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ORIGINAL ARTICLE

Neurodevelopmental problems, general health and academic achievements in a school-based cohort of 11-year-old Swedish children

Valdemar Landgren[1,2] | Leif Svensson[3] | Carl-Johan Törnhage[3,4] | Michail Theodosious[1,5] | Christopher Gillberg[1] | Mats Johnson[1] | Rajna Knez[1,3] | Magnus Landgren[1]

[1]Gillberg Neuropsychiatry Centre, Institute of Neuroscience and Physiology, Sahlgrenska Academy, University of Gothenburg, Gothenburg, Sweden

[2]Department of Psychiatry, Skaraborg Hospital, Skövde, Sweden

[3]Department of Pediatrics, Skaraborg Hospital, Skövde, Sweden

[4]Sahlgrenska Academy, University of Gothenburg, Gothenburg, Sweden

[5]School Health Services, Gothenburg, Sweden

Correspondence
Valdemar Landgren, Department of Psychiatry, Skaraborg Hospital Skövde, Lövängsvägen, Skövde 541 45, Sweden.
Email: valdemar.landgren@gu.se

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Abstract

Aim: Assessing rates of neurodevelopmental problems (NDPs) in 11-year-old children and possible association with other health complaints and school performance.

Methods: In-school study of 11-year-old children as an add-on assessment to the 4th grade regular health check-up, comprising a structured physical neurodevelopmental examination, neuropsychological assessment, behavioural ratings, maternal interview, review of medical records and academic achievements.

Results: Out of 348 children recruited from eight schools, 223 (64%) participated. Any physical condition was found in 102/222 (46%), most commonly atopy (18%). One in five had a BMI *z*-score >2 standard deviations over the reference mean. One or more NDP was found in 86/221 (40%) children. The number of failed national tests correlated positively with NDP severity rated with the clinical global impression severity instrument (Spearman's $r = 0.41$, $p < 0.001$). The majority of participants with failed national tests, also had co-occurring health complaints (≥2 of: stomach or extremity ache, headache, difficulties sleeping, internalising symptoms or obesity) and NDPs.

Conclusion: Health complaints, physical conditions and NDPs are very common in 11-year-old children and warrant adequately staffed, thoroughly equipped school healthcare services.

KEYWORDS
health, neurodevelopmental, school achievement

Abbreviations: BMI, body mass index; CGI-S, clinical global impression severity; ESSENCE, early symptomatic syndromes eliciting neurodevelopmental clinical examinations; IQ, intellectual quotient; NDD, neurodevelopmental disorder; NDP, neurodevelopmental problem; SDQ, strengths and difficulties questionnaire; SEI, socioeconomic index.

1 | INTRODUCTION

The prevalence of neurodevelopmental disorders (NDDs), psychiatric symptoms and their relationships to basic skills development in school children has been the subject of scientific inquiry in recent years.[1] However, there is a lack of empirical studies with comprehensive clinical face-to-face assessments addressing this issue.

Several self-report surveys with longitudinal analysis of mental health complaints are available, such as the World Health Organisation's Health behaviour in school-aged children survey.[2] The proportions of 11–15-year-old pupils reporting daily symptoms of depressed mood, nervousness or difficulties sleeping in Swedish surveys have increased over the last 30 years, with a steep increase seen in the last decade; girls for example report doubled rates of low mood (13% in 2017 vs. 6% in 2009).[1] This trend has persisted in the survey of 2023, with an increase in self-reported complaints and impairment.[3] The extent to which these self-reported complaints translates into an increase in psychiatric morbidity is uncertain. A recent review commissioned by the Swedish government found that most studies conducted in the last 20 years specifically focusing on psychiatric disorders in children have relied on rating scale distributions and/or national registries for case ascertainment and, thus cannot determine whether an observed increase in registered psychiatric diagnoses is due to increased morbidity or reflects trends in healthcare utilisation and diagnostic practices. The situation has been further complicated by the fact that large portions of children's healthcare are not covered in the national registers (e.g., primary care and school healthcare).[1] Importantly, there have been very few studies aspiring to "a holistic approach", that consider as full a range as possible of data sources when assessing the health of children.[4] Such an approach also takes the impact of neurodevelopmental *problems* (NDPs) into account; NDPs are deficits/difficulties in neurodevelopmental areas causing impairments or distress, irrespective of whether or not a diagnostic "cut-off" criterion level for a diagnosis of NDD is met. The concept of ESSENCE (Early Symptomatic Syndromes Eliciting Neurodevelopmental Clinical Examinations) encompasses such an approach.[5] A salient feature of NDDs is deficits in executive function, the planning and execution of tasks and goal-directed activity.[6] It relies on frontal lobe processes and is necessary for both gaining new knowledge and acquiring new skills. Due to the sex- and puberty-related heterogeneity in brain maturation, boys may take longer than girls to develop executive function.[7] It develops at varying speeds for different individuals, something the educational institutions and curricula do not fully account for.

