


## Use of Routinely Collected Registry Data for Undergraduate and Postgraduate Medical Education in Denmark

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### Introduction

Medical education needs to evolve continuously to meet the new requirements created by the ever-changing medical landscape [1]. Changes in patient demographics, comorbidity burden, knowledge, and expectations regarding involvement in treatment decision-making make future patients different from previous ones [1,2]. Also, the development of new technologies, increased specialisation anticipations, and expectations regarding work-life balance demand a new skill set from future physicians [1]. It is thus important to align both the undergraduate and postgraduate medical education with the requirements of the next generation of physicians and patient needs, where research based on big data will be essential [1].

Denmark has a long tradition of epidemiological research [3]. Thanks to the routinely collected administrative and health data in its national registries [4] and the many established clinical quality databases [5], Denmark holds a large potential for population-based research. This review aims to summarise (1) the Danish healthcare system and its types of registry data, (2) the Danish undergraduate and postgraduate medical education including their research training elements, and (3) the advantages and disadvantages of using registry data in medical education.

### The Danish Healthcare System

#### Organisation

The Danish Ministry of Health establishes the overall guidelines of healthcare provisions and legislates on the

responsibilities for the five Danish regions and 98 municipalities [4]. The regions provide free access to general practitioners, emergency medical services, and both somatic and psychiatric hospitals [4]. The municipalities provide free access to general welfare services like home nursing, rehabilitation, physiotherapy (partly compensation), and treatment of alcohol and drug abuse [4]. In 2014, patient payment accounted for 16% of all healthcare expenditures and public expenditures on healthcare services funded by general taxes accounted for 84% [6]. Hospital-provided drugs are free of charge [6] and prescription drugs redeemed at Danish community pharmacies are reimbursed according to annual drug expenditure [7]. In patients above 18 years of age, the percentage of drug expenditures reimbursed are 0% below 136 euros, 50% from 136 to 227 euros, 75% from 227 to 492 euros, 85% from 492 to 2,669 euros, and 100% above 2,669 euros, *i.e.* annual drug expenditure cannot exceed 574 euros [4,7].

#### Civil Registration System

To collect taxes, it has been required by law since 1968 that the Danish Civil Registration System (CRS) registers all children born by a mother already in the CRS, individuals with their birth registered within a Danish church registry, and legal immigrants living in Denmark for at least three months [8]. When registered within the CRS, each individual receives a 10-digit Civil Personal Registry (CPR) number functioning as a personal identifier with the first six digits representing the birthdate (DDMMYY) and the last four digits representing a unique serial number

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enabling distinguishing between individuals born on the same day [8]. The CPR number follows the person from registration within the CRS until death, emigration, or disappearing (residency unknown to the Danish government) of which data is updated daily Monday through Friday [8]. All Danish electronic administrative and medical registries and databases use the CPR number as a personal identifier allowing linkage between the different registries and databases on an individual level [8].

### **Routinely Collected Health and Administrative Data**

To an epidemiologist, the Danish population constitutes an open cohort, with diverse health-related data recorded between defined entry and exit dates [9,10]. The Danish government has for many years routinely collected a large variety of health data organised in databases [4]. A medical database defines a registry or database comprising some form of health-related data (Figure 1) [11]. These medical databases are categorised as administrative, health, and clinical quality databases (Figure 1) [4]. If such a database covers all residents in a given geographic area within a given time, it is considered a *population registry* (e.g. the CRS) [8,12]. If a database is characterised by holding information on a specific set of variables from all residents in a given geographic area within a given time, it is considered a *population-based registry* [12].

