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Epidemiological evaluation of the Nordic health registers for dairy cows – data transfer, validation and human influence on disease recordings

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ACADEMIC DISSERTATION

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In memory of Carlo Magi

Abstract

In Denmark, Finland, Norway and Sweden the National Dairy Disease Registers (NDDRs) collect and store disease information at the individual cow level. Because these registers are monitored nationally they offer access to data that cover most of the dairy population in each country. Data from these registers are used, for example, to carry out herd health assessments, production management, genetic evaluations and epidemiologic research. Register data, also known as secondary data, can suffer from quality issues since they are not usually designed for research purposes. Understanding the recording process, magnitude of data loss during data transfer and human influence on disease diagnosis is important. The knowledge will enhance reliability of frequency measure calculations from the register data and improve the quality of the registers.

This thesis investigated the quality (measured as completeness and correctness) of the Finnish NDDR and compared register qualities among the four Nordic countries. In Finland the quality of recorded information was excellent, but approximately 17% of disease information was lost during the data transfer steps. A large proportion of the data loss was due to artificial insemination (AI) technicians not transferring events. The majority of those events occurred close to culling of the cow, suggesting early removal of the cow health and insemination card from the barn binder after the culling. Therefore, the AI technician could not transfer the disease events from the cow card to the register, resulting in systematic errors. Diagnostic events on purchased cows also had lower chance of being found in the Finnish NDDR compared with those for cows born in the herd. All in all the quality of the register was good but it needs improving in order to reduce the data loss reported in this thesis. An efficient way to improve completeness in the Finnish NDDR is to have veterinarians electronically transfer diagnostic information during farm visits. The benefits of electronic data collection compared with cow cards are: faster data transfer, fewer transcription errors and reduced data loss due to lost or removed cow cards. The use of electronic data collection is likely to provide more accurate data that is more quickly available. The Finnish system has already been modified accordingly.

This thesis also showed how register quality for four reproductive disorders (metritis, retained placenta, assisted calving and oestrous disturbances) varied among the four Nordic countries. Metritis and oestrous disturbance events were well represented in the NDDRs. Farmer-observed completeness (the proportion of all farmer observations that were recorded in the NDDR) was around 0.80 and did not differ significantly among the countries. Assisted calving and retained placenta events showed more among-country variation. Farmer-observed completeness was highest in Denmark and lowest in Finland, ranging between 0.31 and 0.89. Completeness figures were also used to adjust lactation incidence risks for the reproductive disorders. The comparison of completeness-adjusted incidences to incidences calculated from the registers showed that incidences were underestimated for assisted calving and retained placenta. Underestimation was highest in Finland.

This thesis also demonstrated how both farmer and veterinary intentions toward veterinary treatment of mild clinical mastitis could explain the reasons for

different mastitis incidence rates among the countries. The results suggest that when intentions towards veterinary treatment were greater, mild cases received veterinary treatment more often than when intentions towards treatment were reduced. Greater farmer and veterinarian intentions can therefore increase the incidence of the disease in the NDDR.

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Original articles

This thesis is based on the following articles, which are referred to in the text by their Roman numerals:

- I** Rintakoski, S., Taponen, J., Peltoniemi, O.A.T. and Virtala A-M.K. 2012. Validation of the Finnish National Dairy Disease Register—Data transfer from cow health cards to the disease register. *Journal of Dairy Science*. 95: 4309–4318.
- II** Rintakoski, S., Wolff, C., Espetvedt M.N., Lind A-K., Kyyrö, J., Taponen, J. Peltoniemi, O.A.T. and Virtala A-M.K. 2013. Comparison of disease data and incidence risks between Denmark, Finland, Norway and Sweden regarding reproductive disorders of dairy cows. *Submitted manuscript*.
- III** Espetvedt, M.N., Wolff, C., Lind A-K., Rintakoski, S., Virtala A-M.K. and Lindberg, A. 2013. Nordic dairy farmers’ threshold for contacting a veterinarian and consequences for disease recording: Mild clinical mastitis as an example. *Preventive Veterinary Medicine*. 18: 114-124.
- IV** Espetvedt*, M.N., Rintakoski*, S., Wolff, C., Lind, A-K., Lindberg, A. and Virtala A.-M.K. 2013. Nordic veterinarians’ threshold for medical treatment of dairy cows, influence on disease recording and medicine use: Mild clinical mastitis as an example. *Preventive Veterinary Medicine* 112:76-89.

* Chapter IV has shared first authorship between Espetvedt, M.N. and Rintakoski, S.

Contributions

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Abbreviations

AI	artificial insemination
ADPC	Agricultural Data Processing Centre Ltd.
ATT	attitude towards behaviour; one of three TPB model constructs to measure behaviour
CHC	cow health card
DCD	Danish Cattle Database
FOC	farmer-observed completeness
LIR	lactation incidence risk
MCM	mild clinical mastitis
MRS	milk recording scheme
Naseva	Finnish National Dairy Health System
NCR	National Cow Register
NDDR	National Dairy Disease Register
PBC	perceived behavioural control; one of three TPB model constructs to measure behaviour
SBA	Swedish Board of Agriculture
SDA	Swedish Dairy Association
SN	subjective norm; one of three TPB model constructs to measure behaviour
TPB	Theory of Planned Behaviour
VTC	veterinarian-treated completeness

1 Introduction

Understanding how to prevent and reduce diseases of production animals and to enhance the welfare of livestock is an integral part of veterinary epidemiology. Monitoring disease events and frequency of treatment and production parameters, such as inter-calving interval, milk yield and somatic cell count levels, are essential components of improving livestock productivity. Monitoring is implemented in the Nordic countries using national registers that contain data on individual animals from farm records. Data are used for health monitoring in addition to epidemiological research (Rajala-Schultz et al., 2000; Valde et al., 2004; Maizon et al., 2004) and such registers are termed secondary databases (Sørensen et al., 1996). While secondary databases represent an effective way to collect data, the need for quality control and validation has long been recognized (Olsson et al., 2001; Østerås et al., 2003).

2 Review of literature

2.1 Secondary databases

The use of secondary data in different areas of research has become increasingly important. Just to give an impression of how the use of secondary data has changed over the years, Vartanian (2011) randomly selected articles published in 1980 and compared them with articles published in 2007. The proportion of studies that used registers as a source of data in 1980 was 19% and in 2007 it was 82%. Part of the increased use of secondary data is no doubt because

of improved recording systems and easier access to the data, but there are also distinct advantages over primary data collection efforts (Stewart and Kamins, 1999). The use of secondary data is much less expensive than to conduct research with primary data. This is generally true even when costs are associated with obtaining the secondary data. Secondary data can also provide a useful starting point for research by suggesting research hypotheses and methods. While clinical research is used to demonstrate specific benefits under a controlled environment, research using secondary health data aims to show if and how treatment practice could be improved (Huston and Naylor, 1996).

2.1.1 Databases in medical research

Secondary data in the form of health statistics are widely used in medical research worldwide (Best, 1999). Health statistics are population-based and collected over long periods of time to develop health indicators for a community. The community can be a country, a region, a county or a city according to the research interest. Many countries keep population-based medical registers that are nationally monitored and offer resources for epidemiological research. Such registers include the Medical Birth Register (National Institute for Health and Welfare, 2013a), the Finnish Cancer Registry (Carpelan-Holmström et al., 2005) and the Cardiovascular Disease Register (National Institute for Health and Welfare, 2013b) in Finland, the National Hospital Register in Denmark (Andersen et al., 1999) and the Wide-ranging Online Data for Epidemiologic Research Register (Wide-ranging Online Data

for Epidemiologic Research (WONDER), 2013; Friede et al., 1993) in the United States. The number of epidemiological studies using population-based health registers is considerable. Long-term trends in coronary heart diseases have been studied in Finland (Salomaa, 2003; Pajunen et al., 2004). Siegel et al. (2012) analysed trends in colorectal cancer incidence in the United States using multiple cancer registers and Waldenström et al. (2012) used Medical Birth Registers to investigate rates of caesarean delivery in Sweden and Norway.

In Europe there is also the official Eurostat statistical service (Eurostat, 2013), which provides financial and public health data from European countries. The main aim of Eurostat is to promote the harmonization of statistical methods across EU member states (Sverdrup, 2005). Eurostat also provides production parameter information on dairy cows in various countries, but health information is not available in Eurostat.

2.1.2 Databases in veterinary research

The use of secondary databases is becoming more popular in veterinary epidemiology (Houe et al., 2011) and databases have been used for numerous studies, although the numbers of databases are still far fewer than those available for medical research. For dairy cattle most developed countries have national milk recording schemes (ICAR, 2013), but do not collect disease information at the national level. Routine disease records for production animals, which have national coverage, are still rare and mainly exist in the Nordic countries

(Olsson et al., 2001). As an alternative for routine disease recording, the National Animal Health Monitoring System (NAHMS) in the United States collects data through surveys for different livestock species. Some regional recording systems have been established for research purposes, e.g. for Holsteins in New York State (Gröhn et al., 1995) and the dairy herd health database in Michigan (Bartlett et al., 1986).

For small animals and horses secondary data from veterinary hospitals and insurance companies have been used for research purposes. In Sweden, age patterns for diseases of dogs, cats and horses (Bonnett and Egenvall, 2010), mortality of insured dogs (Bonnett et al., 2005; Egenvall et al., 2000) and breed risks of pyometra in dogs (Egenvall et al., 2001) have been studied using insurance data. In North America, the Veterinary Medical Database collects practice information from various veterinary medical colleges and has been used to study cardiac tumours in dogs (Ware and Hopper, 1999), prevalence and risk factors for hip dysplasia in dogs (Witsberger et al., 2008) and time trends and risk factors for diabetes mellitus in cats (Prahl et al., 2007). A new and interesting disease database for small animals is the Disease WatchDog that was first launched in Australia and is now operating also in New Zealand (Disease WatchDog, 2013). Disease WatchDog is a national monitoring system designed for monitoring infectious diseases in real time, using geospatial mapping to illustrate disease occurrence at the sub-urban level (e.g. canine parvovirus outbreaks) (Ward and Kelman, 2011).

2.2 Data validation

The use of secondary data has its merits, but it also has disadvantages for research use. One of the greatest disadvantages is that the quality of the data is often unknown. For primary data the quality control is in the hands of a researcher, but for secondary data, its collection is often independent of the researcher (Sørensen et al., 1996). Lack of controlled data collection methods for secondary data means that the quality of the data needs validating if the data are to be used for research (Hogan and Wagner, 1997). The need for validation is addressed in the literature (Sørensen et al., 1996), but a statement of whether or not validation was actually performed is often not found in research papers, including that for secondary data (Hogan and Wagner, 1997). Validation is time consuming and expensive and probably often ignored.

