondly, the monthly totals offer a convenient summary of the data, for example graphical presentation demonstrating monthly totals of suicides. Thirdly, with regard to a large data-set it is tiresome to work with exact dates of events rather than monthly values. The latter problem is, however, not a major difficulty or problem any longer thanks to computerised databases and statistical analyses.

The monthly values of suicides were usually reported as frequencies. In some studies, they were roughly estimable from graphical presentations. The monthly values of events should always be reported in an article, because it would enable comparisons with previous studies or with a reader's own data. For example, if he/she prefers or is familiar with a particular statistical technique for seasonality, which has not been used in an article, the results could be recalculated with that method provided the monthly totals were presented in the article.

Occasionally, a criticism has been presented against the custom to aggregate the monthly totals to seasonal ones, which was found in 10 articles in our study. When analyses are restricted to 3-month periods, the true seasonal distribution may not be revealed. For example, a peak for one month of two consecutive months in different seasons may not reach statistical significance, if analysed as a part of a season (Torrey *et al.* 1997). There is also no consensus about the definition for seasons. Some researchers have included the months from January to March in the winter season, while others counted the winter months from December to February. Whatever the definition for seasons is, it should always be presented in an article so that reliable comparisons can be made with previous studies. On the other hand, it has been recommended that instead of arbitrarily chosen cut-off points for seasons, investigators should use seasons defined by naturally occurring changes in the photoperiod, i.e. by solstices and equinoxes (Pio-Abreau 1997).

6.3.5.3. Calendar effects

The adjustment of calendar effects (i.e. the effect due to the unequal number of days in a month) was reported to being taken into account in only 10 articles. An ignorance of calendar effects was found to be a shortcoming of several reviewed studies, because it has been shown that the variation due to the unequal lengths of a month may produce spurious significant results in seasonality analyses (Cleveland & Devlin 1980, Walter 1994).

6.3.5.4. Graphical presentations

At least one graph was drawn in over half of the reviewed articles. A visual inspection of the data should be routinely carried out in every research, and especially in analyses of time series data. A plot against time is a useful way in describing the data and in helping to formulate a sensible model. It shows up important features of a time series such as a trend, seasonal variation, outliers and discontinuities (Chatfield 1996).

6.3.5.5. Statistical software

The name of the statistical software was reported in only 5 articles. It should always be clearly stated, because even the popular statistical packages include known errors and subtle pitfalls (Dallal 1988, McGuigan 1995). Furthermore, the name of the statistical software is necessary, if a researcher wants to repeat the statistical analysis of her/his own data exactly in the same manner as was done in an article.

6.3.6. Methodological concerns

6.3.6.1. Sampling of reviewed articles

The number of the reviewed articles was rather small compared with all the medical articles, which can be found through database searches with keywords “suicide” and “season” or which were listed in earlier review articles (Kevan 1980, Massing & Angermeyer 1985). On the other hand, due to the stringent inclusion criteria, the collection of articles formed a homogeneous sample. Thus, the results of the present study can be considered as valid in describing the statistical techniques and the characteristics of data used in suicide seasonality studies in psychiatry. It is likely that the most relevant articles were identified.

6.3.6.2. Limitations of the study

As one limitation of the present study it can be stated that the suicide seasonality studies were not reviewed for statistical errors per se. On the other hand, there exists a lack of consensus as to what should be considered a statistical error in a study (Altman 1991, McGuigan 1995). Whether an article does or does not include the presentation of the crucial information on the data, the experimental design and the statistical methods, is a matter of opinion of the person, who evaluates the quality of a study from his/her own subjective viewpoint. Sham (in: Hand & Sham 1995) has stated that “to say that a paper contains a statistical error is like saying that someone suffers form a mental illness“.

7. Summary and conclusions

7.1. Seasonal variation of suicides in Finland during 1980-95

All completed suicides in Finland during 1980-95 were investigated in terms of their seasonal distribution. The time trends in the rates and the seasonality of violent and non-violent suicides were also examined.

The time series for suicides were obtained from official statistics of the Finnish, Statistics Centre. They included the monthly numbers of suicides according to the year of death, gender and age group of a suicide victim, as well as the method of a suicide. In further analyses, suicides by hanging, drowning, shooting, wrist cutting or jumping from a height were defined as violent and others as non-violent suicides.