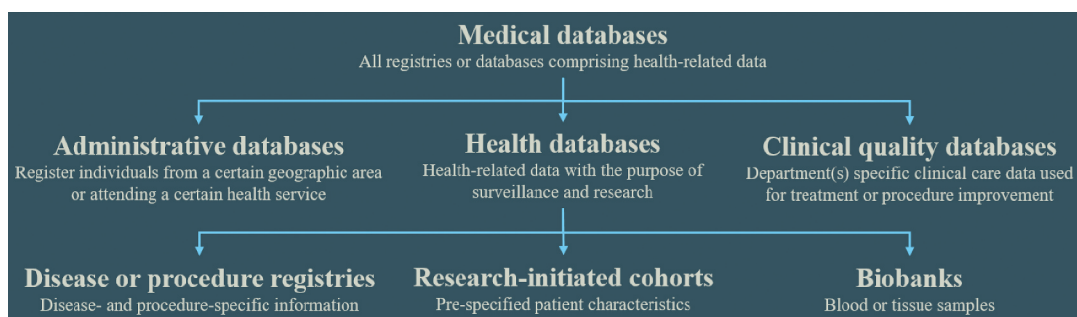
### **Categorisation of Data**

Administrative databases register individuals from a certain geographic area or attending a certain health service (e.g. hospital department or out-patient clinic). The CRS is an administrative database. Other types of information in Danish administrative databases include hospital encounters [13], prescription redemptions

[14], and laboratory results [15]. Figure 2 displays examples of such databases. Health databases include, e.g. disease registries containing information on the time of diagnosis or treatment for a specific disease (e.g. the Danish Cancer Registry) [16], procedure registries containing information on time and type of procedure and other procedure-specific data (e.g. the Western Denmark Heart Registry) [17], and biological biobanks containing blood and tissue samples. Clinical quality databases aim to use clinical care data to improve treatment of specific diseases or clinical procedures, to improve management of specific departments, and for research [18,19]. Currently, the Danish Clinical Quality Program – National Clinical Registries (RKK) has listed 84 clinical quality databases [20] categorised into (1) heart/vascular, surgery, and emergency (e.g. the Danish in-hospital cardiac arrest registry) [21], (2) cancer and cancer screening (e.g. the Danish Colorectal Cancer Group Database) [22], and (3) psychiatry, gynecology/obstetrics, and chronic diseases (e.g. the Danish Depression Database) [23].

### **Data Protection**

Registry data are protected according to Danish legislation upheld by an independent authority, the Danish Data Protection Agency [24]. The responsible research organisation (referred to as the controller) must comply with appropriate technical and organisational measures regarding data protection [24]. These measures include incorporation of up-to-date IT security systems and research organisation data handling. Further, the researcher is never permitted to present data allowing identification of specific individuals, which practically translates to not presenting micro-data, (*i.e.*  $\leq 3$  or  $\leq 5$  observations presented within a single stratum). In case a complaint of a personal data security breach is filed, the Danish Data Protection Agency makes an investigation [25]. The Danish Data Protection Agency then,



**Figure 1.** Classification of the Danish medical databases.

Modified from Schmidt M et al. Clin Epidemiol 2019;11:563–91 [4].



**Figure 2.** Examples of Danish registry data.

With permission from the Department of Clinical Epidemiology, Aarhus University Hospital, Denmark

in mild situations, ends the case directly after the filed complaint (with or without further hearing), or, in more severe cases, conducts additional hearings for further clarification [25]. The severity of the data breach is based on the character and size of the data breach, the type of the involved person-specific data, whether actions regarding optimisation of data protection have been taken by the researcher and/or research organisation, and whether the affected individuals have been informed [25]. The results of the investigation range from demanding certain actions by the research organisation to filing a police report [25].

### **Data Access**

Previously, data access was based on permission from the Danish Data Protection Agency. Today, the

researcher (or research institution) registers the project to an internal record, which for researchers (or research institutions) affiliated with Aarhus University is done online at the Aarhus University webpage [26]. All projects then receive a specific record number. The university is obliged to present the record to the Danish Data Protection Agency upon request allowing the Danish Data Protection Agency to oversee all research projects [26]. Hereafter, data access is granted by the Danish Health Data Authority [27] or Statistics Denmark [28]. Access to the Danish Health Data Authority data is via approval of an online application form. Access to data from Statistics Denmark is via application approval from a staff member at Statistics Denmark. The applicant for data access must submit the received record number, documentation that the required data satisfy the General Data Protection Regulations, a thorough project description, a list of

required registries, a list of the variables needed from each registry for the project, and a specified study period. The applicant further states financial details and who is responsible for the project. To be granted access to data from the Danish Health Data Authority or Statistics Denmark, the applicant must work at or in collaboration with an authorised research environment [27,28]. In Denmark, research projects only using registry data do not need informed consent from individuals in the study cohort or ethical approval by the Danish National Committee on Health Research Ethics [29]. The researcher receives access to the applied data via an online portal. Before handing over to the researcher, the data is pseudonymized (*i.e.* the person-specific CPR number is changed to an arbitrary number) so the data cannot be attributed to a specific individual without the use of additional information. With permission, it is possible to upload and link own pseudonymized data to Danish registry data.