1.1 | Aim

The aim of this study was to provide in-depth data on general morbidity including the prevalence of NDPs and self-reported complaints in relation to the school performances in 11-year-old Swedish children in the general population. We emphasised the identification of children in need of further medical, behavioural, cognitive and psychosocial explorations in conjunction with NDPs. Our initial hypothesis based on clinical experience was that the high rate of self-reported complaints in school children calls for investigations and possible reconsideration and redesign of current school healthcare practices.

Key Notes

- Studies with face-to-face assessments of school-aged children are lacking.
- In a school-based study involving 223 11-year-old children, neurodevelopmental problems physical conditions and self-reported complaints were common, and correlated with academic achievements.
- The interplay of co-occurring health issues and academic achievements calls for an adequately staffed, competent school healthcare service.

2 | METHODS

2.1 | Setting and participants

Schools in western Sweden were in 2018 and 2019 approached as part of a broad research initiative covering pupils' basic academic skills, general health, neurodevelopment and their possible associations with important background factors. Schools were selected based on the last author's knowledge of local school principals' readiness to participate in studies of child health. Caregivers of all pupils attending 4th grade at six public and two private ("free") schools were invited to participate after an oral and written presentation of the study. At each site, one or two academic years of children were recruited, and participation constituted an add-on to the existing regular health check-up conducted in the 4th grade. None of the schools had pupils attending special education. Using the same cohort, we have previously reported on the validity of the ESSENCE questionnaire for detecting clinically relevant NDPs as rated by parents, or by physicians when screening medical records for detecting clinically relevant NDPs.[8,9]

From the 20 classes in eight schools, 348 children were eligible and 223 enrolled in the study, giving a participation rate of 64%. Attrition varied between the two recruited academic years (2018 74% vs. 2019 54% participation), and between schools (range 36%–91%). There were no data available on dropouts. According to statistics from the Swedish National Agency for Education, the participating schools had a socioeconomic index (SEI) of 149, (based on parental education level, income and dependency on social benefits), which is approximately one standard deviation over the national mean index of 103. Expressed in percentiles, the mean SEI

percentile in the study was 27 (range 1st to 75th, no data for one school, $n = 16$).[10,11]

2.2 | Assessments and NDPs

The assessment was based on seven independent sources of information: (1) medical records, (2) neuropsychological assessment, (3) physician-led physical assessment according to structured protocol, (4) maternal interview, (5) caregiver- and (6) teacher rating scales and (7) national tests.

Children presenting with developmental concerns require comprehensive assessments, including history-taking regarding pre- and perinatal risks, possible associated physical conditions, family history of NDPs, detailed clinical observation and examination, as well as a review of possible psychosocial stressors/buffers - against the background of home and school demands and the child's individual maturation trajectory.

Capitalising on the comprehensive assessment, we therefore examined the role of NDPs. The *term NDP* hereafter refers to major difficulties or possible major deficits in intellectual, motor, language, behaviour, emotional, activity, attention or social functions with onset during the developmental period, causing concern, distress or impairments irrespective of whether a diagnostic categorical "cut-off" was met. If such a cut-off was met, the problems would imply a *diagnosis of NDD*.

At the *first level* using all available information, we assessed in a case-conference whether each individual's symptoms or difficulties indicated a need for some kind of clinical assessment/investigation where NDPs were considered to be contributing factors, at least to some extent. In pupils meeting a cut-off criterion for a DSM-5 diagnosis, the problems would lead to a *diagnosis of NDD*. The first outcome level was operationalised as follows: 0 = No indication of NDPs, 1 = Some indication that NDPs cannot be ruled out, but unlikely to be of present clinical significance and do not warrant further evaluation at this stage, 2 = Clinical picture may be consistent with NDPs and warrants further investigation, 3 = Full clinical work-up indicated, NDPs are consistent with one or more specific diagnoses of NDDs.