A total of 21279 suicides were completed during the 16-year study period. Male suicides covered 79% of the total suicide rates. The distribution of suicides between age groups (<=39 years, 40-64, >=65 years) was 44%, 42% and 14%, respectively. Violent suicides accounted for 70% of all suicides.

The observed seasonal distribution of the suicides differed statistically significantly from the expected distribution of suicides under the null hypothesis that the occurrence of suicides follows a uniform distribution after adjusting for calendar effect and leap years. A significant excess of total suicides was found during spring/summer (May-July) and a significant trough during winter/spring (December-March) months.

The seasonal pattern of suicides differed significantly between genders. The seasonal distribution of males was unimodal with a peak in spring/summer (May-July) and a trough in winter/spring (December-March). Female suicides have a significant peak in spring (May) and autumn (October), and a trough in winter (December-February). In all age groups, the incidence of suicides was significantly elevated during spring/summer (May-July) and significantly depressed during winter/spring (November-March). In the oldest age groups, there was also a trend toward a secondary peak of suicides in autumn (August-September). The peak incidence for violent suicides was during spring/summer (May-July), while the troughs fell in the winter/spring (December-March). In non-violent suicides, significant excesses of suicides were present in both spring (May) and autumn (October), but no significant trough periods were observed.

The rate of violent suicides per 100 000 mean population increased significantly during the 1980-1990 period, but decreased significantly thereafter. Regarding violent suicides, overall seasonality existed in every successive time period (1980-84, 1985-90, 1991-95) with a peak in spring/summer and a trough in winter. The rate of non-violent suicides increased significantly over the whole study period. The only period, which showed a significant overall seasonality in relation to non-violent suicides, was the period of 1980-84 with a spring peak and a winter trough. However, also in 1985-89 there was a significant winter trough in non-violent suicides.

The fact that the suicide mortality in Finland is one of the highest in the world means that every study, which might be of help in reducing the incidence of suicides, is justified. To investigate the seasonal distribution of suicides is one way to find explanations for this major public health problem. Based on the results of the present study and on the fact that climatic conditions in Finland vary largely between seasons, it was concluded that the observed seasonal distribution of suicides in Finland is connected at least in part with the seasonal changes in the climatic conditions, such as changes in the amount of light and temperature. However, seasonal changes in the psychosocial habits of people and a human's biological processes are also likely to contribute to the seasonal distributions of suicides. The seasonal distribution of suicides was dependent on gender and age group of a suicide victim, as well as the method of the suicide. Additional studies taking into account also the effect of possible psychological, sociological or biological factors are necessary to identify their putative influences on the seasonal variations of suicides.

7.2. Seasonal variation of homicides in Finland during 1957-95

All homicides (murder, manslaughter) in Finland during 1957-95 were examined in order to clarify whether the occurrence of homicides has a seasonal distribution. In addition, time trends regarding the rates and the seasonality of the homicides were investigated.

The data were obtained from official statistics of the Finnish Statistics Centre, and included the monthly frequencies of murders and manslaughters according to the year of occurrence. A total of 4553 homicides were committed over the 39-year study period. The median number of homicides was 113 per year (range 44-171). The annual monthly means of the homicides varied between 8-11.

The results showed that there was a statistically significant seasonal distribution of homicides in Finland. The observed rate of homicides was about 6% higher in summer and 6% lower in winter than expected under the null hypothesis of a uniform distribution after adjusting for calendar effect and leap years. The excess of homicides occurred in August and the rate was lowest in January. The monthly ratios of homicides were associated significantly (positive correlation) with the monthly ratios of violent suicides but not with the monthly ratios of non-violent suicides.

The crude number of homicides increased by about 58% during the period 1957-95. The annual mean increase was 1.7 homicides. The rate of homicides per 100 000 mean population increased by about 33% over this study period. The seasonal variation of homicides, however, declined significantly, when the overall seasonality and peak-to-trough differences were analysed over successive time periods (1957-59, 1960-64, 1965-69, 1970-74, 1975-79, 1980-1984, 1985-1990, 1991-96).

Due to its northern location, seasonal changes in climatic conditions in Finland are large. If seasons have an effect on the incidence of events, it should be more apparent in countries nearer the poles than the Equator. Several biochemical variables, such as serotonin markers, have been shown to exhibit marked seasonal variations. These variables have been found to be associated with impulsive and aggressive behaviour. Therefore, it is suggested that seasonal variation of homicides may be linked with the observed circannual rhythms of serotonin transmission, as well as dopamine and testosterone levels. This should be clarified in further research.