### Undergraduate Medical Education

In Denmark, undergraduate medical education consists of six years of medical school. Below we describe the structure of the Danish undergraduate medical education and its compulsory and elective research elements.

### Medical School

#### Structure

Students in Denmark may enrol in a medical school immediately after high school graduation. The medical education consists of a three-year Bachelor's program [30–33], after which the medical student receives a Bachelor of Science (BSc) in Medicine degree. The Bachelor's program is followed by a three-year Master's program, culminating in a Master of Science (MSc) in Medicine [34–37]. Medical students can enrol in medical school at any of the four Danish universities: the University of Copenhagen, Aarhus University, Aalborg University, and the University of Southern Denmark. Figure 3 displays the Danish universities and university hospitals. Similarities among the four schools include a focus on the healthy human body during the Bachelor's program and on diseases and clinical practice during the Master's program.

Clinical practice experience is achieved through observational, case-based, and peer-assisted learning at Danish university and regional hospitals. To provide medical students the opportunity to influence their education and thereby encourage specific interests, all four medical programmes offer several elective courses, individualised clinical stays (both national and international), or research activities. Content dissimilarities



**Figure 3.** Danish universities providing undergraduate medical education and university hospitals.



between the four schools include combining the anatomy, physiology, and biochemistry of all organs into three distinct courses at Aarhus University instead of learning the anatomy, physiology, and biochemistry of each organ at a time as is the case at the other three universities. Structural dissimilarities between the four schools include a more case-based learning approach at Aalborg University and the University of Southern Denmark compared with a more lecture and classroom-based learning approach at Aarhus University and the University of Copenhagen. The University of Southern Denmark deviates from the other universities by dividing one school year into four quarters instead of two semesters. Each semester or quarter is completed by passing one or several exams. If needed or desired, Danish medical students can transfer between universities. Figure 4 shows the structure of the Danish undergraduate and postgraduate medical education including the compulsory and elective research elements, which we will further elaborate on below. Because of minor differences in the compulsory and elective research elements among the Danish medical schools, we use the structure at Aarhus University as an example.

### Compulsory Research Elements

During the Bachelor's program, medical students enrol in the compulsory course "Epidemiology and Biostatistics" [30]. This 10 European Credit Transfer and Accumulation System (ECTS) course, offered during the fourth semester, covers the fundamentals of statistical and epidemiological principles and methods to enable understanding and critical evaluation of peer-reviewed reports of epidemiologic studies. Key theoretical topics covered in the course include epidemiological study designs and measures of occurrence and association; basics of causal inference including common sources of confounding and other biases; and

special clinical topics, such as properties of diagnostic tests. Biostatistics topics include the main type of descriptive and inferential analyses (expected values, stratification, standardisation, and regression-based methods) [38]. Medical students may be offered to read and critically evaluate epidemiological studies as the first-time acquaintance with registry data. The course explicitly prepares medical students for the fifth-semester elective Bachelor's project and the subsequent compulsory course in public health.

During the fifth semester of the Bachelor's program, medical students must participate in either a theoretical (10 ECTS) or empirical (15 ECTS) Bachelor's project [30]. Thus, because the focus of the Bachelor's project is elective, it serves as a good opportunity for faculties to identify highly motivated medical students. Within a Bachelor's project, medical students are assigned to a senior supervisor from the health faculty according to their interests and supervisor availability. Together with the supervisor, medical students learn the steps of a research investigation from formulating a research question to reporting and interpreting study results. The student chooses to do either laboratory or epidemiological research. A theoretical project typically entails a critical literature review. An empirical project adds a practical element, such as basic data analysis. In epidemiology, options include meta-analyses, analyses of aggregated data (from public domains, see later), or simple analyses of "mockup" (*i.e.* practice) data generated by the supervisor or of data collected by the student. Up to three medical students may work on one Bachelor's project, which is graded by an external censor. Because Bachelor's projects are semester-long, students are expected to practice technical issues, rather than generate new results or a publication; however, in rare cases, a Bachelor's project may grow into a peer-reviewed publication. An empirical Bachelor's project is a good opportunity for medical students to

