Comorbidities in cerebral palsy: a patient registry study

SANDRA J HOLLUNG[1,2] | INGER J BAKKEN[3,4] | TORSTEIN VIK[2] | STIAN LYDERSEN[5] | ROBERT WIIK[4] | KARI M AABERG[6] | GURO L ANDERSEN[1,2]

1 Cerebral Palsy Registry of Norway, Vestfold Hospital Trust, Tønsberg; **2** Department of Clinical and Molecular Medicine, Norwegian University of Science and Technology, Trondheim; **3** Centre for Fertility and Health, Norwegian Institute of Public Health, Oslo; **4** Norwegian Directorate of Health, Trondheim; **5** Regional Centre for Child and Youth Mental Health and Child Welfare, Department of Mental Health, Norwegian University of Science and Technology, Trondheim; **6** National Center for Epilepsy, Oslo University Hospital, Oslo, Norway.

Correspondence to Sandra J Hollung, Cerebral Palsy Registry of Norway, Vestfold Hospital Trust, PB 2168, 3103 Tønsberg, Norway. E-mail: sandra.julsen.hollung@siv.no

PUBLICATION DATA
Accepted for publication 16th May 2019.
Published online

ABBREVIATION
NPR Norwegian Patient Registry

AIM To describe the total burden of disease in individuals with cerebral palsy (CP) in Norway.
METHOD A comprehensive set of disorder categories were extracted from the Norwegian Patient Registry using International Statistical Classification of Diseases, 10th Revision diagnosis codes for individuals born between 1996 and 2010 who received specialist healthcare between 2008 and 2017 (0–21y). Individuals with CP were identified through a validation study in cooperation with the Cerebral Palsy Registry of Norway. Risk differences (proportions of individuals recorded with each disorder) were used to compare individuals with CP with the general population without CP.
RESULTS The study included 966 760 individuals. Among these, 2302 (0.24%) had CP (1330 males, 972 females). Of the individuals with CP, 95.0% were recorded with one or more comorbidity, and the risks of medical, neurological, and mental/behavioural disorders were higher compared with the risks in the general population. The most common neurological and mental/behavioural disorders were cocausal, i.e. attributed to the same injury to the developing brain that caused CP, while medical disorders were most often complications of CP or coincidentally co-occurring with CP.
INTERPRETATION Individuals with CP have a considerably higher burden of medical, neurological, and mental/behavioural disorders compared with the general population, including disorders that are not directly caused by, or complications to, the brain injury.

Cerebral palsy (CP) is a group of permanent disorders of motor impairment resulting from a non-progressive injury in the developing brain.[1] The prevalence of CP has been reported to vary between 1.5 and 3.0 per 1000 live births.[2,3] However, in the past decades there has been a decline in the prevalence and severity of the disorder.[4–7] According to the latest definition of CP, motor impairments are often accompanied by 'disturbances of sensation, perception, cognition, communication, and behavior, by epilepsy, and by secondary musculoskeletal problems'.[8] This definition has led not only to an increase in the awareness of the occurrence of comorbidities in individuals with CP, but also of the need for interdisciplinary management of these comorbidities as they change over the lifespan.[9–12]

Brown et al. defined a comorbidity as any disorder associated with CP, but which can also occur as a stand-alone disorder in individuals without CP.[9] Furthermore, while some disorders may be caused by the same injury to the developing brain which caused CP (i.e. epilepsy and intellectual impairment), other disorders may be regarded as complications of the main CP condition (i.e. scoliosis and hip dislocation). Thus, Brown et al. categorized types of comorbidities in individuals with CP as comorbid (hereafter referred to as co-occurring), cocausal, and complications (Table I).[9] While disorders defined as cocausal and complications of CP are more likely to occur in individuals with CP, one might expect that coincidentally co-occurring disorders, i.e. those not caused by or complications of CP, would not be more common in this population than in the general population.

Furthermore, it is important to recognize that one comorbidity may influence another.[10] For example, oral motor impairments are often associated with eating difficulties, poor nutrition, and impaired growth. Moreover, a characteristic feature of oral motor impairment is disturbed coordination of swallowing and breathing and/or gastro-esophageal reflux, which may lead to aspiration of food into the trachea and lower respiratory tract, followed by choking and respiratory tract infections. Thus, comorbidities may adversely affect the quality of life and health of an individual with CP more than the motor impairment itself.