Data validation is carried out 1) to define data quality and 2) to determine if data are fit for specific research use and 3) to outline the type of research the data can be used for (Arts et al., 2002). Different methods are used to validate databases. Egenvall et al. (1998) used data agreement on insurance registers for dogs and cats, and Pollari et al. (1996) studied

discrepancies between summary sheets and computerized recordings of veterinary hospital data for small animals. Penell et al. (2007) used sensitivity and specificity for an equine register and Jansson et al. (2005) used a capture-recapture method to assess the validity of the Swedish statutory surveillance system for communicable diseases.

In the field of medicine most of the data are validated using sensitivity, specificity as well as positive and negative predictive values (Pajunen et al., 2005; Stapelfeldt et al., 2012; Mähönen et al., 2013). Presenting completeness and correctness values, first described by Hogan and Wagner (1997), is a commonly used method for data validation for registers. It is also used in this thesis. Completeness is a proportion of events that are actually recorded in the database. Correctness is the proportion of recorded events that are correct (Table 1). Although completeness, in principle, is equal to sensitivity, and correctness to positive predictive value, there often is no true gold standard in data validation. There are situations in which it can be unclear which of the two recordings is correct when data are validated. For this reason differences in terminology exist. It is also important not to confuse sensitivity in data validation with sensitivity in diagnostic testing.

Some degree of data loss is almost

Table 1. *Completeness and correctness are used to assess the proportion of the total health records in the secondary database and the validity of the information.*

		True health status from cow card		
		Diseased	Healthy	Total
National disease register	Record present	a	b	a + b
	Record absent	c	d ¹	c + d
	Total	a + c	b + d	a + b + c + d
		Completeness = $a/(a+c)$		Correctness = $a/(a+b)$

¹ = Cell d would be truly healthy animals but because of diagnostic events it is not possible to determine how many times each individual had actually been healthy

always characteristic of secondary data, which indicates that data collection is not perfect. To be able to exploit secondary data fully and to improve their quality it is important to know the reasons for data loss. Data loss is caused by errors that can be systematic or random (Dohoo et al., 2009). Systematic errors include programming errors, unclear definitions for data items, or violation of the data transfer protocol (Arts et al., 2002). Both systematic errors and random errors have negative effect on data quality (Scheiner and Gurevitch, 2001).

The National Dairy Disease Registers (NDDRs) have long been operative in Denmark, Finland, Norway and Sweden and contain substantial amounts of disease data. Over the years data from the NDDRs have been used to study, *inter alia*, mastitis (Bartlett et al., 2001; Schneider et al., 2007), metritis (Emanuelson and Oltenacu, 1998; Bruun et al., 2002; Østerås et al., 2007), reproductive performance (Oltenacu et al., 1998; Gröhn and Rajala-Schultz, 2000; Maizon et al., 2004) and genetic evaluation (Holmbeg and Andersson-Eklund, 2004). Only in recent years has interest been taken in quality of the data (Gulliksen et al., 2009; Mörk et al., 2010; Espetvedt et al., 2013; Wolff et al., 2012; Lind et al., 2012a)

2.3 Dairy herds in the Nordic countries

As production efficiency is expected to increase, the structure of dairy herds has continued to change in all the Nordic countries. A small number of cows in tie stalls managed by one family are no longer economically profitable. Modern herds are of larger average size and are kept in loose

housing with adequate staff to manage them. The farming structure differs in Denmark, Finland, Norway and Sweden. Denmark has the lowest number of herds but the largest average herd size (Danish Agriculture and Food Council, 2012) (Table 2). Finland and Norway have smaller average herd sizes but many more herds compared with Denmark (TINE Rådgiving, 2012; Pro-Agria, 2012). Sweden has second largest average herd size but about only half of the herds than in Norway and Finland (Swedish Dairy Association, 2012). Geographic, and especially topographic, differences account partly for differences in farm structures. Denmark is relatively flat and as the most southern country is able to use a larger proportion of the land for farming, whereas a colder climate and mountains restrict land use for farming in Norway.

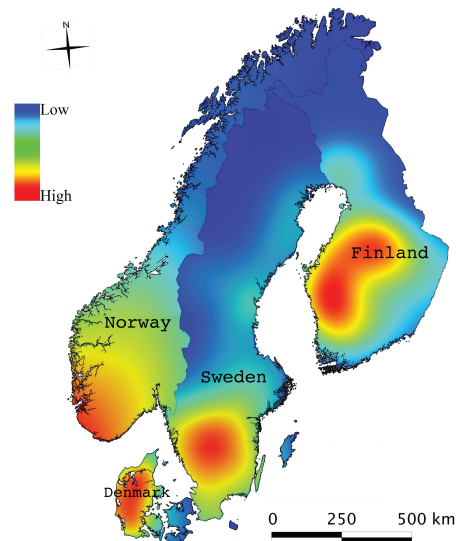


Figure 1. Dairy herds densities based on random sampling of 1000, 900, 800 and 400 herds in Denmark, Finland, Norway and Sweden, respectively

Figure 1 illustrates the dairy dense areas in the Nordic countries calculated from randomly sampled herds.

Table 2. Herd statistics and annual milk production (thousand tonnes) in the four Nordic countries (Eurostats, 2010).

Country	Herds ¹	Size ²	Milk ^{3,a}
Denmark	3,794 ^b	142 ^b	4,818
Finland	10,171 ^c	28 ^c	2,289
Norway	10,350 ^d	23 ^d	1,526 ^f
Sweden	4,900 ^e	70 ^e	2,860

¹= Number of herds

² = Average herd size

³ = Total annual milk production

^a = Eurostats, 2010

^b = Danish Agriculture and Food Council, 2012

^c = Pro-Agria, 2012

^d = Tine Rådgiving, 2012

^e = Swedish Dairy Association, 2012

^f = Statistics from 2003

2.4 Finnish National Milk Recording Scheme

In Finland there are three registers that collect information related to dairy production in the country; the National Cow Register (NCR), the National Milk-Recording Scheme (MRS) and the new National Dairy Health System (Naseva). Health monitoring in a nationwide MRS was initiated in 1982 in Finland (Gröhn et al., 1986). Participation has always been, and still is, voluntary for milk producers. The MRS keeps records of different production parameters such as test milk results and inseminations. The National Dairy Disease Register is part of the MRS. The National Cow Register keeps registers on cow identification, the herd they belong to as well as cow birth, transfer and removal data. The register is managed by the Finnish Food and Safety Authority (Evira) and is thereby state regulated. Participation in the NCR is

mandatory for all milk producers. The Naseva cow disease register is a new electronic system that is to gradually replace the old NDDR in the MRS. Naseva is administered by the Association for Animal Disease Prevention (ETT), which is supported by the food industry and producers. The technical developer and maintainer of all the three databases is the Agricultural Data Processing Centre Ltd. (ADPC). In 2010, 223,346 cows (80% of all dairy cows) were part of the MRS in Finland (Nokka, 2011).

2.5 Dairy health surveillance in Finland

The data transfer route from herds to the NDDR is as follows; each individual animal has a health and insemination card, which is termed a 'cow card'. Each heifer is registered with an official cow card from the ADPC at approximately one year of age. It is imprinted with EU identification, herd identification and ear tag number. Before issue of the official cow card, all health information is collected on a temporary recording sheet. The cow card has all the insemination and disease history of the cow from birth to death. Cow cards are held on the farm and veterinarians and artificial insemination (AI) technicians record health and insemination information, respectively, on the cards. By law it is mandatory to keep records of all treatments given to the cows for a minimum of three years (Ministry of Agriculture and Forestry, 2000); in practice the cow cards serve as medication records. Most commonly disease information is transferred into the NDDR database by AI technicians during their routine farm visits. Producers have computer

software (WinAmmu) that they can use for disease information transfer. However, the proportions transferred by AI technicians and producers in 2008 were about 90% and 10%, respectively (Simpanen M., personal communication, ADPC, 2012). The benefit for producers to participate is that they receive a summary report of treatments (treatment amount / total number of cows) and a summary report that has treatments for the most common diseases. Not all herds are included in the health surveillance system. From all dairy cows that had test milk recordings in the MRS register, approximately 90% were part of the health surveillance.

For hoof trimmer treatments (non-medical) the route to the register is different. When a hoof trimmer visits a farm he/she writes a report on all treated animals and the producer or the herd health advisor transfers this information to the NDDR register.

2.6 New Naseva health surveillance system

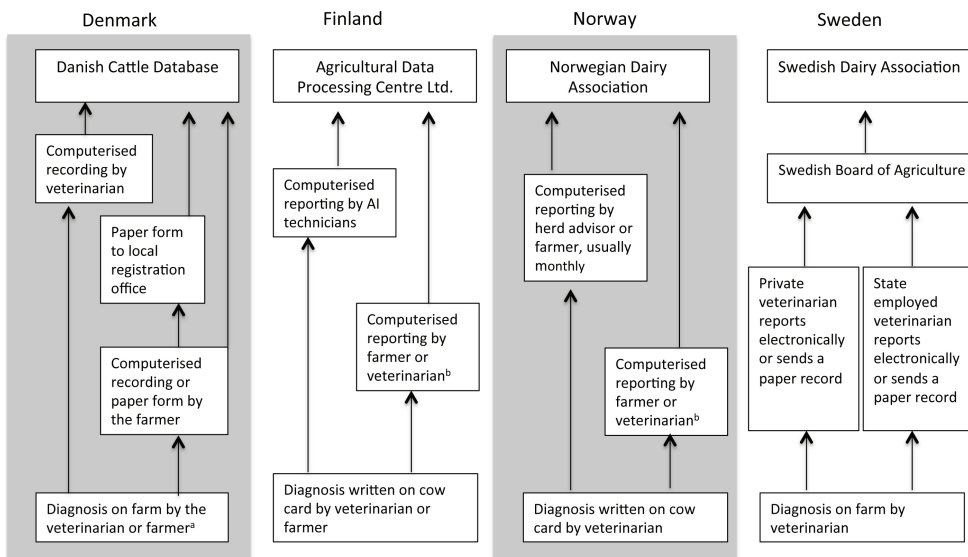
Up until 2006 all dairy cow disease data were recorded in the NDDR register. In 2006 a new electronic disease recording system (Naseva) was launched (Kortesniemi and Halkosaari, 2010). Naseva is an important part of the new development for disease recording system in Finland. Currently Naseva and the NDDR work in tandem, but Naseva is being increasingly implemented in Finland and the old cow card system will eventually become obsolete. The largest difference between Naseva and the cow card system is that a veterinarian rather than an AI technician transfers the treatment information (electronically) while on the farm. Disease data from Naseva could not

be validated in the work for this thesis because it was not sufficiently established in 2008, when most of the data for this thesis were collected. The new system will, however, need quality assessment in the future.

2.7 Health surveillance in other Nordic countries

In the Nordic countries disease recording first started in 1975 in Norway (Østerås et al., 2007). In Sweden recording started in 1982, the same year as in Finland, and the country had nationwide coverage in 1984 (Emanuelson, 1988; Olsson et al., 2001). Disease recording also started in the 1980s in Denmark and reached nationwide coverage in 1991 (Bartlett et al., 2001). Of all the Nordic countries, Iceland is the only one without a NDDR database. The National Dairy Disease Register is integral in the national milk recording schemes in Norway, Sweden and Denmark, which makes the nationwide coverage comprehensive for disease recording. Approximately 90%, 97% and 80% of the herds are included in disease recording in Denmark, Norway and Sweden, respectively.