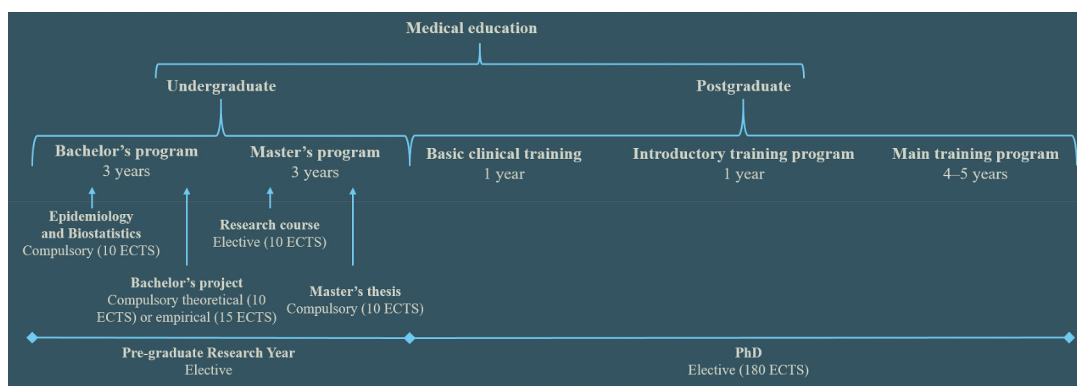


Figure 4. Undergraduate and postgraduate medical education in Denmark\*.

Abbreviation: ECTS, European Credit Transfer and Accumulation System\*Based on the structure at Aarhus University

gauge their potential research interest, specifically in public health and clinical epidemiology.

During the Master's program, a 10-ECTS research course is offered during the third semester as an option in an interest-specific elective course [34]. Other options in this course include innovation and an extended clinical stay [34]. Over the eight-week research course, students conduct full-time research at a research facility affiliated with the university, supervised by a senior researcher. At the end of the course, the student submits a product conducted during the eight weeks (e.g. a protocol, poster, or abstract). The course aims at strengthening the student's methodological and academic approach to problem-solving.

A Master's thesis is a compulsory 10-ECTS course offered during the fourth semester of the Master's program [34]. The Master's thesis is similar to the Bachelor's thesis in structure and is also supervised by a senior researcher. The Master's thesis introduces a more formal research process, whereby medical students must document skills in formulating and sharpening a hypothesis and the corresponding research question, propose and justify the selected methods, discuss the underlying theory, communicate the research purpose and results with the general public, and generate or collect own data provided by the supervisor or data based on literature studies [39]. The resulting thesis is expected to follow the Introduction, Methods, Results, and Discussion (IMRAD) structure and be written in English.

### **Elective Research Elements**

Danish medical students have the opportunity to take a 12-month leave from medical school to do full-time research at a research institution affiliated with their university [40]. The medical student will during this Pre-graduate Research Year take lead on a pre-specified research project and thereby acquire the knowledge to conduct research from the protocol to the publication stage. The Pre-graduate Research Year thus bridges the research gained during medical school and the PhD program. Preferably, the output of the Pre-graduate Research Year is a publication of an article in an international peer-reviewed journal. Should the Pre-graduate Research Year project not be published before the end of the year, the medical student is expected to complete the work next to the resumed medical studies.

After deciding on the main type of research and speciality of interest, the medical student contacts a relevant supervisor. To facilitate contact between medical students and potential supervisors, the Danish Society for Medical Student Research hosts an