 DOI: 10.1111/dmcn.14307

The aim of this study was to describe the total burden of disease in individuals with CP in Norway, by comparing the occurrence of comorbidities in the population with CP with the same disorders in the general population. We also describe the overall distribution of cocausal, complications, and co-occurring comorbidities that are likely to be associated with CP.

What this paper adds

- Nearly all individuals with cerebral palsy (CP) had one or more comorbidity.
- Fifty-two per cent had at least one comorbidity attributed to the same cause as CP, complications of CP, and coincidentally co-occurring with CP.
- Risks of medical, neurological, and mental/behavioural disorders were considerably higher than in the general population.

METHOD

Study design and population

The data used in this study were obtained from the Norwegian Patient Registry (NPR). The NPR is a compulsory registry that records demographic, administrative, and clinical health data on all patients treated by the national specialist healthcare services, with person-identifiable data from 2008. This includes inpatient admissions and outpatient clinics at public general and psychiatric hospitals. The NPR provided data recorded between 2008 and 2017 for children and adolescents born between 1996 and 2010 (0–21y). The data included diagnosis codes grouped into disorder categories according to the International Statistical Classification of Diseases, 10th Revision (ICD-10; Table SI, online supporting information) and information on birth year and sex. In addition, ICD-10 CP diagnosis codes (G80.*) were added for individuals with CP previously identified through a validation study in cooperation with the Cerebral Palsy Registry of Norway.[3] All individuals with CP in Norway are diagnosed by a paediatrician in the specialized healthcare services, and are routinely seen by a multidisciplinary team. We included both transient and chronic disorders, ranging from mild to severe, excluding disorders unlikely to occur in children and adolescents (Table SI). Data from private hospitals were excluded because they account for a very small proportion of services. However, it is possible that some disorders may not have been recorded in the NPR. The total number of individuals born during the same time and residing in Norway as of 31st December 2017 by birth year and sex was obtained from Statistics Norway (https://www.ssb.no).

We further sorted each disorder category into three main groups: medical, neurological, and mental/behavioural to compare the occurrence of comorbidities in individuals with CP with the same disorders in the general population (Table SI). To assess the relative burden of comorbidities for individuals with CP, comorbidity categories were grouped into cocausal, complications, or co-occurring, as described by Brown et al.[9] (Table SII, online supporting information).

Table I: Comorbidity categories for individuals with cerebral palsy (CP), as proposed by Brown et al.[9]

Cocausal	Disorders caused by the same injury to the developing brain that caused CP (i.e. epilepsy and cognitive impairment)
Complications	Disorders that are complications of the main CP condition (i.e. scoliosis and hip dislocation)
Co-occurring	Disorders not caused by the injury to the developing brain, nor are complications of the main CP condition

Statistical analyses

In this study, risk was defined as the occurrence of a disorder, i.e. the number of individuals who were recorded with the disorder in the NPR, divided by the total number of individuals in the respective population. Risk differences with 99% Wald confidence intervals (CIs) were computed between individuals with CP and the general population without CP. We used 99% CIs because of the large number of comparisons. We also calculated the frequency distribution of ICD-10 CP diagnosis codes per comorbidity category and the mean number of comorbidities with standard deviation (SD) per CP diagnosis code. Stata 15.1 software (StataCorp LP, College Station, TX, USA) was used for the analyses.

Ethics approval

This study was conducted under the NPR Regulations 1 and 2. Data were delivered pursuant to NPR Regulations 3 to 5, in an anonymous form. Studies using anonymous data, where information cannot be traced back to an individual, do not require ethical approval.

RESULTS

In total, 966 760 Norwegian residents born between 1996 and 2010 were included. Among these, 691 003 were recorded in the NPR and 2302 (0.24%) had a validated diagnosis of CP. The distribution of ICD-10 CP diagnosis codes is shown in Table II. The proportion of males was slightly higher in the population with CP (n=1330, 57.8%) than in the general population (n=496 064, 51.4%).

Overall disorder occurrence

Of the individuals with CP, 95.0% had at least one recorded comorbidity, and 36.4% had at least one disorder within the three main groups of medical, neurological, and mental/behavioural disorders. In comparison, 45.3% of the general population were recorded with the same disorders, while only 2.9% had a disorder within the three main groups.