Keeping records of treatments of cows is compulsory in each country, but the enforcement measures differ (Figure 2). Norway uses cow health cards (CHC), similarly to Finland, and it is the animal owners' responsibility to ensure that all disease events and treatments are recorded on CHC on the farms (Norwegian Ministry of Agriculture and Food). Disease information is then transferred from CHCs to the NDDR database either by the farmer or by the herd health advisor. The Norwegian Dairy Association



^a Farmers with herd health contract are able to use medication without veterinarian

^b New digital recording system where veterinarian is responsible for the data transfer; introduced in 2008 in both Finland (Naseva) and Norway (VETIN).

Figure 2. Data flow from farm level to the national dairy disease registers in the four Nordic countries.

maintains the national MRS register, including the NDDR. From 2008 Norway launched a new digital data collection system called VETIN. It is similar to Finland's Naseva, in which veterinarians report disease events electronically to the NDDR.

In Sweden both the disease recording and the disease transfer to the Swedish Board of Agriculture (SBA) are compulsory for a veterinarian. The database maintained by the SBA can be seen as "raw" disease data. The disease data from the SBA are transferred to the NDDR only for the herds that participate in the MRS. The NDDR is managed by the Swedish Dairy Association (SDA). Data from the NDDR are then used for herd evaluations and research.

The Danish Cattle Database (DCD) maintains the NDDR in Denmark. The disease recording and transfer use two different systems due to herd

health contracts. The herd health contract is an arrangement in which a producer is allowed to treat animals without a veterinarian's involvement, but the arrangement requires a weekly veterinary inspection on the farm. For herds that are not in the herd health contract, a veterinarian is called for a visit to treat the animal. The producer is responsible for reporting the diagnostic code and the treatment given. They can either transfer the information themselves or pay a veterinarian to do the transfer to the DCD.

2.8 Diagnostic coding in the Nordic countries

Each of the four countries has their own diagnostic coding systems that vary quite extensively among countries. All of the countries use numerical codes for disease definitions in the NDDRs.

Table 3. List of country-specific disease codes for four reproductive disorders in Denmark, Finland, Norway and Sweden.

Retained placenta	
Denmark	4 Retained placenta
Finland	091 Retained placenta, 640 Retained placenta
Norway	326 Retained placenta
Sweden	2186 Retained placenta, 2187 Retained placenta
Assisted calving	
Denmark	112 Assisted calving, 92 Caesarean, 91 Uterine torsion
Finland	070 Dystocia, 071 Foetal oversize/narrow pelvis, 072 Malpresentation, 073 Twins, 074 Abnormal foetus, 075 Uterine torsion
Norway	323 Dystocia, 321 Uterine torsion, 324 Malformations
Sweden	10540 Caesarean, 2157 Uterus torsion, 9799 Uterine torsion, 2169 / 9805 Dystocia, 2170 Dystocia (weak labour, primary), 2171 Dystocia (weak labour, secondary), 9809 Dystocia weak labour, 10539 Induction of partus, 2181 Dystocia (large foetus), 2182 Dystocia (narrow birth canal), 2172 / 9806 Dystocia (malpresentation of the foetus), 2173 Dystocia (foetus's head flexed to the side), 2174 Dystocia (foetus with front limb flexed back), 2179 Dystocia (foetus presented with posterior first), 9807 Dystocia, foetus dog sitting, 2305 / 9850 Malformed foetus, 9730 Twins, 10538 Normal partus treatment
Metritis	
Denmark	2 Metritis
Finland	041 Acute metritis (<6 weeks), 042 Endometritis (< 6 weeks), 043 Pyometra (<6 weeks), 051 Acute metritis (> 6 weeks), 052 Chronic endometritis (> 6 weeks), 053 Pyometra (> 6 weeks)
Norway	333 Metritis, vaginitis and salpingitis
Sweden	9762 Acute endometritis/metritis, 2083 Acute metritis, 2085 Purulent metritis, 2086 Pyometra, 2087 Metritis, 2094 Acute puerperal metritis, 2096 Acute mucometra, 2097 Fusometra
Oestrous disturbance	
Denmark	1 Silent heat, 3 Ovarian cysts, 65 Ovarian cysts (hormone therapy), 68 Inactive ovaries
Finland	011 Anoestrus, 012 Suboestrous, 021 Delayed ovulation, prolonged oestrous, 022 Follicle atresia, 023 Cystic ovaries, 031 Repeat breeder, 032 Embryonic death, 033 Hypofunction of the corpus luteum
Norway	331 Anoestrus/ lack of heat, 334 Cystic ovaries, 340 Silent heat, 341 Repeat breeder (3 or more repeat breedings without obvious explanation/symptoms)
Sweden	9722 Anoestrus, 10534 Heat induction, 2059 Cystic ovaries, 2060 Follicle cyst, 2063 Cystic corpus luteum, 2009 Abnormal heat/oestrous, 2010 Prolonged oestrous, 9744 Prolonged oestrous, 2011 / 9745 / 9746 / 2012 / 9747 Silent heat, 2013 Regular return without symptoms, 9749 Split oestrous, 2015 Nymphomania

In Finland there are 144 diagnostic codes for veterinary or farmer-treated diseases and an additional 20 codes for hoof trimmer treatments. Denmark has about 170 diagnostic codes, and Norway has 300 diagnostic codes. For Finland and Denmark the disease codes are species-specific whereas in Norway the codes are for all production animals. In Finland and Norway the

diagnostic codes all have three digits and are grouped within disease groups. In Denmark the diagnostic codes have one to three digits. In Sweden the diagnostic coding is very different from the other three countries and has numbers up to five digits and the coding system is for both production and pet animals. There are around 4000 codes used in the Swedish system. As the disease

information is transferred from the SBA to the NDDR database 1491 translations are used for the 4000 codes to obtain the cattle-specific diagnostic codes (Wolff C., personal communication, 2013). To illustrate the differences in the coding systems the codes for four reproductive disorders are provided in Table 3.

2.9 Model diseases

The most common diseases of dairy cows can be roughly grouped into four classes: udder diseases, metabolic diseases, locomotor disorders and reproductive disorders. Previous validation studies looked at differences in disease recording among the Nordic countries for udder diseases (Wolff et al., 2012), metabolic diseases (Espetvedt et al., 2012) and locomotor disorders (Lind et al., 2012a). In this thesis the focus is on validation of the reproductive disorder data among the four Nordic countries. The model diseases for reproductive disorders were metritis, retained placenta, assisted calving and oestrous disturbances. Mild clinical mastitis (MCM) was used as a model disease to study whether intentions toward medical treatment differ among the four countries.

There is considerable variation in the definition of uterine inflammatory diseases among different countries, including among the four Nordic countries. To harmonize the definition Sheldon et al. (2006) published a suggestion for defining postpartum uterine diseases. In brief, they divided the cases during the first three weeks after calving into acute puerperal metritis and clinical metritis, depending on the severity of clinical signs. Later cases were diagnosed as either clinical or subclinical endometritis. In this thesis all uterine inflammatory

processes were defined as metritis. Treatment for metritis ranges from antibiotic and hormone therapy to supportive therapy (Youngquist and Threlfall, 2007). Retained placenta means that all or part of the foetal membranes are left behind in the uterus after 24h from calving (Esslemont and Peeler, 1993). Retained placenta is treated with prostaglandins and antibiotics and manual removal is employed occasionally. It is also common to leave retained placenta untreated. Retained placenta can lead to metritis and reduce reproductive efficiency (Guard, 1999). Assisted calving includes any help given during the calving process. Help is commonly needed when the foetus is over-sized or postured incorrectly or the cow is suffering from milk fever and is not in good enough condition to calve unaided.

Metritis, assisted calving and retained placenta are known to lead to short-term drop in milk production and cause economic losses (Gröhn and Rajala-Schultz, 2000). Oestrous disturbances included various types of disorders, such as cystic ovaries, anoestrus and silent heat. All of the disturbances in the group generally prolong the inter-calving interval on a cow. In addition to loss in milk production, non-pregnant cows have a higher risk of being culled and cause the farmer economic losses (Youngquist and Threlfall, 2007).

Mastitis is inflammation of the mammary gland and udder tissue and is the most common disease of dairy cows, MCM being a milder form of the disease. Mastitis is commonly caused by a variety of bacteria and is often treated using antibiotics (Hillerton and Berry, 2005). For MCM, other treatment strategies are also used, such as frequent milking,

wait-and-see and udder ointments. Because of its common occurrence, curing mastitis is important for both animal welfare and economic reasons (Pyörälä, 2008).

2.10 Impact of human intention to the disease data

In addition to different steps in the disease data recording, it is important to know how much human intentions can influence the data that is recorded. Human perception has been found to influence both disease detection and criteria for treatment (Vaarst et al., 2002) and different people have been shown to perceive similar situations differently (Baadsgaard and Jørgensen, 2003). Using methods well known in the social sciences, but rarely used in the field of veterinary epidemiology, intentions towards the use of a treatment can be predicted.

The Theory of Planned Behaviour (TPB) is based on behaviour change (Ajzen, 1988) and is derived from an earlier method, the Theory of Reasoned Action (Fishbein, 1967). The TPB is a questionnaire-based research method that is used to investigate attitudes and beliefs towards specific behaviour (Francis et al., 2004). The TPB model has been used in social sciences to study different behaviours, such as healthy eating (Conner et al., 2002), compliance of speed limits among drivers (Elliott et al., 2003) and green consumerism (Sparks and Shepherd, 1992). Different health-related behavioural studies have found TPB to be a useful tool (Levin, 1999; Rashidian and Russell, 2012) and it has also been used to study farmer behaviour (Garforth et al., 2006, 2004).

Using the TPB model Lind et al. (2012b) found that farmers with access to medication had significantly higher intention towards medical treatment compared with farmers who contacted a veterinarian for treatment. Lastein et al. (2009) found human influence to cause variation in diagnosing metritis among veterinarians. Because the NDDRs primarily record medical treatment data, human influence can significantly increase variation in the NDDR if the threshold for medical treatment differs among countries. The treatment and recording procedures also vary among the countries and can affect interpretations of the results when national statistics are compared.

2.11 Comparing register information among the countries

Comparison of disease information among the countries creates special challenges regarding data quality. None of the countries studied collect data in an exactly similar manner. Teaching of treatment policy also varies among the countries and disease coding also differs among the countries. Plym-Forsehell et al. (1995) were the first to compare incidences among Denmark, Finland, Norway and Sweden and found significant differences in disease incidences. In later studies both Østerås et al. (2003) and Valde et al. (2004) found similar patterns in which the risk for production diseases was higher in one country compared with the others.