annual event entitled *Research dating*, where researchers can advertise Pre-graduate Research Year projects for the medical students [41]. The Danish Society for Medical Student Research has furthermore created an online research project portal where researchers can post potential Pre-graduate Research Year projects [42]. The medical student applies for enrolment as a Pre-graduate Research Year student through the drafting of an application together with the supervisor. The application should contain a project description, a motivational letter, the planned scientific output, a list of supervisors (one principal and up to three co-supervisors), and a funding plan [43]. Medical students can apply for funding from Aarhus University simultaneously with the application. A Pre-graduate Research Year committee from Aarhus University, constituting researchers within a variety of fields, evaluates the applications [44]. After enrolment, the medical student (now Pre-graduate Research Year student) conducts full-time research and thereby learns about data acquisition (e.g. laboratory experiments, patient examination, or data management on registry data), data analysis, scientific writing, and project communication. The Pre-graduate Research Year student is encouraged to attend research-relevant courses (e.g. epidemiology, biostatistics, and scientific writing) provided by the PhD school [45], journal clubs, and national or international conferences. The Danish Society for Medical Student Research host an annual congress with participation from more than 100 undergraduate medical students from all Danish universities [46]. The Pre-graduate Research Year may include an international research stay planned and financed by the Pre-graduate Research Year student and supervisors. The Pre-graduate Research Year officially ends after 12 months, after which the principal supervisor reports whether the Pre-graduate Research Year was completed satisfactorily. The Pre-graduate Research Year student subsequently returns to medical school.

### **Postgraduate Medical Education**

The Danish postgraduate medical education consists of a 1-year basic clinical training program, a 1-year introductory training program, and a 4 – or 5-year main training program. Further, the medical doctor may apply to engage in a 3-year PhD program. Below we describe the desired skills obtained during the postgraduate medical education and the structure of its elements.

## **The Seven Roles of the Physician**

All postgraduate medical education in Denmark is based on “the seven roles of the physician”, a concept originally defined by the Fellows of the Royal College of Physicians and Surgeons of Canada [47]. These seven core roles required for high-quality patient care include medical expert, communicator, collaborator, manager/administrator/organiser, health advocate, scholar/researcher/teacher, and professional and are incorporated into the learning objectives of all specialities [48]. Thus, the individual employers are responsible for implementing skill training within each role through some pre-defined elements stated by the Danish Commission on Medical Specialists – the set of skills depending on the speciality. Such training can be through everyday clinical work, supervision from more experienced medical doctors, and compulsory education like the teaching of speciality relevant theory, practicing of speciality relevant procedures, and research training [47–49].

## **Basic Clinical Training Program**

After medical school, the first clinical postgraduate year – referred to as a “basic clinical training” year – generally contains six-month employment at an emergency, internal medicine, or surgical department combined with six-month employment at a general practitioner [50]. After completion of the basic clinical training, the medical doctor can apply for “the right to practice medicine independently” [51], which is a pre-requisite for applying for further medical education for the 39 Danish medical specialities [48,49]. The postgraduate medical education for these specialities involves both an introductory and a main training program.

## **Introductory Training Program**

The introductory training program contains one year of employment within one speciality and allows when completed, the medical doctor to apply for the main training program of that same speciality. Completion of some introductory training programs (e.g. some internal medicine and surgical specialities) allow an application to several main training programs within comparable specialities (e.g. an introductory training program in cardiology allows the medical doctor to apply for the main training program in respiratory medicine). There is no upper limit on the number of introductory training programs the medical doctor can apply for [48,49].

## **Main Training Program**

The main training program (residency) consists of a series of employments at different hospital departments, general practitioners, and other public or private institutions each lasting from three to 36 months. The total length of the main training program is between 48 and 60 months of which typically 24 months are within the specific speciality [49]. The medical doctor can after completion of the main training program apply for the title of medical specialist within the specific speciality at the Danish Patient Authority [52].

## **PhD**

The Danish PhD is a 3-year program (equivalent to 180 ECTS points) and aims to qualify the medical doctor in research, teaching, and development tasks at an international level within both the private and public sectors [53]. According to the seven roles of the physician, the PhD program provides skills both within the roles of communicator, collaborator, manager/administrator/organiser, scholar/researcher/teacher, and professional [47]. The ministerial PhD Order published by the Ministry of Higher Education and Science contains the requirements of the PhD program. Admission to the PhD program requires a Master’s degree or a corresponding education – except for the integrated PhD (also referred to as the MD-PhD), where the medical student initiates the PhD program during the Master’s program and receives the Master’s degree while enrolled in the PhD program.