All medical disorders were more common in individuals with CP compared with their peers (Table III). The most common disorders among individuals with CP were musculoskeletal system and connective tissue diseases, affecting 49.8%, followed by diseases of the digestive system (39.1%), congenital malformations (non-nervous system; 33.6%), and respiratory diseases and infections (29.7% and 27.2% respectively). In the general population, the

Table II: Occurrence of comorbidity categories in individuals with cerebral palsy (CP) born between 1996 and 2010 by ICD-10 CP diagnosis code

Comorbidity category			Cocausal		Complications		Co-occurring	
ICD-10 code	ICD-10 text	*n* (%)	*n*	%	*n*	%	*n*	%
G80.0	Spastic quadriplegic	376 (16.3)	335	89.1	356	94.7	331	88.0
G80.1	Spastic diplegic	664 (28.8)	448	67.5	522	78.6	506	76.2
G80.2	Spastic hemiplegic	803 (35.0)	458	57.0	523	65.1	547	68.1
G80.3	Dyskinetic	129 (5.6)	110	85.3	111	86.0	110	85.3
G80.4	Ataxic	93 (4.0)	79	84.9	70	75.3	72	77.4
G80.8	Other (mixed)	29 (1.3)	25	86.2	23	79.3	24	82.8
G80.9	Unspecified (NOS)	208 (9.0)	157	75.5	162	77.9	163	78.4
	Total	2302 (100.0)	1612	70.0	1767	76.8	1753	76.2

Data recorded in the Norwegian Patient Registry between 2008 and 2017. ICD-10, International Statistical Classification of Diseases, 10th Revision; NOS, not otherwise specified.

occurrence of the same disorders varied between 7.6% (respiratory infections) and 13% (respiratory diseases; Table III). Moreover, individuals with CP had an excess risk of almost all medical disorders compared with the risk in the general population. This was most notable for the disorders mentioned above (risk difference 16.7–40.0%), in addition to malnutrition and eating difficulties (risk difference 21.7%, 99% CI 19.5–24.0%) and scoliosis (risk difference 14.3%, 99% CI 12.4–16.3%; Fig. 1).

Among individuals with CP, 60.9% had at least one recorded additional neurological disorder, while this was the case for 7.2% of their peers. The dominating neurological disorder in individuals with CP was epilepsy, diagnosed in 39.0% compared with 1.2% in the general population (Table III). The risks of epilepsy and 'neurological disorders – other' in individuals with CP were considerably higher than in the general population (Fig. 1). In addition, nervous and musculoskeletal system symptoms and congenital malformations of the nervous system occurred more often among individuals with CP (Table III), and the risk of sleep, cerebrovascular, and headache disorders were increased compared with the general population (Fig. 1).

Individuals with CP were also recorded more frequently with mental/behavioural disorders (53.8%) compared with the general population (14.2%). The risk of intellectual disability was considerably higher for individuals with CP (risk difference 27.4%, 99% CI 25.0–29.8%), observed in 28.1% compared with only 0.7% in the general population (Fig. 1 and Table III). Individuals with CP had an excess risk of psychological developmental disorders 16.8% (99% CI 14.7–18.9%) compared with their peers. Although the occurrence of all other mental/behavioural disorders was less than 10% in individuals with CP, the risk was higher than in the general population (Table III and Fig. 1).

Sex differences

Analyses showed that the excess risk of comorbidities was similar for males and females with CP compared with the general population. There was also no significant difference in risk for males versus females with CP (Table SIII, online supporting information).

Comorbidities among individuals with CP

Fifty-two per cent of individuals with CP had at least one disorder within the three comorbidity categories of cocausal, complications, and co-occurring (Fig. 2). Figure 2 also illustrates that less than 20% had only one comorbidity within either the cocausal (5%), complications (7%), or co-occurring (5%) categories. Table III shows that within the medical disorders group, most comorbidities were categorized as either complications or co-occurring, while less than 13% were categorized as cocausal. Similarly, four of the five disorders with the highest excess risk were complications of CP (musculoskeletal system and connective tissue diseases, digestive system diseases, malnutrition and eating difficulties, and respiratory infections). Within the group of neurological disorders, cocausal comorbidities such as epilepsy, nervous and musculoskeletal system symptoms, and congenital malformations of the nervous system were most common. Although, it may be noted that more than 25% had a 'neurological disorders – other' comorbidity, categorized as co-occurring. Within the group of mental/behavioural disorders, the majority of the most common comorbidities were categorized as cocausal (Table III).