Differences found in the studies, however, raised questions about data validity of the between-country comparisons. The differences can be due to different treatment thresholds and/or recording practices. Results

can produce misinterpretations if data are not comparable and lead to unnecessary changes in veterinary, farming or data recording practices in efforts to improve animal health and welfare. Validations for secondary data are essential to avoid possible bias and misinterpretation, especially when separate databases are compared.

3 Aims of the thesis

The main aims of this thesis were to investigate the effects of the data transfer process, disease diagnosis and human intentions toward a treatment on data quality in the NDDRs of Denmark, Finland, Norway and Sweden. The results from Chapters I-IV provide better insight into current NDDR quality and how to make improvements.

The first aim of this thesis was to validate the Finnish NDDR data (I) to establish how well the disease data are recorded and transferred to the NDDR. Although NDDR data have been used in research, to our knowledge this was the first time the quality of the data was validated in Finland. The next aim was to establish how similar diseases are diagnosed, treated and recorded in the NDDRs in the four Nordic countries and how differences can affect the frequency measures in the four countries (II). Both farmer observation and veterinary diagnosis were studied for four reproductive disorders: metritis, assisted calving, retained placenta and oestrous disturbances.

After the data quality for Finland and the disease-specific recording differences were established for the four Nordic countries, the aim was directed towards uncovering the effects of human intentions towards

treatment of dairy cows. The aims of Chapters III and IV were to study whether the intentions towards treatment of MCM were different for farmers and veterinarians among the four countries. In Chapter III the aim was to establish if the farmers in different countries had different thresholds for taking initiatives towards medical treatment by calling a veterinarian for a visit or taking a milk sample for bacteriological examination. In Chapter IV the aim was to establish if the veterinarians in the different countries had different thresholds for initiating treatment of a cow with clinical mastitis.

4 Materials and methods

4.1 Data collection

4.1.1 Joint collaboration among the countries

In Chapters II, III and IV the data collection was done collaboratively among Denmark, Finland, Norway and Sweden. Each researcher was responsible for data collection in the home country. This allowed simultaneous data collection for all four countries. In Chapter I data were only collected in Finland. For Chapters I, II and III the data from NDDRs were used to select herds needed for the studies with specific inclusion and exclusion criteria. The use of NDDRs automatically excludes herds that do not participate in MRS. The average herd size had to be at least 15 cows to illustrate the increasing average herd size. In study III herds participating in the Danish herd health contract were excluded in order to measure similar behaviour among the countries. In Chapter IV the NDDR veterinary treatment data were used in Sweden and Norway to

select veterinarians working mostly with dairy cattle. Veterinarians providing ≥ 250 treatments per year were included in the study. In Denmark only cattle-specific veterinarians were included and in Finland all municipal veterinarians were included, with the exception of pig and small animal veterinarians.

4.1.2 Study populations

In Chapter I all cow cards from cows that died between 2002 and 2008 were collected from 49 herds in Finland. In Chapter II 105, 167, 179 and 129 farmers agreed to record all disease information observed on-farm during two-month periods in spring and autumn 2008 in Denmark, Finland, Norway and Sweden, respectively. Data from each country's NDDR was extracted six months after the autumn period to minimise the lag time in data transfer from farm level to the NDDR. For questionnaire-based studies in Chapter III and IV, the questionnaires were sent to 400 farmers and 293, 202, 269 and 283 veterinarians in Denmark, Finland, Norway and Sweden, respectively. The number of completed questionnaires from farmers (% response rate) was 256 (65%), 176 (45%), 214 (54%) and 206 (52%), and for veterinarians 147 (51%), 106 (53%), 155 (58%) and 142 (53%) in Denmark, Finland, Norway and Sweden, respectively.

4.1.3 Diseases studied

Chapter I addresses the transfer of the disease information in general from cow cards to the NDDR. No specific diseases were of interest in the study. However, the data transfer was compared among four disease groups: mastitis, metabolic, lameness

and reproductive disturbances. In Chapter II four reproductive disorders were specified in each of the four countries: metritis, retained placenta, assisted calving and oestrous disturbances. Mild clinical mastitis was used to study human intentions towards medical treatment in Chapters III and IV. The International Dairy Federation's definition (1999) of the MCM is "observable abnormalities in milk, generally clots or flakes with little or no signs of swelling of the mammary gland or systemic illness". The same definition was used in this thesis.

4.2 Data transfer from farm to register

The validation of data transfer from cow cards to the NDDR in Finland was calculated by comparing the cow identification, diagnostic code and diagnostic date information from cow cards with the information in the NDDR. A discrepancy of ± 7 days was allowed for the disease date in order to avoid discarding information with possible human transcription error. All other variables were required to be similar in both databases. Completeness and correctness were calculated for NDDR to evaluate the quality of the data; reasons for data loss were analysed using logistic regression models.

In Chapter II the participating farmers recorded all clinical diseases on the farm during the study period and also recorded whether a veterinarian treated the cow or not (Appendix 1). All farmer-observed disease events were then compared with disease events from the NDDR in each country for the same period. Completeness was calculated for the farmer-observed disease events (Farmer-observed completeness;

FOC) and the veterinarian-treated disease events (Veterinarian-treated completeness; VTC) separately. Farmer-observed completeness included all abnormal clinical signs for reproductive disorders that the farmer noticed during the study period. Veterinarian-treated completeness only included events diagnosed by a veterinarian during the study period. For each country, FOC and VTC were calculated separately for four reproductive disorders.

Farmer-observed completeness measures how many of the actually observed, but not necessarily treated, disease events are recorded in the NDDR. Veterinarian-treated completeness measures how many treated events are actually recorded in the NDDR. A significant difference in between-country completeness comparison would indicate that NDDRs in different countries do not record disease events uniformly.

4.3 Lactation incidence risk

Incidence risk for each reproductive disorder was calculated retrospectively for all herds included in the NDDR data between January 1st 2007 and May 15th 2009. Lactation incidence risk (LIR), expressed as affected lactations per 100 lactations, was calculated for each of the four disorders separately as follows: (number of lactations with one or more cases of reproductive disorder) / (number of lactations) × 100. For assisted calving and retained placenta, a case was counted as a disease event if it occurred within 30d of calving. For oestrous disturbance and metritis a case was counted as a disease event if it occurred within 365d of calving. For diseases with a 30d risk time, all calving events that began before

December 31st 2008 were included in the study. For diseases with a 365d risk time, all calving events that started before 15th of May 2008 were included.

The LIRs calculated from NDDR data were adjusted according to each country's disease-specific completeness figure. For each disorder the number of estimated new disease events was calculated for both VTC adjusted and FOC adjusted LIRs using the completeness figures as follows: disease events / VTC completeness = VTC adjusted disease events and disease events / FOC completeness = FOC adjusted disease events.

4.4 Behaviour of farmers and veterinarians

In Chapters III and IV the behaviour of farmers and veterinarians was studied using the Theory of Planned Behaviour model (Ajzen, 1991). The TPB model combines qualitative and quantitative research and aims to predict specific behaviour using intention as a proxy for behaviour (Ajzen, 1991; Conner and Armitage, 1998). The specific interest of these two studies was to establish whether both veterinarians and farmers in the four countries had different intentions towards medical treatment of a cow. “*Contacting the veterinarian for a visit the same day as detecting a case of mild clinical mastitis in a lactating dairy cow*”, was the definition used to measure farmers' behaviour towards treatment. In Finland an alternative behaviour, “*Taking a milk sample and sending it for analysis the same day as detecting a mild clinical mastitis in a lactating dairy cow*”, was also added to the questionnaire. This alternative behaviour was

included because a milk sample represents a standard procedure preceding antibiotic treatment in Finland. The veterinarians' behaviour of interest was, "Starting treatment of a lactating dairy cow on the same day as diagnosing mild clinical mastitis" in all of the four Nordic countries.

4.4.1 Predicting behaviour

The TPB questionnaire comprised background information, intentions towards behaviour and three behavioural constructs: 1) attitudes toward behaviour (ATT), 2) subjective norms about the behaviour (SN) and 3) perceived behavioural control (PBC) (Figure 3). In a background section basic demographic information about recipients, such as age and gender, was collected. Both farmer and veterinarian intentions towards behaviour were measured with

intention scenarios. Eight case scenarios (specific description of time, place and signs of the disease) were used to capture the wider range and complexity of behaviour. For each scenario only treatment decisions "yes" or "no" were allowed. Behavioural constructs ATT, SN and PBC were measured using a series of direct and indirect questions. Both direct and indirect questions were measured using a seven point Likert scale (Likert, 1932). Finally, the questionnaire had a section for free comments (see Appendix 2 for the questionnaire for farmers and Appendix 3 for the questionnaire for veterinarians).

4.4.2 Qualitative background

In order to have good background knowledge on the farmers' and veterinarians' thoughts about treatment of the MCM, a series of interviews with farmers and

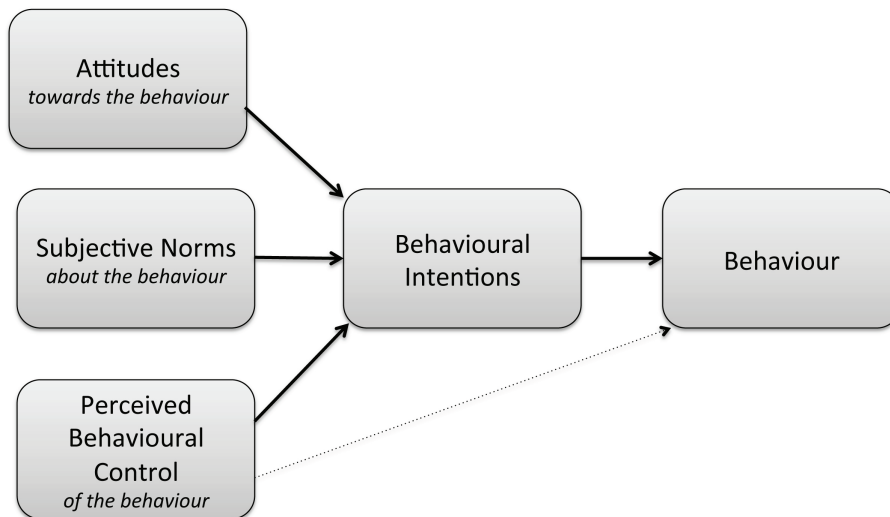


Figure 3. Theory of Planned Behaviour model (Ajzen, 1991). Behavioural intentions are used to predict human behaviour. Three behavioural constructs are used to explain variation in behavioural intentions.

veterinarians was conducted. The commonly held beliefs from these interviews represented the basis of the TPB questionnaire. Beliefs of ATT, SN and PBC that were mentioned in more than 50% of the interviews were used in the questionnaire in a form of question or statement.