The process of applying for PhD program enrolment and funding differs depending on the applicant and graduate school. Usually, the medical doctor contacts a potential principal supervisor within his or her research area, and together the two (with potential co-supervisors) prepare the application to the institution including a PhD project description and financing plan. However, the medical doctor can also prepare the project description independently or be provided one by the supervisor [54]. Regardless, it is the individual institution that evaluates the applications and decides who is accepted into the PhD program. The criteria by which the institution judges the applications are pre-specified [55]. Typically, applicants can seek part or all of the necessary funding as well as enrolment at their chosen graduate school. Other funding sources include private and public funding agencies. Funding should cover all research-related expenses (including the PhD student’s salary). The principal supervisor is officially designated upon

enrolment and must be a recognised researcher within the relevant research field employed at the institution at which the PhD student will be enrolled. The principal supervisor oversees all elements of the PhD student's program [55], whereas co-supervisors provide expertise complementing that of the principal supervisor.

The PhD program consists of five elements: (1) carry out a research project independently, (2) complete the PhD thesis based on the research project, (3) participate in six months' worth of accredited PhD courses, (4) attain teaching experience or similar knowledge dissemination, and (5) participate in research environments including a change to a preferably foreign research institution [53]. The PhD student can both be employed at a hospital department, at a university (and then affiliated with a hospital department), or at a private company (the latter known as an industrial PhD). A PhD student affiliated with a hospital department can be employed as a clinical assistant. If so, the department can require the student to take part in the ongoing clinical work [56]. The PhD program ends with a public defence of the PhD thesis, after which, provided satisfactory results, the PhD degree is awarded by the universities or higher educational institutions. The universities need to conduct research and have a PhD school within a specific research field to be allowed to award PhD degrees within that field [55].

## Use of Registry Data in Medical Education

Registry data can be used in both undergraduate and postgraduate medical education. We elaborate on these advantages and disadvantages of using registry data for medical education below and in Table 1.

### Use in Undergraduate Medical Education

Because of legal requirements for accessing Danish registry data, medical students usually cannot access individual-level data as part of their Bachelor's project or Master's thesis. However, medical students have several opportunities to work with aggregate data from Danish databases. In many cases, such aggregated data are provided by Danish government agencies as freely available online data in an analysis-friendly format. Table 2 shows an overview of such aggregated data sources and the accessible data. Statistics Denmark maintains aggregate data on age, sex, and calendar year specific population sizes, births, deaths, migrations, and income from the same data that is used in the Danish socioeconomic registries [57]. Aggregate data on hospital encounters by diagnostic code, setting (in/outpatient), and calendar year are publicly available from the Danish National Patient Registry and include statistics on disease groups, operations, hospital departments, radiologic exams, and drug poisonings and suicide attempts [58]. Aggregate data on gross sales of

**Table 1.** Advantages and disadvantages of using registry data for medical education.

	Advantages	Disadvantages
Methodology	<ul style="list-style-type: none"> <li>Advanced training in epidemiology and biostatistics</li> <li>The learned methodology can be applied to various medical fields</li> </ul>	<ul style="list-style-type: none"> <li>Potential down-prioritisation of other research methodologies, e.g. laboratory tests, clinical procedures, and examinations</li> </ul>
Public-domain aggregated data	<ul style="list-style-type: none"> <li>Nationwide</li> <li>Population-based</li> <li>Freely available</li> <li>No data permission required</li> </ul>	<ul style="list-style-type: none"> <li>Only limited data are available</li> <li>Individual-level data not available</li> <li>Most often not possible to link to other registries</li> <li>Many research questions cannot be answered with aggregated data</li> <li>Susceptible to ecological bias</li> </ul>
Individual-level data	<ul style="list-style-type: none"> <li>Nationwide</li> <li>Population-based</li> <li>Linkage of various registries possible using the person-specific Civil Personal Registry number</li> <li>Virtually complete follow-up owing to the Danish Civil Registration System</li> </ul>	<ul style="list-style-type: none"> <li>Waiting time for access to data</li> <li>To ensure data protection and permissions are upheld, official affiliation to a research institution is often required for access to data</li> <li>Temptation for data-driven instead of hypothesis-driven research</li> <li>Evaluation of validity and completeness of routinely collected data must be stressed when using them</li> </ul>
Talent recruiting	<ul style="list-style-type: none"> <li>Possible to identify medical students motivated for epidemiological research</li> <li>Annual meetings hosted by the Danish Society for Medical Student Research</li> <li>Online research project portal created by the Danish Society for Medical Student Research</li> <li>Possible continued affiliation with the same epidemiological research facility from Bachelor's project, through a Pre-graduate Research Year, to a PhD</li> </ul>	<ul style="list-style-type: none"> <li>No compulsory stay at an epidemiological department during medical school requires active identification of medical students by researchers/research departments</li> </ul>