At the *second level*, the overall severity of symptoms/degree of functional impairment from NDPs of all the participants was rated with the ordinal scale Clinical Global Impression-Severity instrument (CGI-S, range 1–7).[12] The CGI-S reflect the clinician impression of the degree of impairment with reference to the distribution of the specific condition under study, based on all available information about the participant. In the context of NDPs, we adapted the scale as follows: 1 = no indications of NDPs; 2 = some symptoms but negligible functional impairment unlikely to amount to a clinical level; 3 = some symptoms likely accounting for a level of impairment that would benefit from a further work-up, but not necessarily amounting to a clinical NDD diagnosis; 4 = obvious symptoms, either subsyndromal across several functional areas or likely amounting to one clinical NDD diagnosis with mild impairment; 5 = obvious symptoms, likely amounting to at least one clinical NDD diagnosis with moderate impairment; 6 = severe symptoms amounting to more than one clinical NDD diagnosis with moderate impairment reflected in difficulties with academic achievement and daily functioning requiring extensive support from others in addition to caregivers; 7 = very severely impaired with more than two NDDs. In a clinical setting based on our experience, participants with CGI 1–3 would not be referred for regular healthcare, while CGI 4–7 would likely indicate symptoms/impairments warranting clinical attention and probable diagnosis.

All case conferences were attended by a child neurologist (ML) and neuropsychologist (LS), both with more than 25 years of clinical experience working with families of children with NDDs, and a psychiatrist (RK or VL). Where information was sufficient, descriptive symptomatic areas were assigned comprising externalising spectrum (symptoms of attention-deficit hyperactivity disorder [ADHD], oppositional defiant disorder [ODD], conduct disorder [CD]), autism spectrum (social interaction deficits), speech-language or learning (indications of language problems, dyscalculia, dyslexia), general intellectual functioning (intellectual disability, borderline intellectual functioning), developmental coordination (gross motor skill deficits) and internalising symptoms (significant anxiety and/or depressive symptoms from >1 informant). Reliability of the case–conference adjudication was established by three clinicians with extensive experience of NDDs (a professor of child psychiatry [CG], an associate professor of child psychiatry [MJ] and a child neurologist [MT]), who independently from the other study assessors rated 11 cases. There was perfect agreement in six cases, slight disagreement in three and disagreement in two cases (rated by the independent experts as consistent with NDPs, and by study assessors as no significant indication of NDPs). It was concluded that the study assessors were slightly more restrictive than the independent experts in their definition of whether or not NDPs were present.

2.3 | Data sources

An overview of data sources and completion rates is provided in Figure S1.

2.3.1 | Physical neurodevelopmental examination

The physician performed a structured 20-min physical examination. It included anthropometric measurements, motor performance (muscle tone, reflexes, diadochokinesia, standing on one leg for 30 s, alternating jumps), dysmorphology (to be reported in subsequent publications), mental status, brief questions to the pupil about frequency of symptoms ("often" = occurring >1 day/week, "sometimes" = a few times per month, or "never" = never or rarely) and blood pressure, all according to a standardised form, with a secretary taking notes following the protocol. The average of the blood pressure measured three times in the right arm, with the participant in a sitting position using an automatic electronic monitor (Omron

M2 HEM 7121-E) was registered. Measurements were transformed to standardised indices (centiles, *z*-scores) as appropriate.[13–15]

2.3.2 | Maternal interview

Nurses who were trained for this study performed independent interviews on another occasion, mostly in school. The interviews were standardised with an emphasis on demographic, hereditary and nutritional factors related to index pregnancy. The results will be reported in another paper.

2.3.3 | Psychological assessment

Participants were assessed in school with the Leiter-III non-verbal IQ test by an experienced psychologist, with 60 min allocated for the test.[16] The test probes abilities in cognition and attention/memory, comprising 10 subtests, providing measures of non-verbal IQ, non-verbal memory and processing speed. Additionally, it contains a Stroop test of interference, testing the ability to inhibit distracting stimuli. It is coupled with standardised qualitative ratings in two domains about the observed behaviour in the test situation: social/cognition (interpersonal skills such as sociability, activity level and organisational ability) and emotion/regulation (degree of emotional stability and regulative adaptiveness to the situation). As Sweden has had significant immigration from abroad in recent years, a non-verbal IQ test measuring raw intelligence unconfounded by verbal abilities and linguistic knowledge (impacted by the number of years spent in Sweden, or prior school experience) was considered an advantage.