Comorbidities according to ICD-10 CP subtype

As many as 98.4% of individuals with spastic quadriplegic CP had at least one comorbidity, and the proportion of disorders within the three comorbidity categories was higher in spastic quadriplegic CP than in any other subtype (Table II). Individuals with this subtype also had the highest mean number of comorbidities (mean 8.1 [SD 4.0]). However, individuals with other subtypes also had a high number of comorbidities ranging from a mean number of 3.6 (SD 3.0) among individuals with spastic hemiplegic CP to 6.5 (SD 3.5) for those with dyskinetic CP.

DISCUSSION

Main findings

In this national registry study, using validated CP diagnosis codes, we found that individuals with CP have a considerably higher burden of medical, neurological, and mental/behavioral disorders than the general population. The

Table III: Occurrence of comorbidities in individuals with cerebral palsy (CP) born between 1996 and 2010 versus the same disorders in the general population (GP)

		CP (*n*=2302)		GP (*n*=964 458)	
Disorder category	Comorbidity category[a]	*n*	%	*n*	%
Medical disorders		1994	86.6	461 010	47.8
Musculoskeletal system and connective tissue diseases (excl. scoliosis)	Complications	1147	49.8	95 124	9.9
Digestive system diseases	Complications	900	39.1	115 008	11.9
Congenital malformations (excl. nervous system)	Co-occurring	774	33.6	81 207	8.4
Respiratory diseases	Co-occurring	683	29.7	125 541	13.0
Respiratory infections	Complications	626	27.2	73 329	7.6
Malnutrition and eating difficulties	Complications	529	23.0	11 968	1.2
Skin and subcutaneous tissue diseases	Co-occurring	358	15.6	77 848	8.1
Scoliosis	Complications	346	15.0	6589	0.7
Intestinal infectious diseases	Co-occurring	250	10.9	25 552	2.6
Hearing impairment/deafness	Cocausal	214	9.3	18 353	1.9
Urinary tract disorders	Co-occurring	201	8.7	26 559	2.8
Endocrine disorders	Co-occurring	173	7.5	19 820	2.1
Genital disorders	Co-occurring	159	6.9	41 277	4.3
Blood disorders	Complications	131	5.7	10 954	1.1
Visual impairment/blindness	Cocausal	90	3.9	792	0.1
Circulatory system diseases	Co-occurring	89	3.9	12 515	1.3
Benign neoplasms	Co-occurring	80	3.5	25 278	2.6
Obesity	Complications	75	3.3	9856	1.0
Chromosomal abnormalities	Cocausal	69	3.0	3580	0.4
Metabolic disorders	Co-occurring	36	1.6	4039	0.4
Nutritional deficiencies	Complications	35	1.5	3031	0.3
Immune disorders	Co-occurring	29	1.3	1192	0.1
Dislocation of hip	Complications	21	0.9	177	0.0
Malign neoplasms	Co-occurring	19	0.8	2212	0.2
Neurological disorders		1403	60.9	69 710	7.2
Epilepsy	Cocausal	898	39.0	11 347	1.2
Neurological disorders - other	Co-occurring	666	28.9	20 567	2.1
Nervous and musculoskeletal system symptoms	Cocausal	423	18.4	16 843	1.7
Congenital malformations of nervous system	Cocausal	239	10.4	1962	0.2
Sleep disorders	Complications	192	8.3	8663	0.9
Headache disorders	Complications	132	5.7	23 891	2.5
Cerebrovascular diseases	Co-occurring	109	4.7	822	0.1
CNS infections and inflammatory diseases	Co-occurring	52	2.3	2520	0.3
CNS neoplasms	Co-occurring	17	0.7	914	0.1
Mental/behavioral disorders		1239	53.8	136 691	14.2
Intellectual disability	Cocausal	647	28.1	6997	0.7
Psychological developmental disorders (excl. autism)	Cocausal	449	19.5	26 200	2.7
Behavioral and emotional disorders	Cocausal	226	9.8	47 663	4.9
ADHD	Cocausal	193	8.4	37 516	3.9
Psychiatric disorders - other	Co-occurring	110	4.8	33 047	3.4
Autism	Cocausal	99	4.3	11 816	1.2
Anxiety disorders	Co-occurring	70	3.0	19 422	2.0
Depressive episode	Co-occurring	50	2.2	19 486	2.0
Eating disorders	Co-occurring	26	1.1	5096	0.5
Obsessive-compulsive disorder	Co-occurring	21	0.9	3826	0.4