**Table 2.** Overview of aggregated registry data available in public domain.

Public domain (data source)	Type of data	Examples of accessible data
Statistics Denmark*	Aggregated data on demographic	<ul style="list-style-type: none"> <li>Population sizes, births, and deaths by calendar year, region/municipality, sex, and age group</li> </ul>
	Aggregated data on employment, income, and assets	<ul style="list-style-type: none"> <li>Employment status by calendar year, region/municipality, sex, and age</li> <li>Income amount/type by calendar year and region/municipality</li> <li>Family/household asset amount/type by calendar year, region/municipality, sex, and age group</li> </ul>
	Aggregated data on living prices and expenses	<ul style="list-style-type: none"> <li>National gross domestic product by industry/sector and calendar year</li> <li>Public expenses by sector and calendar year</li> </ul>
	Aggregated data on living conditions	<ul style="list-style-type: none"> <li>Population size on social support, pension (state/early retirement), and maternity/paternity pay by calendar year, sex, and age group</li> <li>Number/type of reported/convicted offences by calendar year</li> </ul>
	Aggregated data on education and knowledge	<ul style="list-style-type: none"> <li>Highest achieved education by region/municipality, parentage, calendar year, sex, and age group</li> <li>Public research expenses by type and calendar year</li> </ul>
	Aggregated data on geographic, environment, and energy	<ul style="list-style-type: none"> <li>Region/municipality area size by calendar year</li> <li>Industry energy usage by industry type and calendar year</li> <li>Electricity expenses by calendar year</li> </ul>
eSundhed† (The National Patient Registry) <sup>[13]</sup>	Aggregated data on nationwide non-psychiatric hospital contacts since 1977 and outpatient and emergency contacts since 1995	<ul style="list-style-type: none"> <li>Number of hospital diagnoses by diagnosis group, diagnosis type (inpatient/outpatient/emergency room), calendar year, region, sex, and age group</li> <li>Number of drug poisonings/suicide attempts by calendar year, sex, and age group</li> <li>Number of operations by operation type (inpatient/outpatient/emergency room), calendar year, sex, and age</li> <li>Number of radiological examinations by region, calendar year, sex, and age group</li> </ul>
eSundhed† (The Danish National Prescription Registry) <sup>[14]</sup>	Aggregated data on nationwide community pharmacy dispensing since 1995	<ul style="list-style-type: none"> <li>Users/dispensings of antibiotics (total/per capita) by ATC code, calendar year, sex, and age group</li> <li>Defined daily doses (total/per user) of antibiotics by ATC code, region/municipality, calendar year, sex, and age group</li> <li>Drug sales by ATC and calendar year</li> </ul>
eSundhed† (The Danish Cancer Registry) <sup>[16]</sup>	Aggregated data on nationwide cancer incidence since 1943	<ul style="list-style-type: none"> <li>Incidence of cancer diagnoses by cancer type, sex, and age group</li> <li>Survival (1-/3-/5-/10-year) by cancer type, region, and calendar year</li> </ul>
eSundhed† (The Danish Register of Causes of Death) <sup>[65]</sup>	Aggregated data on causes of death in Denmark since 1943	<ul style="list-style-type: none"> <li>Number of cause-specific deaths by region</li> </ul>
MEDSTAT‡ <sup>[59]</sup>	Aggregated data on gross sales of drugs in the Danish primary health care sector since 1996 (including over-the-counter sales) and the hospital sector since 1997	<ul style="list-style-type: none"> <li>Revenue, amount sold (total/per capita), different individuals (total/per capita), and reimbursement by drug group/ATC code by region, sector (primary/secondary), calendar year, sex, and age group</li> <li>Aggregate amounts of prescription drugs in hospital stock</li> </ul>
Danish Heart Statistics§ <sup>[63]</sup>	Aggregated data on diagnoses, examinations, therapy, and prognosis of cardiovascular diseases since 2006	<ul style="list-style-type: none"> <li>Incidence/prevalence, (re)hospitalisations, mortality (30-day/1-year/5-year) by disease (e.g. myocardial infarction, deep vein thrombosis, and atrial fibrillation), region/municipality, calendar year, sex, age group, level of education, and ethnicity</li> <li>Number of patients/procedures and mortality (30-day/1-year) by procedure (e.g. percutaneous coronary intervention, coronary artery bypass grafting, and pacemaker implantation), region/municipality, calendar year, sex, age group, and level of education</li> <li>Number of patients by drug (e.g. anti-hypertensive, anti-thrombotic, and cholesterol-lowering) by region/municipality, calendar year, sex, age group, level of education, and ethnicity</li> </ul>