2.3.4 | Teacher and caregiver ratings

Teachers and caregivers independently filled out the strengths and difficulties questionnaire (SDQ) with 25 items yielding a total difficulties score (range 0–40) that covers five subscales; emotional symptoms, conduct problems, hyperactivity–inattention, peer problems, and prosocial behaviour (prosocial behaviour is scored in reverse and not included in the total difficulties score).[17]

2.3.5 | Medical records review

In Sweden, almost all children attend child health care check-ups from birth up to 5 ½ years of age, comprising about 14 visits to a nurse and at least two visits attended by a physician. The check-ups are intended for developmental and anthropometric assessments and vaccinations. Formerly these check-ups were often performed by paediatricians and paediatric nurses. Responsibility, complete records and/or a summary report is transferred to school healthcare upon school entry, where a nurse continues registering growth charts, vaccinations and at least two general health check-ups with interviews at school entry and in fourth grade (at about age 10 years). In this study child health, school health and associated regular medical charts were reviewed for signs of developmental deviations (e.g., raised concerns, referrals, descriptions, prescriptions, diagnoses) and taken into consideration.

2.3.6 | National tests

Results from national tests in Swedish and Mathematics were reviewed. On a national level, the success rate in the eight subtests in the Swedish language ranges from 90% to 98% but about 21% fail at least one test, with boys faring worse than girls.[18] The proportion of pupils passing the nine mathematical subtests ranges from 83% to 96%, 35% failing at least one test, with no major gender differences. About 2%–3% of students are considered unfit to take the tests because they are deemed to lack sufficient skills.[19] Non-participation and an increased number of failed tests were therefore both taken into consideration.

2.4 | Statistics

Variables were reported and analysed as parametric or non-parametric based on their visual distribution. When applicable, individual quantitative data were transformed to *z*-scores or percentiles, that denote the distance of a raw score to that of the reference mean value. Statistical studies were exploratory. The non-parametric tests Spearman's rank correlation test and the Mann–Whitney U Test/Wilcoxon Rank Sum test were used in order to make explorative statistical comparisons.

2.5 | Ethics

All the caregivers and children signed informed consent forms. The study was approved by the ethical review board at Gothenburg University (No. 852-17).

3 | RESULTS

3.1 | Participation and attrition

There were 98 girls (44%) and 125 boys (56%). Attrition in study participation (223 of 343 eligible individuals participated in the study) was deemed contingent on school principals' and teachers' commitment to the project and their communication with caregivers, but the degree of impairment from NDPs as rated with the CGI-S seemed slightly higher among those participating in 2019 (mean CGI-S 3.0) vs. 2018 (mean CGI-S 2.7, Wilcoxon test, $p = 0.06$). Data availability for participants ranged from 70% for the maternal interview to 98%

for the teacher-rated SDQ (see Figure S1 for participant flow diagram and overview of measures). Both the psychological assessment and the nutritional interview were carried out after the in-school medical workup and involved attrition caused by the SARS-CoV-2 pandemic. The correlation between missing data from the eight sources and the CGI-S rating was negligible (Spearman $r=0.16$, $p=0.07$).

Of the 155 mothers providing information, 113 (73%) were born in Sweden and 137 (88%) were studying or employed, rates similar to the general population (76% of parents were born in Sweden and 89% were employed or studying according to Statistics Sweden, 2020).

3.2 | Symptoms

Results regarding complaints reported in the physician's structured interview by the pupils are shown in Table 1. Stomach pain (20% vs. 8%), headache (24% vs. 8%) and difficulties sleeping(11% vs. 6%) were more common in girls than in boys. In 86 (42%) participants who reported pain complaints "often" compared with those who did not, difficulties sleeping (18% vs. 2%) and internalising symptoms (55% vs. 20%) were more common.

3.3 | Clinical "physical" conditions, NDPs and anthropometry

Ascertained physical conditions, NDP areas and anthropometry are reported in Table 2. Due to the preponderance of male participants in the study and the fact that diagnosed NDDs are more common in boys we stratified results by gender. Physical conditions were in general equally distributed among girls and boys. However, internalising symptoms were more common in girls (50%) than boys (25%). NDPs overall (44% vs. 32%) and externalising and speech-language-learning problems in particular, were more common in boys (27% and 6%, respectively) than girls (15% and 2%).

The mean *z*-score for all anthropometric measures in the total cohort was higher than the mean reference values, and this difference was more pronounced in boys than in girls. Of participants with NDPs, 21 (24%) had a BMI >2 SD above the reference mean indicating obesity, vs. 23 (17%) of those without NDPs. High blood pressure (systolic or diastolic pressure >95th centile) was slightly more common in children with NDPs ($n=14\%$, 18%) than those without NDPs ($n=15\%$, 12%).