Data recorded in the Norwegian Patient Registry between 2008 and 2017. [a]Comorbidity category refers only to individuals with CP. CNS, central nervous system; ADHD, attention-deficit/hyperactivity disorder.

majority (95%) of individuals with CP had at least one additional disorder, but somewhat surprisingly, nearly half (45%) of the general population were also recorded in the specialist healthcare services with the same mild-to-severe and transient-to-chronic disorders. However, while 36% of individuals with CP had at least one disorder within all the three categories of medical, neurological, and mental/behavioural disorders, this was only 3% for the general population.

For individuals with CP, the most common comorbidities within the neurological and mental/behavioural disorder categories were cocausal, i.e. caused by the same injury to the developing brain that caused CP. In the medical category, complications of the main CP diagnosis and comorbidities coincidentally co-occurring with CP were most common. Nonetheless, the proportion of individuals with comorbidities regarded as co-occurring with CP occurred just as often as cocausal and complications. Nearly all individuals with spastic quadriplegic CP had at least one comorbidity and, on average, more than eight. However, even individuals with spastic hemiplegic CP had an average of more than three comorbidities.

Strengths and limitations

A strength of this study is that it provides a comprehensive evaluation of mild-to-severe and transient-to-chronic

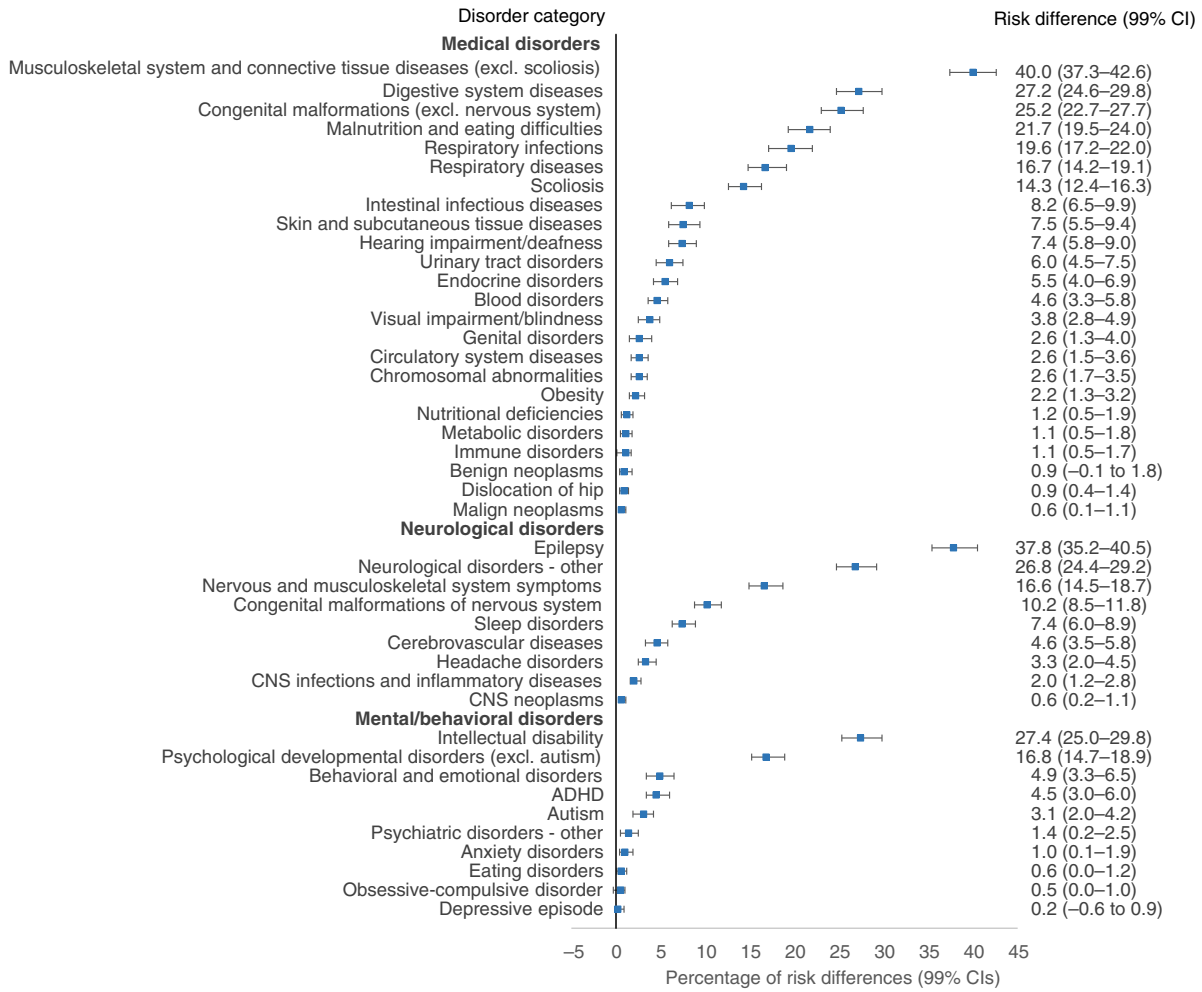

Figure 1: Risk differences with 99% confidence intervals (CIs) comparing the occurrence of disorders between individuals with cerebral palsy and the general population born from 1996 to 2010. CNS, central nervous system; ADHD, attention-deficit/hyperactivity disorder. [Colour figure can be viewed at wileyonlinelibrary.com]

comorbidities in individuals with CP, including a comparison of the distribution of the same disorders in the general population. In addition, we attempted to classify comorbidities associated with CP as cocausal, complications, or co-occurring, to gain a better understanding of how the brain injury may influence the overall burden of disease.