7.3. Use of statistical techniques in studies of suicide seasonality

The use of statistical techniques for seasonality as well as some other important characteristics of the data was investigated from articles primarily examining the seasonal variation of suicides. The articles, which were located through database searches, had to fulfil the following inclusion criteria: (a) suicide seasonality was one aim of the study, (b) article was published during 1970-97 in a major psychiatric journals, (c) suicide data covered a national or regional population, and (d) the article was written in the English language.

A total of 44 articles from 15 different journal were reviewed. Three journals contained 53% of all articles: the British Journal of Psychiatry (9 articles), Acta Psychiatrica Scandinavica (8 articles) and the Journal of Affective Disorders (6 articles). The number of authors per article varied from 1 to 6 and 33 different names of the first author were discerned.

About half of the reviewed articles used data from European countries. Only two studies came from the Southern Hemisphere. National suicide data were used in 73% of the publications. The lengths of the time series for suicides varied from 1 to 59 years. The total number of suicides was given in 71% of articles. In these articles, the number of suicides ranged from 31 to 26918 per year.

The monthly variation of suicides was studied in 32 articles and the quarter-yearly variation in 10 articles. In addition, the time periods defined by days of a week, lunar phases, and national holidays were frequently used. The monthly values of suicides were reported in 9 articles as frequencies and in 7 articles with units such as monthly mean values or percentage deviation from chance expected values. The monthly values were estimable roughly from graphical presentations in 9 articles. Only 10 articles reported that the suicide rates were adjusted for the calendar effect before statistical analyses were undertaken.

The reviewed studies examined the seasonal distribution of the suicides themselves, compared seasonal patterns between subgroups of a population or related the seasonal suicide patterns to seasonality of a phenomenon other than suicides. Although the use of statistical significance tests was found in most of these articles, their frequency of utilisation varied depending on the type of study that was carried out.

When the purpose of the study was to investigate purely the seasonal distribution of the suicides themselves, a statistical significance test was used in the majority of these articles. The most frequently used of these tests was the chi-square one. Other popular methods were the analysis of variance tests or harmonic and spectral analyses. No substantial change in the use of the statistical tests occurred during the study period, except regarding spectral analyses, which began to be more widely applied in the 1990s.

Subgroup differences in the seasonal pattern of suicides were considered in 30 studies. The most common subgroup variables were the gender and the age group of a suicide victim. Subgroup differences were assessed with some statistical test in only 7 articles. The test was most commonly the chi-square test or a correlation analysis. The rest of the articles based their conclusions concerning subgroup differences either on graphical presentations or seasonal analyses, which were made separately in each category of a grouping variable.

The seasonal pattern of suicides was related to the seasonal pattern of a phenomenon other than suicides in 19 studies. Most often the seasonal trends in suicides were compared with the seasonality of meteorological factors or deaths due to causes other than suicides. A statistical significance test was used in 13 articles. Most frequently researchers were utilising the chi-square test or a correlation analysis. In 6 articles the interpretation of the findings was based on graphs or the seasonality analyses, which were made separately for each time series to which the suicide seasonality was related.

The adequate description of statistical techniques (mathematical formulae, brief presentation of the method, statistical references or appendix) was found in 20 articles. In 17 articles, such standard and well-known methods were used that the name of the test was considered to be satisfactorily provided for and the exact name of the test as well as that of relevant statistics were clearly apparent from the text. A total of 25 articles contained at least one drawn graphical presentation. The name of the statistical software was reported in only 11% of the articles.

Based on the results of this study it is suggested that statistical and methodological approaches must be standardised in suicide seasonality studies so that comparisons between different studies are possible and, moreover, useful. Furthermore, the total number of suicides must always be given and definitions, for example, the timeframe “winter” or “month” (not all have the same number of days) should be clearly stated. Enough details on the types of statistical techniques used in a study and an explanation why the latter was chosen should be provided.

A review study like the present one, which examined the statistical and methodological issues of published articles, is one way to increase the awareness among researchers on how important it is to pay attention to the statistical quality of a study. When the basic elements, such as the study design, characteristics of the data, and statistical methods, are clearly and unambiguously presented in an article, a study gets the attention that it deserves. Thus, it is very important to continue studying and addressing the statistical and methodological issues, even if they focus on only a limited aspect of a scientific problem as has happened, for instance, in this study.

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