5 Results and Discussion

In addition to validating the disease transfer process, this thesis also provides insight into how various reproductive disorders are diagnosed and recorded differently in Denmark, Finland, Norway and Sweden. To explore the among-country differences further in disease recording from the farm level to the NDDR, thresholds for medical treatment for both farmers and veterinarians were studied. The results presented in this thesis will help to improve disease-recording processes in the Nordic countries and also improve the quality of disease frequency comparisons among the countries.

5.1 Correctness

In Chapter I, the correctness of transfer of disease information from

cow cards to the NDDR in Finland was over 90%. With such results the quality of the data can be considered excellent and very suitable for most research use. It is notable, however, that the level of correctness assessed here did not take into account follow-up treatment and allowed a ± 7 day discrepancy for the disease date. For most research purposes this is acceptable, but for more detailed studies (such as that for follow-up treatments) the level of correctness may be lower than in the present study.

According to Hogan and Wagner (1997) correctness is often neglected when data validation is done. This statement is further supported by a review from Thiru et al. (2003), who found that most studies used only completeness figures or sensitivity for validation. Presenting only completeness (or sensitivity) may lead to a situation in which data are regarded as “accurate” when in fact the recorded information is incorrect. In other words, high completeness can be achieved at the expense of low correctness and vice versa (Jordan et al., 2004). The Norwegian NDDR was also recently validated and its correctness was 97% (Espetvedt et al., 2013) (Table 4). Correctness figures from Finnish and Norwegian

Table 4. *Completeness and correctness of the national dairy disease registers in the four Nordic countries. The results according to (Benedsgaard, 2003) from Denmark, Rintakoski et al. (2012) from Finland, Espetvedt et al. (2013) from Norway and Mörk et al. (2010) from Sweden.*

	Completeness (CI)	Correctness (CI)
Denmark	0.80 - 0.85 (NA)	NA
Finland	0.83 (0.82-0.84)	0.92 (0.91-0.93)
Norway	0.87 (0.85-0.89)	0.97 (0.97-0.98)
Sweden	0.75 (NA), 0.84 ^a (NA)	(NA)

CI = 95% confidence interval

NA = Information not available

^a = Completeness of the raw disease data from the Swedish Board of Agriculture

NDDRs, and validation studies from Denmark and Sweden, suggest that the disease data in the Nordic NDDRs are correctly recorded and contained very few mistakes.

5.2 Completeness

The 82% completeness of the Finnish NDDR established in Chapter I can be considered good but not excellent (Egenvall et al., 1998; Jordan et al., 2004). The major reason for unreported events was that the AI technician had not transferred events from the cow cards to the NDDR. Forty per cent of all non-transferred disease events did not have a check box “transferred to NDDR” ticked by the AI technician on the cow card. Closer examination revealed that the time of the disease event had a significant effect on whether the event was marked as “transferred to the NDDR” or not. Disease events closest to culling had a significantly lower probability to be marked “transferred to the NDDR”. The reason for this was the removal of the cow card after culling but before the next AI technician’s visit to the farm. The AI technician therefore had no possibility to transfer the disease information. This finding suggests underreporting in the Finnish NDDR, which can specifically affect studies focused on reasons for cow removals.

Significant differences were also found among four disease groups: mastitis, metabolic diseases, lameness and reproductive disorders. Lameness was associated with the lowest probability to be transferred, whereas reproductive disorders had the highest probability (twice the odds compared with lameness). The differences in data transfer between the disease groups indicate that not all diseases had equal probability of being recorded in the NDDR in

Finland. Also the disease events for cows purchased later in life were associated with lower odds to be transferred to the NDDR. Data loss for disease events for purchased cows is likely explained by possible duplication of the ear tag number on the farm. The AI technicians use the ear tag for cow identification when they transfer disease events from the cow card. These errors could probably be avoided by using EU cow identification that is unique for each individual.

Other validation studies in Denmark, Sweden and Norway also identified data loss as being fairly similar. In Norway the completeness was 0.87 (Espetvedt et al., 2013), being slightly higher than in Finland. Of the Nordic countries, the Norwegian system is closest to the Finnish system. The lower completeness in Finland is partly explained by the data loss close to culling. Espetvedt et al. (2013) did not look at the possibility of data loss for disease events close to culling. Although here is nothing to suggest that similar data loss occurred in Norway, the possibility cannot be completely excluded. Herd health advisors visit the farms more frequently, which lessens the possibility of data loss close to culling. Bennedsgaard (2003) found the completeness to range between 80% and 85% in Denmark, being similar to the results for Finland. In Sweden, Mörk et al. (2010) found 75% completeness in the NDDR data, but 84% completeness for the SBA raw disease data. The lower 75% completeness was most likely due to an error in disease coding at the data transfer stage from SBA to SDA (Mörk, M., personal communication, 2013).

The results of the validation studies in the Nordic countries

suggest that completeness figures are fairly similar in all the four countries. Approximately 13 – 20% of the data are lost after the treatment record is made on the farm. While the completeness of the NDDR data for Finland can be considered good, the total data loss of 17%, and the systematic error represented by missing disease events close to culling, leaves room for improvement in the data quality.

The results in Chapter I show the data loss that occurs during the transfer steps after the disease is recorded on the farm. They do not, however, show how treatment and recording practices can change the outcome, that is, which events are recorded and which are not. In Chapter II completeness was calculated for four reproductive disorders in the four Nordic countries by comparing farmer-reported disease events with the NDDR recordings. Farmer-observed completeness and VTC were fairly high for metritis (VTC: 0.78 – 0.92, FOC: 0.70 – 0.92) and oestrous disturbances (VTC: 0.85 – 0.96, FOC: 0.82 – 0.91) in all the countries, but varied considerably for assisted calving (VTC: 0.55 – 0.88, FOC: 0.31 – 0.73) and retained placenta (VTC: 0.63 – 0.93, FOC: 0.34 – 0.89). Typically both metritis and oestrous disturbance require veterinary diagnoses. Metritis, as defined here, includes practically all inflammatory diseases of the uterus, viz. acute puerperal metritis, clinical metritis and endometritis. Especially acute puerperal metritis is severe and can lead to death quickly without medical treatment. Oestrous disturbances are never lethal, but are often difficult to diagnose and require examination by a veterinarian for correct diagnosis. Moreover, from an economic

perspective, these diseases rarely heal in due time.

As for the assisted calving and retained placenta, the opposite is true. The severity for both diseases varies greatly from life-threatening cases to cases that heal without medication aid. Results in Chapter II suggest that for assisted calving and retained placenta the completeness of the NDDRs is affected by different treatment and data recording practices among the countries. Finland, having the lowest FOC for both assisted calving (0.31) and retained placenta (0.34), is a case that suggests that veterinarian involvement is less frequent compared with other countries with higher FOC. A similar trend can also be seen in recent studies in the Nordic countries regarding metabolic diseases (Espetvedt et al., 2012) and locomotor disorders (Lind et al., 2012a). A metabolic disease such as milk fever is likely to be severe; milk fever had higher completeness figures (e.g. Norway FOC: 0.79) than locomotor disorders, which can range from severe to mild lameness (e.g. Norway FOC: 0.30). Jordan et al. (2004) also stated that in medicine, diseases that are easier to diagnose seem to be better represented in the disease database than diseases associated with subjective criteria. It can be said that databases underestimate diseases that vary in severity and are characterised by an unclear or subjective disease definition.

5.3 Incidences

Lactation incidence risks for reproductive disorders were calculated from each country's NDDR data and adjusted using VTC and FOC completeness figures (Table 5).

Table 5. Lactation incidence risks (LIRs) for four reproductive disorders in Denmark (DK), Finland (FI), Norway (NO) and Sweden (SE). LIRs were calculated from NDDR data. Veterinary treated completeness (VTC) and farmer observed completeness (FOC) figures were used to adjust LIRs due to data loss in the NDDR.

	n	NDDR LIR (CI)	VTC adjusted LIR (CI)	FOC adjusted LIR (CI)
Metritis				
DK	14,456	4.77 (3.78 - 6)	5.18 (4.18 - 6.41)	5.18 (4.18 - 6.41)
FI	7,422	0.96 (0.72 - 1.27)	1.28 (1 - 1.63)	1.28 (1 - 1.63)
NO	5,048	0.57 (0.38 - 0.87)	0.67 (0.45 - 1)	0.75 (0.54 - 1.06)
SE	9,270	0.59 (0.43 - 0.82)	0.77 (0.6 - 0.98)	0.85 (0.64 - 1.13)
Assisted calving				
DK	19,741	2.94 (2.29 - 3.78)	3.34 (2.69 - 4.15)	4.03 (3.34 - 4.86)
FI	10,142	0.95 (0.74 - 1.21)	1.73 (1.46 - 2.03)	3.06 (2.68 - 3.48)
NO	7,445	0.71 (0.53 - 0.96)	1.22 (0.97 - 1.55)	1.61 (1.33 - 1.95)
SE	12,630	0.5 (0.36 - 0.69)	0.63 (0.48 - 0.82)	0.77 (0.58 - 1.01)
Retained placenta				
DK	19,741	8.19 (6.96 - 9.62)	8.76 (7.54 - 10.15)	9.2 (7.97 - 10.6)
FI	10,142	1.13 (0.81 - 1.58)	1.8 (1.45 - 2.25)	3.33 (2.9 - 3.83)
NO	7,445	2.76 (2.26 - 3.37)	3.41 (2.86 - 4.06)	3.63 (3.06 - 4.29)
SE	12,630	1.17 (0.85 - 1.61)	1.33 (1.01 - 1.75)	1.81 (1.4 - 2.32)
Oestrous disturbance				
DK	14,456	1.34 (0.9 - 1.99)	1.39 (0.94 - 2.05)	1.47 (1.02 - 2.11)
FI	7,422	10.37 (8.8 - 12.2)	11.16 (9.55 - 12.99)	11.28 (9.69 - 13.09)
NO	5,048	3.09 (2.1 - 4.53)	3.65 (2.62 - 5.04)	3.65 (2.62 - 5.04)
SE	9,270	0.92 (0.59 - 1.43)	1.22 (0.87 - 1.7)	1.12 (0.77 - 1.63)

n = Total number of lactations

CI = 95% confidence interval

Changes in LIRs after the adjustments show how imperfect completeness, whether caused by differences in treatment, recording practice or data loss during data transfer, can bias the results. For metritis and oestrous disturbance, which both had fairly high completeness values, the adjustment had only a small effect. For assisted calving and retained placenta, the FOC adjustment increased LIR substantially in Finland. After the adjustment, LIR for retained placenta was very close to LIR in Denmark, whereas without adjustment the LIR was three times larger in Denmark.

For assisted calving, Finland was on a par with Norway after the adjustment, whereas without the adjustment LIR in Finland was 1.1% compared with 2.8% in Norway. Denmark had the highest LIR for all diseases except oestrous disturbances. The risk was exceptionally high for retained placenta and 3–8 times greater compared with other countries. It is very likely that the high risk is due to routine screening of animals after calving and that the treatment threshold is lower for retained placenta in Denmark. The risk for oestrous disturbances was greatest in

Finland. High LIR is explained by different routines in the use of hormonal treatments in the Nordic countries. Changes in LIR levels when completeness was taken into account further support the need for validation and improvements in the NDDRs when data are used for frequency measure calculations.