TABLE 1 Self-reported symptoms and complaints in the 11-year-old children, n (%).

	Often	Sometimes	Never
Sleeping is fine, *n* (%)	171 (84)	26 (13)	6 (3)
Leg pain	34 (17)	70 (34)	101 (49)
Headache	30 (15)	100 (49)	75 (36)
Cough	29 (14)	104 (51)	72 (35)
Joint pain	28 (14)	53 (27)	118 (59)
Stomach pain	27 (13)	109 (54)	67 (33)
Worried/anxious	24 (12)	94 (47)	84 (42)
Low mood	19 (9)	132 (65)	53 (26)
Sleeping is poor	17 (8)	79 (39)	108 (53)
Hard stool	17 (8)	76 (37)	113 (55)
Arm pain	4 (2)	50 (24)	151 (74)
Loose stool	3 (1)	77 (37)	126 (61)

Note: Symptoms elicited from participants in the physician's structured interview ($N=223$). Answers were defined as "often" = occurring >1 day/week, "sometimes" = a few times per month, or "never" = never or rarely. Answers were clarified as needed by the examining physician (e.g., localisation of pain). Due to non-participation or missing information, each item had missing data ranging from 17 to 24.

3.4 | Neurodevelopmental problems

According to the case-conference assessments based on all available information, 133 (60%) of the 223 participants were considered in need of further clinical investigation, where NDPs may to some extent be a contributing factor. In total, 86 (39%) had NDPs at a clinically impairing level (CGI-S 4-7), most commonly due to externalising behaviour problems (see Figure S2 for CGI-S distribution in the cohort). This corresponds to a minimum prevalence rate of 25% (86/348) of NDPs in the eligible sample. Of these 86, three (2% of 180 participants with a child healthcare summary report) had received a diagnosis of NDD before school entry and another 49 (62%, missing data $n=4$) had attended a child psychiatry clinic in their school years, most contacts occurring after participating in the study. Of all participants, nine (5% of 183 participants with school healthcare records) had been seen by the school physician for evaluation of NDPs and 34 (19%) had been seen for other complaints, most commonly an examination of the spine or feet.

3.5 | Neurodevelopmental measures

Neurodevelopmental measures and academic achievements stratified by clinically relevant NDPs are reported in Table 3. Ratings in the SDQ were higher from caregivers than teachers (See Table S1 for descriptive statistics of the SDQ). Disorientation in relation to the situation (i.e., poorly oriented to the situation and/or date), low mood and poor concentration were clinical observations in the physician's assessment that were most predictive of clinically relevant NDPs, whereas observed hyperactivity was just as common in those with no NDPs. Participants assessed as having poor concentration by the physician had higher SDQ-ratings in the hyperactivity/inattention domain as rated by teachers, but not caregivers (Wilcoxon test $p<0.001$, and $p=0.19$, Figures S3A,B). There were three individuals with neuropsychological testing suggestive of intellectual disability (all with a CGI-S of 4 or more) of whom none had previously been identified by the school or health care services. Overall,

TABLE 2 Physical conditions and neurodevelopmental problem areas in 11-year-old children.