Another strength of this study is the reduction of selection bias by the use of data from a large, national, population-based registry. Moreover, the NPR has a service to evaluate the quality of diagnosis codes recorded in the NPR versus each of the Norwegian national quality medical registries,[13] where numerous studies have shown high completeness of data in the NPR. This includes a validation study of all CP diagnosis codes recorded in the NPR for individuals during our study period, in cooperation with the Cerebral Palsy Registry of Norway.[3] The completeness (sensitivity) of CP diagnosis codes in the NPR was reported to be 98%, and there was good agreement between the distribution of ICD-10 CP subtypes recorded in the NPR and the Cerebral Palsy Registry of Norway.[3] On the other hand, most of the remaining diagnosis codes have not been through a validation process, and, therefore, data quality may vary. Additionally, because the NPR became person-identifiable from 2008, data from before this time are missing. Although this information bias is a non-differential misclassification that applies to the entire population, it may result in an underestimation of risk of those disorders that are often recorded only at an early age.

Using diagnosis codes recorded in a national administration registry is not unproblematic. Data in this study solely describe those disorders recorded by the specialist healthcare services. Therefore, less severe disorders, such as respiratory infections, are underdiagnosed because they are often treated in the primary healthcare services, or because medical care is not sought for them. Moreover, there may be a disproportionately higher recording of milder

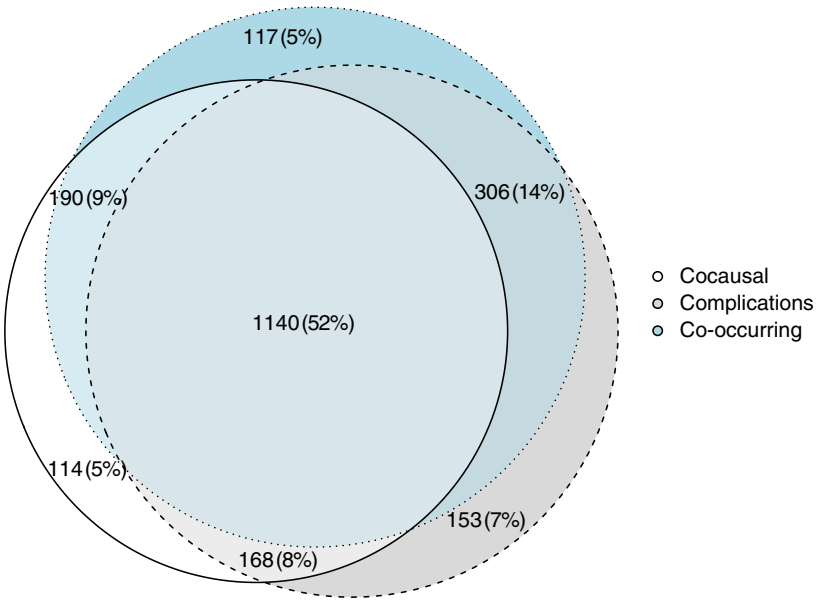

Figure 2: Area-proportional Venn diagram of the proportion of individuals with cerebral palsy per comorbidity category. [Colour figure can be viewed at wileyonlinelibrary.com]

conditions for individuals with CP, who are already being followed by the specialist healthcare services, than for the general population. In fact, because individuals with CP are continually followed-up by specialists, the chances of being diagnosed with a comorbidity and recorded in the NPR is increased (Berkson's bias).[14]