The time of the data extraction from the NDDR can also significantly affect the frequency measures and validation calculations. In 2007, the number of days for disease data transfer from farm level to NDDR (lag time) varied greatly among the countries (Table 6) (Virtala, A-M. K., unpublished data, 2013). In Finland and Norway, for the NDDRs to have 90% coverage of reported diseases, it took 223d and 199d, respectively. In Sweden the lag time for 90% coverage was 89d. It was not possible to get the calculations from Denmark, but the estimated lag time for 90% coverage was approximately one week. A lag time of around one week has also been reported for the new computerized VETIN system in Norway (Østerås, O., personal communication, 2011). These results indicate that new computerized recording systems would expedite the data transfer process and benefit farm health assessments and research by making them more accurate and faster. Before Naseva and VETIN gain broader coverage and lag time is properly investigated, it is advisable for research purposes

to use NDDR data older than six months to assure sufficient disease coverage for Finland and Norway.

5.4 Behaviour towards a treatment

While completeness and correctness are important for improved frequency comparisons among countries, they only measure how large proportions of disease events are recorded. As the NDDR relies mainly upon veterinary records of treated animals, it is important to measure the threshold towards medical treatments from both farmers and veterinarians in each country. The TPB has been shown to predict human intentions well and is therefore used successfully to study health-related behaviours (Armitage and Conner, 2001; Ajzen et al., 2007).

Farmer intention scores towards calling a veterinarian for a visit when noting MCM differed significantly among all four countries, except between Norway and Denmark. Intention was lowest in Finland, being almost non-existent (median 0.00, CI 0.00-0.25). Intention scores for Denmark, Norway and Sweden were 0.50, 0.50 and 0.38, respectively. The intention scores towards medical treatment of MCM for veterinarians were 0.71, 0.42, 0.58 and 0.50 for Denmark, Finland, Norway and Sweden, respectively.

Table 6. The number of days data transfer takes from the farm level to the national dairy disease register in Finland, Norway and Sweden in 2007. The data for Denmark were not available.

Country	Days to transfer 25%	Days to transfer 50%	Days to transfer 75%	Days to transfer 90%	Days to transfer 95%
Finland	16	47	120	223	284
Norway	11	24	63	199	352
Sweden	17	11	30	89	147

Only Sweden and Norway did not differ in between-country comparisons.

Both farmer and veterinarian intention showed similar trends in all countries. In Denmark the intentions were high for both farmers and veterinarians and in Finland and Sweden the intentions were low for both groups. When intention scores were compared against mastitis incidence rates calculated by Wolff et al. (2012) from the NDDR data in each country, they showed a positive correlation (Table 7). Denmark had both highest intentions and highest incidence. These results support the hypothesis that high farmer and veterinary intention affect NDDR data by increasing the numbers of medical treatments and therefore increasing the numbers of recorded disease events. In Chapter IV, from ten MCM cases only five would be registered in the NDDR in Sweden, whereas Denmark would have records of seven events according to intention scenarios, assuming all other conditions were equal.

Treatment intentions are also interesting from another point of view. As a large proportion of MCM treatments include the use of

antibiotics, the threshold for treatment can also affect antimicrobial resistance. A global trend of increasing antimicrobial resistance is well-documented and the use of antibiotics for mastitis in dairy cows also contributes to antimicrobial resistance (Livermore, 2003). There is global interest to find an optimal strategy for use of antibiotics in dairy cattle to decrease antimicrobial resistance as well as to increase productivity (Oliver et al., 2011; Pinzón-Sánchez et al., 2011).

As stated above, high intentions towards a treatment from both farmers and veterinarians seem to correlate positively with disease incidence for MCM. Because in all four countries the same scenarios were used, the likely reason for higher intention in Denmark is that veterinarians start medical treatment for MCM in situations where veterinarians, for example in Sweden do not see the need for treatment. However, the results for milk yield and somatic cell count levels between Denmark and Sweden do not support the assumption that the higher treatment frequency in Denmark would improve quality and productivity. In 2007, energy-

Table 7. *Intention scores for farmer to call a veterinarian for a visit when noting mild clinical mastitis (MCM) in a dairy cow, for veterinarians to start a treatment for a cow with MCM and incidence rates (IRs) for mastitis calculated directly from the registers and after adjustment in Denmark (DK), Finland (FI), Norway (NO) and Sweden (SE).*

Country	Farmer intention	Veterinary intention	NDDR IR ^a (CI)	VTC adjusted IR ^b (CI)
DK	0.50	0.71	39.4 (35.4-43.9)	42.1 (37.4-47.5)
FI	0.00/0.63 ^c	0.42	19.3 (16.4- 22.8)	34.7 (30.6-39.4)
NO	0.50	0.58	23.2 (19.8-27.3)	28.1 (24.3-32.6)
SE	0.38	0.58	17.5 (14.9-20.6)	22.6 (19.7-25.8)

VTC = veterinarian-treated completeness

NDDR = National Dairy Disease Register

CI = 95% confidence interval

^a Incidence rate per 100 cow years in the NDDR databases (Wolff et al., 2012)

^b Incidence rate adjusted by each countries veterinarian treated completeness (Wolff et al., 2012)

^c Additional behaviour in FI, “taking a milk sample for bacteriology

corrected milk yield was 9,257 kg versus 9,410 kg per cow-year in Denmark and Sweden, respectively, and the geometric mean for bulk milk somatic cell count was 234,000 cells per millilitre and 189,000 cells per millilitre in Denmark and Sweden, respectively (Østerås O., unpublished data, 2012). In addition to the intentions towards medical treatment, the TPB method can also be used to identify the important factors that affect the treatment decision. Knowledge of these factors could help shape the behaviour according to a wanted treatment policy. The TPB and similar methods could provide valuable tools in the struggle against antimicrobial resistance.

Low intentions, however, do not automatically mean lower incidence. In Finland the treatment procedure for MCM differs greatly from other countries because of the routine use of milk sampling prior to treatment. The intention towards alternative behaviour, “taking a milk sample”, was very high in Finland (0.63) and also explains the almost non-existent intention to call a veterinarian for a visit. Incidence rate for mastitis was low in Finland when calculated from the NDDR data, but after adjusting using the low completeness for mastitis treatments in Finland, the incidence doubled and was the second highest of the four countries (Wolff et al., 2012). The reason for low completeness for mastitis in Finland was poor recording of phone prescription medicines; the majority of those treatments were missing from the NDDR data.

In most of the MCM cases, Finnish veterinarians do not make treatment decisions on the farm as in the other countries but base their diagnosis on test results. Therefore, the intentions may not be strictly comparable with

the other three countries. This is also supported by the different behavioural constructs that explained most of the variation for intentions. Attitude and SN explained most of the variation for veterinarian intention in Denmark, Norway and Sweden. This was expected as ATT is frequently found to be high in health-related behaviours (Gaston and Kok, 1996). Also SN - particularly farmers' opinions - is expected to influence veterinarians' decisions because a treatment decision is frequently made on the farm together with the farmer. For Finland the most important component was PBC. This difference is likely due to the difference in routine use of bacteriology results.

The TPB model is designed to study very specific behaviour (Francis et al., 2004). Different diseases have very specific treatment methods and intentions towards MCM cannot be generalized to other diseases. The positive correlation established between incidence rate and intentions for MCM can, however, be used to select diseases for future intention studies. For example, oestrous disturbances in Finland have high incidence risk compared with the other three countries and this could partly be due to higher treatment intentions.

6 Conclusions, future plans and implications

This thesis describes the disease data transfer process from observations of a disease on farm to the use of data for research purposes. Results presented in this thesis showed that even if NDDRs were able to capture 100% of all veterinarian-treated MCM events, the differences in intention scores would lead to

differences in incidence rates purely because of the differences in both farmer and veterinary treatment intentions. The severity of a disease is also likely to affect the treatment decision substantially, and particularly so for mild diseases. It is also shown that the incidence risk varied more for assisted calving and retained placenta and caused more variation in the NDDR recordings among the four countries. After the treatment was given and recorded on the farm, approximately 17% of the NDDR data were lost during the transfer process in Finland. Systematic errors - that can cause bias in disease calculations - were also evident in the Finnish NDDR. Random errors were caused by AI technician, veterinarian and farmer transcription errors. For specific diseases data loss can vary significantly and seriously complicates the interpretations of frequency measure calculations among the countries.

Improvements are needed as collaboration across borders continues to increase. It is important that disease and other production data can be reliably compared among countries. This thesis provides more knowledge on how NDDRs function in each of the four countries and the associated strengths and weaknesses of the registers used. For future research, the adjusted incidences can be used together with production parameters to re-evaluate treatment practices in each of the Nordic countries. For example, higher oestrus disturbance incidence but equal or higher inter-calving intervals compared to other countries, could indicate that treatment practices are not optimal.

The future challenges lie in harmonization of the NDDR registers to make them completely comparable

among countries. New and improved computerized systems, like Naseva and VETIN, make data collection easier, faster and more reliable. One substantial task in the future is represented by disease code harmonization. Different coding can severely complicate disease comparison. Some of these suggestions are already being implemented while others are new suggestions to improve data quality.

1) The data transfer process should be harmonized in all countries in such a way that disease information can be transferred in real time (or close to it) to reduce errors caused by a middleman (e.g. AI technician or herd health advisor) and lag time from diagnosing the disease to recording it in the register.

2) NDDR should clearly separate whether the diagnostic event required medical attention or not.

3) A clear distinction should be made between regular routine treatments and diagnosis-based treatment.

4) NDDR should use the EU cow identification numbers instead of ear tag numbers to avoid misplaced recordings.

5) Recordings for prescription treatments in Finland should be better monitored. As mastitis is commonly considered to have the greatest effect on milk productivity, the current estimated 50% data loss for mastitis recordings is not acceptable for a reliable disease register.