**Abbreviations:** ATC, Anatomical Therapeutic Chemical Classification code

\*[www.statistikbanken.dk](http://www.statistikbanken.dk)

†Selected registries listed in the table. For all available registries see [www.esundhed.dk/Registre](http://www.esundhed.dk/Registre)

‡[www.medstat.dk](http://www.medstat.dk)

§[www.hjerteforeningen.shinyapps.io/HjerteTal](http://www.hjerteforeningen.shinyapps.io/HjerteTal)

drugs from the Register of Medicinal Product Statistics are freely available online ([www.medstat.dk](http://www.medstat.dk)) [59]. This online resource allows, among other things, estimation of drug utilisation over time by age and sex [60], drug expenditure over time [61], and proportion of drugs dispensed by prescription [62]. Online linkage, already done on the public domain, between the Danish National Prescription Registry and Danish Medical Birth Registry, allows analysis of the use of drugs in pregnancy by individual drugs, calendar year, and trimester of use [63,64].

During a Pre-graduate Research Year in epidemiology, the student in several ways acquires competencies in data analysis similar to that of the PhD (see below). Because of limited time for planning, the protocol may be partly provided by the supervisor and is often based on already available data. Thus, the Pre-graduate Research Year student may not obtain knowledge about the data application process.

### **Use in Postgraduate Medical Education**

Epidemiological PhD projects use Danish registry data to conduct large population-based studies of both common and rare diseases [9]. Epidemiological PhD students get detailed insights into the strengths and limitations of the Danish registries. The PhD students will acquire knowledge regarding epidemiological methodology, including study designs, measures of effects and associations, statistical precision and calculations, and potential biases (selection bias, information bias, and confounding). To facilitate the acquisition of these skills, the PhD student attends epidemiology-specific courses, joins journal clubs focused on research methodology, and collaborates with professional epidemiologists and statisticians. Thus, an epidemiological PhD can to a higher degree than other types of research be regarded as a methodological PhD, which prepares the PhD student to apply the learned methodology in future research within their medical field of interest.

### **Summary**

The Danish healthcare system provides universal tax-financed healthcare providing free access to general practitioners, emergency medical services, and hospitals as well as partial reimbursement for prescription drugs to all Danish citizens. The person-specific CPR number allows linkage between the Danish registries on an individual level. Routinely collected administrative and health data make the entire Danish population, in epidemiological terms, an open cohort with

various data recorded between fixed entry and exit dates.

The Danish undergraduate medical education consists of a 3-year Bachelor's program and a 3-year Master's program both incorporating several research training courses. During the Bachelor's program, the medical student must complete the compulsory course "Epidemiology and Biostatistics" and decide on either a theoretical or an empirical Bachelor's project. During the Master's program, the medical student must complete a Master's thesis and further has the opportunity during an elective course to perform eight weeks of full-time research at a university-affiliated research department. Additionally, medical students can at any time during medical school apply for 12-month leave to do full-time research during a Pre-Graduate Research Year also at a university-affiliated research department. During postgraduate medical education, medical doctors have the opportunity to enrol in a 3-year PhD program.

Registry data are valuable for both undergraduate and postgraduate medical education. Because of legal requirements and time restrictions, undergraduate medical students usually cannot access individual-level data. However, several public domains provide free access to aggregated data available for data analyses. In postgraduate medical training, PhD students can access and work with individual-level nationwide registry data, providing optimal conditions for advanced epidemiological training.

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