Also, because clinical information is not reported to the NPR, a 100% correct classification of disorders within the medical, neurological, and mental/behavioural disorder categories, as well as within the comorbidity categories (cocausal, complications, and co-occurring) in individuals with CP is not likely to be possible. This limitation is particularly evident regarding the categorization of mental/behavioural disorders, which can be regarded as either cocausal, a complication, or co-occurring with CP. For example, disorders such as anxiety and eating disorders, classified as co-occurring, may be more likely to develop in individuals with a vulnerability due to an early brain insult or the experience of being different from peers, and, therefore, may also be categorized as cocausal or complications. Thus, caution is needed in the interpretation of the exact proportions of each comorbidity category. However, this limitation does not affect the main results showing the high overall burden of disease in individuals with CP. It is also noteworthy that some co-occurring disorders (i.e. genital and immune disorders) that are not intuitively considered cocausal or complications were more commonly diagnosed in the population with CP than in the general population.

Comparison with other studies

Several studies have reported on the most common comorbidities associated with CP. In 2009, a smaller study was performed describing five comorbidities (cortical blindness, severe hearing impairment, non-verbal communication, gavage feeding, and seizures) in children born between 1999 and 2002 and recorded in the Quebec Cerebral Palsy Registry.[15] Although we are not able to compare distributions of comorbidities between that study and ours because of the explicit severity of their chosen comorbidities, and a lack of comparison with a control group, both studies found that children with more severe CP subtypes had a higher proportion and number of comorbidities.

Meehan et al. reported on paediatric hospital admissions between 2008 and 2012 for children born between 1993 and 2008 and registered in the Victorian Cerebral Palsy Register.[16] They used ICD-10 diagnosis codes to explore admission rates and found that 66% of children with CP had one or more hospital admission. This proportion is lower than in our study most likely because we included all hospitals in the country, as well as both inpatient admissions and outpatient consultations. Meehan et al. found respiratory disease was the most common medical disorder and musculoskeletal system diseases the most common surgical disorder; both are also among the most common medical disorders in our study. Lastly, Novak et al. performed a systematic review of the rates of 13 comorbidities in individuals with CP.[11] Although a comparison in proportions between this review and our study is difficult because of differences in the categorization of comorbidities, the proportion of individuals with epilepsy and hip dislocation were similar. However, Novak et al. reported a higher proportion of intellectual disability (49%) compared with 28% in our study, as well as 23% with a sleep disorder, compared with 8% in our study. Although the

findings of the aforementioned studies are consistent with our results of an increased risk of the same disorders, along with a higher occurrence for those with a more severe CP subtype, these studies lack a comprehensive evaluation of disorders, as well as a comparison to the general population.

Interpretation

The higher burden of disease in individuals with CP compared with their peers in the general population is mainly explained by the excess risk of disorders categorized as cocausal with CP as well as complications of CP. However, even disorders classified as coincidentally co-occurring with CP were significantly more common in individuals with CP than in the general population. Nevertheless, we speculate that for some comorbidities classified as co-occurring, the exact aetiology is unknown, and it is possible that the injury to the developing brain and/or complications of CP may directly or indirectly play a role. For some of these disorders (e.g. circulatory system diseases), the higher occurrence might be reasonable since they may be related to reduced physical activity, while a higher prevalence of metabolic and immune disorders is not as evident. In addition, some of the co-occurring comorbidities may have a common cause, or may be complications that are not apparent in registry-based data. Conversely, several of the comorbidities are not intuitively related to CP. Therefore, before reasonable speculations on mechanisms can be explained, more research should be undertaken and results confirmed in other populations.

CONCLUSION

Individuals with CP have a considerably higher burden of medical, neurological, and mental/behavioural disorders compared with the general population. As expected, comorbidities considered to be cocausal with CP or complications of CP were common. However, surprisingly, this was also the case for comorbidities regarded as coincidentally co-occurring with CP, i.e. that are not directly caused by or complications of CP. In addition, the majority of individuals with CP, regardless of subtype, had a high number of comorbidities. Thus, identification of comorbidities and appropriate interventions are necessary to minimize or prevent the impact they may have on participation and quality of life.