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Literature

- Ajzen, I. 2005. Attitudes, personality and behaviour. McGraw-Hill International. pp. 191.
- Ajzen, I. 1991. The theory of planned behavior. *Organizational Behavior and Human Decision Processes* 50: 179–211.
- Ajzen, I., Albarracín, D., and Hornik, R. 2007. Prediction and Change of Health Behavior. Applying the Reasoned Action Approach. Lawrence Erlbaum Associates, Mahwah, New Jersey.
- Andersen, T. F., Madsen, M., Jørgensen, J., Mellekjoer, L., and Olsen, J. H. 1999. The Danish National Hospital Register. A valuable source of data for modern health sciences. *Danish Medical Bulletin* 46: 263–268.
- Armitage, C. J., and Conner, M. 2001. Efficacy of the Theory of Planned Behaviour: A meta-analytic review. *British Journal of Social Psychology* 40: 471–499.
- Arts, D. G. T., De Keizer, N. F., Scheffer, G. J., and Sheffer, G.-J. 2002. Defining and improving data quality in medical registries: a literature review, case study, and generic framework. *Journal of the American Medical Informatics Association* 9: 600–611.
- Baadsgaard, N. P., and Jørgensen, E. 2003. A Bayesian approach to the accuracy of clinical observations. *Preventive Veterinary Medicine* 59: 189–206.
- Bartlett, P. C., Agger, J. F., and Houe, H. 2001. Incidence of clinical mastitis in Danish dairy cattle and screening for non-reporting in a passively collected national surveillance system. *Preventive Veterinary Medicine* 48: 73–83.
- Bartlett, P. C., Kaneene, J. B., Kirk, J. H., and Wilke, M. A. 1986. Development of a computerized dairy herd health data base for epidemiologic research. *Preventive Veterinary Medicine* 4: 3–14.
- Bennedsgaard, T. W. 2003. Reduced use of veterinary drugs in organic dairy herds - Potentials and consequences. Doctoral thesis. Royal Veterinary and Agricultural University, Frederiksberg, Denmark.
- Best, A. E. 1999. Secondary data bases and their use in outcomes research: a review of the area resource file and the Healthcare Cost and Utilization Project. *Journal of Medical Systems* 23: 175–181.
- Bonnett, B N, and Egenvall, A. 2010. Age patterns of disease and death in insured Swedish dogs, cats and horses. *Journal of Comparative Pathology* 142: 33–38.
- Bonnett, B N, Egenvall, Agneta, Hedhammar, A., and Olson, P. 2005. Mortality in over 350,000 insured Swedish dogs from 1995–2000: I. Breed-, gender-, age- and cause-specific rates. *Acta Veterinaria Scandinavica* 46: 105–120.
- Bruun, J., Ersbøll, A. K., and Alban, L. 2002. Risk factors for metritis in Danish dairy cows. *Preventive Veterinary Medicine* 54: 179–190.
- Carpelan-Holmström, M., Nordling, S., Pukkala, E., Sankila, R., Lüttges, J., Klöppel, G., and Haglund, C. 2005. Does anyone survive pancreatic ductal adenocarcinoma? A nationwide study re-evaluating the data of the Finnish Cancer Registry. *Gut* 54: 385–387.
- Conner, M., and Armitage, C. J. 1998. Extending the Theory of Planned

- Behavior: A review and avenues for further research. *Journal of Applied Social Psychology* 28: 1429–1464.
- Conner, M., Norman, P., and Bell, R. 2002. The theory of planned behavior and healthy eating. *Health Psychology* 21: 194–201.
- Danish Agriculture and Food Council. 2012. Dairy statistics 2011. Retrieved May 2, 2013, from http://www.agricultureandfood.dk/~media/lf/Tal_og_analyser/Aarsstatistikker/Mejeri_statistik/2011/NY_Mejeristatisti_WEB.ashx
- Disease WatchDog. 2013. Companion Animal Disease Surveillance Centre. Retrieved June 15, 2013, from <http://www.diseasewatchdog.org>
- Dohoo, I., Martin, W., and Stryhn, H. 2009. *Veterinary Epidemiologic Research*. Charlottetown, Prince Edward Island, Canada: VER Inc.
- Egenvall, A., Bonnett, B. N., Olson, P., and Hedhammar, Å. 1998. Validation of computerized Swedish dog and cat insurance data against veterinary practice records. *Preventive Veterinary Medicine* 36: 51–65.
- Egenvall, A., Bonnett, B. N., Shoukri, M., Olson, P., Hedhammar, A., and Dohoo, I. 2000. Age pattern of mortality in eight breeds of insured dogs in Sweden. *Preventive Veterinary Medicine* 46: 1–14.
- Egenvall, A., Hagman, R., Bonnett, B. N., Hedhammar, Å., Olson, P., and Lagerstedt, A.-S. 2001. Breed risk of pyometra in insured dogs in Sweden. *Journal of Veterinary Internal Medicine* 15: 530–538.
- Elliott, M. A., Armitage, C. J., and Baughan, C. J. 2003. Drivers' compliance with speed limits: an application of the theory of planned behavior. *The Journal of Applied Psychology* 88: 964–972.
- Emanuelson, U. 1988. The national Swedish animal disease recording system. *Acta Veterinaria Scandinavica. Supplementum* 84: 262–264.
- Emanuelson, U., and Oltenacu, P. A. 1998. Incidences and effects of diseases on the performance of Swedish dairy herds stratified by production. *Journal of Dairy Science* 81: 2376–82.
- Espetvedt, M. N., Reksen, O., Rintakoski, S., and Osterås, O. 2013. Data quality in the Norwegian dairy herd recording system: Agreement between the national database and disease recording on farm. *Journal of Dairy Science* 96: 1–12.
- Espetvedt, M. N., Wolff, C., Rintakoski, S., Lind, A., and Osterås, O. 2012. Completeness of metabolic disease recordings in Nordic national databases for dairy cows. *Preventive Veterinary Medicine* 105: 25–37.
- Esslemont, R. J., and Peeler, E. J. 1993. The scope for raising margins in dairy herds by improving fertility and health. *British Veterinary Journal* 149: 537–547.
- Eurostat. 2013. European commission, Eurostat. Retrieved March 1, 2013, from <http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/>
- Fishbein, M. 1967. *Readings in attitude theory and measurement*. New York: Wiley. pp. 499.
- Francis, J. J., Eccles, M. P., Johnston, M., Walker, A., Grimshaw, J., Foy, R., Kaner, E. F. S., Smith, L., and Bonetti, D. 2004. *Constructing questionnaires based on the Theory of Planned*

- Behaviour: A manual for health services researchers. Newcastle.
- Friede, A., Reid, J. A., and Ory, H. W. 1993. CDC WONDER: a comprehensive on-line public health information system of the Centers for Disease Control and Prevention. *American Journal of Public Health* 83: 1289–94.
- Garforth, C., Rehman, T., McKemey, K., Tranter, R., Cooke, R., Yates, C. M., Park, J., and Dorward, P. 2004. Improving the design of knowledge transfer strategies by understanding farmer attitudes and behaviour. *Journal of Farm Management* 12: 17–32.
- Garforth, C., McKemey, K., Rehman, T., Tranter, R., Cooke, R., Park, J., Dorward, P., and Yates, C. 2006. Farmers' attitudes towards techniques for improving oestrus detection in dairy herds in South West England. *Livestock Science* 103: 158–168.
- Gaston, G., and Kok, G. 1996. The Theory of Planned Behavior: A Review of Its Applications to Health-related Behaviors. *American Journal of Health Promotion*: November/December 1996, Vol. 11, No. 2, pp. 87–98. *American Journal of Health Promotion* 11: 87–98.
- Gröhn, Y. T., Eicker, S. W., and Hertl, J. A. 1995. The association between previous 305-day milk yield and disease in New York State dairy cows. *Journal of Dairy Science* 78: 1693–702.
- Gröhn, Y. T., and Rajala-Schultz, P. J. 2000. Epidemiology of reproductive performance in dairy cows. *Animal Reproduction Science* 60–61: 605–14.
- Gröhn, Y. T., Saloniemi, H., and Syväjärvi, J. 1986. An epidemiological and genetic study on registered diseases in Finnish Ayrshire cattle, 3: metabolic diseases. *Acta Veterinaria Scandinavica*.
- Guard, C. 1999. Retained placenta: causes and treatments. *Advances in Dairy Technology* 11: 81–86.
- Gulliksen, S. M., Lie, K. I., and Østerås, O. 2009. Calf health monitoring in Norwegian dairy herds. *Journal of Dairy Science* 92: 1660–1669.
- Hillerton, J. E., and Berry, E. a. 2005. Treating mastitis in the cow - a tradition or an archaism. *Journal of Applied Microbiology* 98: 1250–5.
- Hogan, W. R., and Wagner, M. M. 1997. Accuracy of data in computer-based patient records. *Journal of the American Medical Informatics Association* 4: 342–55.
- Holmbeg, M., and Andersson-Eklund, L. 2004. Quantitative trait loci affecting health traits in Swedish dairy cattle. *Journal of Dairy Science* 87: 2653–2659.
- Houe, H., Egenvall, A., Virtala, A.-M., Olafsson, T., and Østerås, O. 2011. Databases in veterinary medicine - validation, harmonisation and application: introduction. *Acta Veterinaria Scandinavica* 53 Supplementum 1: 1.
- Huston, P., and Naylor, C. D. 1996. Health services research: reporting on studies using secondary data sources. *Canadian Medical Association journal* 155: 1697–709.
- ICAR. 2013. International Committee for Animal Recording. Retrieved April 17, 2013, from <http://icar.org/>
- IDF. 1999. Suggested interpretation of mastitis terminology. *Bulletin of the International Dairy Federation* 338: 3–26.
- Jansson, A., Arneborn, M., and Ekdahl, K. 2005. Sensitivity of

- the Swedish statutory surveillance system for communicable diseases 1998-2002, assessed by the capture-recapture method. *Epidemiology and Infection* 133: 401-407.
- Jordan, K., Porcheret, M., and Croft, P. 2004. Quality of morbidity coding in general practice computerized medical records: a systematic review. *Family Practice* 21: 396.
- Kortesniemi, P., and Halkosaari, P. 2010. Nautojen terveydenhuollon seurantajärjestelmän Nasevan kakkosvaiheen kehityshanke: Loppuraportti. [Second stage of the Naseva development project; Final report] Retrieved March 3 2013, from http://www.laatuketju.fi/laatuketju/www/fi/liitetiedostot/TIEDO_TUKSEEN_Nasevan_kakkosvaiheen_hankkeen_loppuraportti__2_.pdf
- Lastein, D. B., Vaarst, M., and Enevoldsen, C. 2009. Veterinary decision making in relation to metritis - a qualitative approach to understand the background for variation and bias in veterinary medical records. *Acta Veterinaria Scandinavica* 51: 36.
- Levin, P. F. 1999. Test of the Fishbein and Ajzen models as predictors of health care workers' glove use. *Research in Nursing and Health* 22: 295-307.
- Likert, R. 1932. A technique for the measurement of attitudes. *Archives of Psychology* 140: 1-55.
- Lind, A., Thomsen, P. T., Ersbøll, A. K., Espetvedt, M. N., Wolff, C., Rintakoski, S., and Houe, H. 2012. Validation of Nordic dairy cattle disease recording databases - Completeness for locomotor disorders. *Preventive Veterinary Medicine* 107: 204-213.
- Lind, A.-K., Thomsen, P. T., Rintakoski, S., Espetvedt, M. N., Wolff, C., and Houe, H. 2012. The association between farmers' participation in herd health programmes and their behaviour concerning treatment of mild clinical mastitis. *Acta Veterinaria Scandinavica* 54: 62-70.
- Livermore, D. M. 2003. Bacterial resistance: origins, epidemiology, and impact. *Clinical Infectious Diseases* 36: 11-23.
- Mähönen, M., Jula, A., Harald, K., Antikainen, R., Tuomilehto, J., Zeller, T., Blankenberg, S., and Salomaa, V. 2013. The validity of heart failure diagnoses obtained from administrative registers. *European Journal of Preventive Cardiology* 20: 254-9.
- Maizon, D., Oltenacu, P. A., Gröhn, Y. T., Strawderman, R., and Emanuelson, U. 2004. Effects of diseases on reproductive performance in Swedish Red and White dairy cattle. *Preventive Veterinary Medicine* 66: 113-126.
- Ministry of Agriculture and Forestry. 2000. Decree B7 No. 13/EEO/2000. Retrieved March 13, 2013, from <http://www.mmm.fi/fi/index/lainnsaadanto/elainlaakintolainsaadanto/sisalto/bhakemisto.html>
- Mörk, M., Wolff, C., Lindberg, A., Vågsholm, I., and Egenvall, A. 2010. Validation of a national disease recording system for dairy cattle against veterinary practice records. *Preventive Veterinary Medicine* 93: 183-192.
- National Institute for Health and Welfare. 2013a. Finnish National Birth Register. Retrieved April 15, 2013, from http://www.thl.fi/en_US/web/en/statistics/information/register_description/newborns

- National Institute for Health and Welfare. 2013b. Finnish National Cardiovascular Diseases Register. Retrieved April 15, 2013, from <http://www3.thl.fi/stat/>
- Nokka, S. 2011. Pro-Agria tuotosseurannan tulosseminaari [Pro-Agria Dairy production statistics]. Retrieved May 15, 2012, from ftp://ftp.proagria.fi/pub/tuloksia/maidonjanurmentuotannontulosseminaari/sanna_nokka.pdf
- Oliver, S. P., Murinda, S. E., and Jayarao, B. M. 2011. Impact of antibiotic use in adult dairy cows on antimicrobial resistance of veterinary and human pathogens: a comprehensive review. *Foodborne Pathogens and Disease* 8: 337–355.
- Olsson, S.-O., Baekbo, P., Rautala, H., and Østerås, O. 2001. Disease recording systems and herd health schemes for production diseases. *Acta Veterinaria Scandinavica. Supplementum* 94: 51–60.
- Oltenacu, P. A., Hultgren, J., and Algers, B. 1998. Associations between use of electric cow-trainers and clinical diseases, reproductive performance and culling in Swedish dairy cattle. *Preventive Veterinary Medicine* 37: 77–90.
- Østerås, O., Solbu, H., Refsdal, O., Roalkvam, T., Filseth, O., and Minsaas, A. 2007. Results and evaluation of thirty years of health recordings in the Norwegian dairy cattle population. *Journal of Dairy Science* 90: 4483–4497.
- Østerås, O., Valde, J. P., Lindberg, A., Lawson, L., Saloniemi, H., and Agger, J. F. 2003. Final scientific report of the project NKJ: 1.276: Disease incidence in dairy cows in Nordic countries - Comparison of national disease reporting systems. 1–30.
- Pajunen, P., Koukkunen, H., Ketonen, M., Jerkkola, T., Immonen-Raiha, P., Karja-Koskenkari, P., Mahonen, M., Niemela, M., Kuulasmaa, K., Palomaki, P., Mustonen, J., Lehtonen, A., Arstila, J., Vuorenmaa, T., Lehto, S., et al. 2005. The validity of the Finnish Hospital Discharge Register and Causes of Death Register data on coronary heart disease. *European Journal of Cardiovascular Prevention and Rehabilitation* 12: 132–137.
- Pajunen, P., Pääkkönen, R., Juolevi, A., Hämäläinen, H., Keskimäki, I., Laatikainen, T., Moltchanov, V., Niemi, M., Rintanen, H., and Salomaa, V. 2004. Trends in fatal and non-fatal coronary heart disease events in Finland during 1991–2001. *Scandinavian Cardiovascular Journal* 38: 340–4.
- Penell, J. C., Egenvall, A., Bonnett, B. N., and Pringle, J. 2007. Validation of computerized Swedish horse insurance data against veterinary clinical records. *Preventive Veterinary Medicine* 82: 236–251.
- Pinzón-Sánchez, C., Cabrera, V. E., and Ruegg, P. L. 2011. Decision tree analysis of treatment strategies for mild and moderate cases of clinical mastitis occurring in early lactation. *Journal of Dairy Science* 94: 1873–92.
- Plym Forshell, K., Østerås, O., Aagaard, K., and Kulkas, L. 1995. Disease recordings and cell count data in 1993 in Sweden, Norway, Denmark and Finland. In *Proc 3rd Int. Mastitis Seminar* May 28th- June 1st, Tel Aviv, Israel.

- Pollari, F. L., Bonnett, B. N., Allen, D. G., Bamsey, S. C., and Martin, S. W. 1996. Quality of computerized medical record abstract data at a veterinary teaching hospital. *Preventive Veterinary Medicine* 27: 141–154.
- Prahl, A., Guptill, L., Glickman, N. W., Tetrick, M., and Glickman, L. T. 2007. Time trends and risk factors for diabetes mellitus in cats presented to veterinary teaching hospitals. *Journal of Feline Medicine and Surgery* 9: 351–8.
- Pro-Agria. 2012. Tuotosseuranta kunnittain 2010 [Production statistics on municipal level in 2010]. Retrieved January 8, 2013, from <http://www.proagriaoulu.fi/fi/protuotos>
- Pyörälä, S. 2008. Mastitis in postpartum dairy cows. *Reproduction in Domestic Animals* 43 Supplementum: 252–259.
- Rajala-Schultz, P. J., Gröhn, Y. T., and Allore, H. G. 2000. Optimizing breeding decisions for Finnish dairy herds. *Acta Veterinaria Scandinavica* 41: 199–212.
- Rashidian, A., and Russell, I. 2012. General practitioners' intentions and prescribing for asthma: using the theory of planned behaviour to explain guideline implementation. *International Journal of Preventive Medicine* 3: 17–28.
- Salomaa, V. 2003. Trends in coronary events in Finland during 1983–1997; The FINAMI study. *European Heart Journal* 24: 311–319.
- Scheiner, S. M., and Gurevitch, J. 2001. Design and analysis of ecological experiments. Oxford University Press. pp. 403.
- Schneider, M. P., Strandberg, E., Emanuelson, U., Grandinson, K., and Roth, A. 2007. The effect of veterinary-treated clinical mastitis and pregnancy status on culling in Swedish dairy cows. *Preventive Veterinary Medicine* 80: 179–192.
- Sheldon, I. M., Lewis, G. S., LeBlanc, S., and Gilbert, R. O. 2006. Defining postpartum uterine disease in cattle. *Theriogenology* 65: 1516–1530.
- Siegel, R. L., Ward, E. M., and Jemal, A. 2012. Trends in colorectal cancer incidence rates in the United States by tumor location and stage, 1992–2008. *Cancer epidemiology, biomarkers and prevention: a publication of the American Association for Cancer Research, cosponsored by the American Society of Preventive Oncology* 21: 411–416.
- Sørensen, H. T., Sabroe, S., and Olsen, J. 1996. A framework for evaluation of secondary data sources for epidemiological research. *International Journal of Epidemiology* 25: 435–42.
- Sparks, P., and Shepherd, R. 1992. Self-identity and the Theory of Planned Behavior: Assessing the role of identification with “Green Consumerism”. *Social Psychology Quarterly* 55: 388–399.
- Stapelfeldt, C. M., Jensen, C., Andersen, N. T., Fleten, N., and Nielsen, C. V. 2012. Validation of sick leave measures: self-reported sick leave and sickness benefit data from a Danish national register compared to multiple workplace-registered sick leave spells in a Danish municipality. *BMC Public Health* 12: 661–671.
- Stewart, D. W., and Kamins, M. A. 1999. Secondary research - information sources and

- methods. California: SAGE Publications, Inc. pp. 168.
- Sverdrup, U. 2005. Administering information: Eurostat and statistical integration. Centre for European Studies, University of Oslo. pp. 31.
- Swedish Dairy Association. 2012. Svensk Mjölk statistik [Swedish milk statistics]. Retrieved May 2, 2013, from <http://www.svenskmjolk.se/Statistik/#.UYIlfiuPhY4>
- Thiru, K., Hassey, A., and Sullivan, F. 2003. Systematic review of scope and quality of electronic patient record data in primary care. *British Medical Journal* 326: 1070-1072.
- TINE Rådgiving. 2012. TINE SA. Norway dairy statistics. Retrieved November 5, 2012, from <https://medlem.tine.no/tp/page?id=647>.
- Vaarst, M., Paarup-Laursen, B., Houe, H., Fossing, C., and Andersen, H. 2002. Farmers' choice of medical treatment of mastitis in Danish dairy herds based on qualitative research interviews. *Journal of Dairy Science* 85: 992-1001.
- Valde, J., Lawson, LG, Lindberg, A, Agger, J. F., Saloniemi, H., and Østerås, O. 2004. Cumulative risk of bovine mastitis treatments in Denmark, Finland, Norway and Sweden. *Acta Veterinaria Scandinavica* 45: 201-210.
- Vartanian, T. P. 2011. Secondary data analysis. New York: Oxford University Press, Inc. pp. 216.
- Waldenström, U., Gottvall, K., and Rasmussen, S. 2012. Caesarean section in nulliparous women of advanced maternal age has been reduced in Sweden and Norway since the 1970s: a register-based study. *International Journal of Obstetrics and Gynaecology* 119: 1591-1596.
- Ward, M., and Kelman, M. 2011. Companion animal disease surveillance: a new solution to an old problem? *Spatial and Spatio-temporal Epidemiology* 2: 147-157.
- Ware, W. A., and Hopper, D. L. 1999. Cardiac tumors in dogs: 1982-1995. *Journal of Veterinary Internal Medicine* 13: 95-103.
- Wide-ranging Online Data for Epidemiologic Research (WONDER). 2013. Center for Disease Control. Retrieved March 1, 2013, from <http://www.healthdata.gov/data/dataset/wide-ranging-online-data-epidemiologic-research-wonder>
- Witsberger, T., Villamil, J., Schultz, L., Hahn, A., and Cook, J. 2008. Prevalence of and risk factors for hip dysplasia and cranial cruciate ligament deficiency in dogs. *Journal of the American Veterinary Medical Association* 232: 1818-1824.
- Wolff, C., Espetvedt, M. N., Lind, A.-K., Rintakoski, S., Egenvall, A., Lindberg, A., and Emanuelson, U. 2012. Completeness of the disease recording systems for dairy cows in Denmark, Finland, Norway and Sweden with special reference to clinical mastitis. *BMC Veterinary Research* 8: 131-143.
- Youngquist, R. S., and Threlfall, W. R. 2007. Current therapy in large animal Theriogenology. Philadelphia: Saunders, Elsevier Inc. pp. 1032.