ACKNOWLEDGEMENTS

The Vestfold Hospital Trust provided funding for this study. The authors have stated that they had no interests that might be perceived as posing a conflict or bias.

SUPPORTING INFORMATION

The following additional material may be found online:

Table SI: Disorder categories based on ICD-10 diagnosis codes.

Table SII: Comorbidity categories based on ICD-10 diagnosis codes, and as described by Brown et al.[9]

Table SIII: Occurrence of comorbidities in individuals with cerebral palsy born 1996 to 2010 versus the same disorders in the general population born during the same years, per sex.

REFERENCES

1. Bax M. Terminology and Classification of Cerebral Palsy. *Dev Med Child Neurol* 1964; **6**: 295–7.
2. Oskoui M, Coutinho F, Dykeman J, Jetté N, Pringsheim T. An update on the prevalence of cerebral palsy: a systematic review and meta-analysis. *Dev Med Child Neurol* 2013; **55**: 509–19.
3. Hollung SJ, Vik T, Wiik R, Bakken IJ, Andersen GL. Completeness and correctness of cerebral palsy diagnoses in two health registers: implications for estimating prevalence. *Dev Med Child Neurol* 2017; **59**: 402–6.
4. Hollung SJ, Vik T, Lydersen S, Bakken IJ, Andersen GL. Decreasing prevalence and severity of cerebral palsy in Norway among children born 1999 to 2010 concomitant with improvements in perinatal health. *Eur J Paediatr Neurol* 2018; **22**: 814–21.
5. Hoei-Hansen CE, Laursen B, Langhoff-Roos J, Rackauskaite G, Uldall P. Decline in severe spastic cerebral palsy at term in Denmark 1999-2007. *Eur J Paediatr Neurol* 2018; **23**: 94–101.
6. Sellier E, Platt MJ, Andersen GL, et al. Decreasing prevalence in cerebral palsy: a multi-site European population-based study, 1980 to 2003. *Dev Med Child Neurol* 2016; **58**: 85–92.
7. Galea C, Mcintyre S, Smithers-Sheedy H, et al. Cerebral palsy trends in Australia (1995–2009): a population-based observational study. *Dev Med Child Neurol* 2019; **61**: 186–93.
8. Rosenbaum P, Paneth N, Leviton A, et al. A report: the definition and classification of cerebral palsy April 2006. *Dev Med Child Neurol* 2007; **49**(Suppl. 109): 8–14.
9. Brown JK, Eunson P, Bax M. Heterogeneity in cerebral palsy: variations in neurology, comorbidity and associated conditions. In: Bax M, Gillberg C, editors. Comorbidities in Developmental Disorders. London: Mac Keith Press, 2011: 20–39.
10. Pruitt DW, Tsai T. Common medical comorbidities associated with cerebral palsy. *Phys Med Rehabil Clin N Am* 2009; **20**: 453–67.
11. Novak I, Hines M, Goldsmith S, Barclay R. Clinical prognostic messages from a systematic review on cerebral palsy. *Pediatrics* 2012; **130**: e1285–312.
12. Baxter P. Comorbidities of cerebral palsy need more emphasis – especially pain. *Dev Med Child Neurol* 2013; **55**: 396.
13. Helsedirektoratet [Norwegian Directorate of Health]. Norsk pasientregister (NPR) Innhold og kvalitet, Datakvalitet [Norwegian Patient Registry (NPR) Content and Quality, Data Quality]. https://helsedirektoratet.no/norsk-pasientregister-npr/innhold-og-kvalitet#data kvalitet. (accessed 2 February 2019).
14. Berkson J. Limitations of the application of fourfold table analysis to hospital data. *Biometrics* 1946; **2**: 47–53.
15. Shevell MI, Dagenais L, Hall N. REPACQ Consortium. Comorbidities in cerebral palsy and their relationship to neurologic subtype and GMFCS level. *Neurology* 2009; **72**: 2090–6.
16. Meehan E, Freed GL, Reid SM, et al. Tertiary paediatric hospital admissions in children and young people with cerebral palsy. *Child Care Health Dev* 2015; **41**: 928–37.