	Overall	Girls	Boys
Any physical condition[a] *n* (%)	102 (46)	49 (50)	53 (42)
Atopical disease[b]	41 (18)	20 (20)	21 (17)
Allergy	25 (11)	10 (10)	15 (12)
Asthma	20 (9)	10 (10)	10 (8)
Atopical eczema	11 (5)	8 (8)	3 (2)
Migraine	16 (7)	10 (10)	6 (5)
Tension headache	14 (6)	8 (8)	6 (5)
Eye conditions[c]	13 (6)	6 (6)	7 (6)
Birth defects[d]	11 (5)	6 (6)	5 (4)
Ear, Nose & Throat[e]	10 (5)	3 (3)	7 (6)
Gastrointestinal conditions[f]	5 (2)	2 (2)	3 (2)
Other conditions[g]	19 (9)	6 (6)	13 (10)
Neurodevelopmental problem areas[h]	86 (40)	31 (32)	55 (44)
Externalising	49 (22)	15 (15)	34 (27)
Developmental coordination	21 (9)	10 (10)	11 (9)
Autism spectrum	14 (6)	6 (6)	8 (6)
Speech-language or learning	10 (4)	2 (2)	8 (6)
Internalising symptoms[i]	78 (36)	48 (50)	30 (25)
Non-verbal intellectual quotient,[j] mean (SD)	108 (9.7)	109 (9.3)	107 (10.0)
Intellectual quotient <85, *n* (%)	5 (3)	2 (3)	3 (3)
Anthropometry, mean *z*-score[k] (SD)			
Height	0.3 (1.2)	0.2 (1.1)	0.4 (1.2)
Head circumference	0.4 (1.2)	−0.1 (1.3)	0.7 (1.1)
Weight	0.8 (1.6)	0.6 (1.7)	0.9 (1.5)
Body mass index (BMI)	0.9 (1.5)	0.7 (1.5)	1.0 (1.6)
z-score of BMI >2 SD[j], *n* (%)	44 (20)	15 (15)	29 (23)
Systolic blood pressure mean centile (SD)	54 (30)	51 (32)	57 (28)
Diastolic blood pressure mean centile (SD)	66 (24)	66 (26)	66 (22)
Systolic or diastolic pressure >95th centile, *n* (%)	29 (14)	14 (16)	15 (13)

[a]Physical condition ascertainment was based on all available data.

[b]Included any of allergy, asthma, atopical eczema.

[c]Eye conditions included strabismus, hypermetropy, anisometropy and astigmatism.

[d]Birth defects included heart, urogenital and skeletal malformations.

[e]Ear, nose and throat included sleep apnoea, tonsillectomy, tinnitus.

[f]Gastrointestinal conditions included coeliac disease, obstipation and irritable bowel syndrome.

[g]Including e.g., acne, diabetes, scoliosis.

[h]Neurodevelopmental problem (NDP) areas were defined as having a Clinical Global Impression—Severity of 4–7 (range 1–7). Externalising problems included symptoms of Attention-Deficit/Hyperactivity Disorder, Oppositional Defiant Disorder and Conduct Disorder; Developmental coordination problems included gross motor coordination problems in the physicians' assessment; Autism spectrum problems were defined as marked social interaction difficulties based on all data; Speech-language or learning problems were defined by evidence of ongoing/recent contact with a speech therapist or dyslexia/dyscalculia.

[i]Internalising symptoms defined as low mood or anxiety reported from 2 or more sources (physical assessment, psychologist, medical records, caregiver or teacher ratings).

[j]Intellectual quotient derived from the Leiter-3 non-verbal IQ-test, $n = 177$.

[k]Mean *z*-scores denote the group mean distance of raw scores to that of the reference mean value.

Abbreviation: SD, standard deviation.

TABLE 3 Neurodevelopmental measures and academic achievements in 11-year-old children.

Measures	Overall ($N=223$)	Clinical level NDP[a] ($n=86$)	No clinical level NDP ($n=137$)
Strengths and difficulties questionnaire[b]			
Teacher rated total difficulties, mean (SD)	6.9 (6.2)	11.1 (6.4)	4.2 (4.3)
Caregiver rated total difficulties	8.7 (6.8)	13.5 (7.2)	5.9 (4.6)
Physician's assessment findings, *n* (%)			
Mental status exam			
Disoriented to time or situation	14 (7)	11 (15)	3 (3)
Unreciprocal communication	14 (7)	12 (15)	2 (2)
Poor concentration	21 (10)	16 (20)	5 (4)
Uncooperative	4 (2)	4 (5)	0 (0)
Hyperactivity	65 (31)	29 (37)	36 (28)
Low mood	7 (4)	7 (9)	0 (0)
Neurological status exam			
Dysdiadochokinesia Bilateral	40 (18)	20 (24)	20 (14)
Unilateral	34 (15)	16 (19)	18 (13)
Standing on one leg >30 s, abnormal	20 (9)	9 (11)	11 (8)
Simple alternating jumps, abnormal	53 (26)	27 (35)	26 (20)
Advanced alternating jumps, abnormal	110 (54)	46 (59)	64 (51)
Neuropsychology[c], mean (SD)			
Non-verbal intellectual quotient	107.8 (9.7)	104.0 (9.5)	109.9 (9.2)
Non-verbal memory	105.5 (9.3)	101.9 (9.2)	107.6 (8.8)
Processing speed	103.2 (13.0)	97.9 (11.0)	106.2 (13.2)
Emotion/regulation <10th centile	22 (13)	14 (22)	8 (7)
Social/cognition <10th centile	18 (10)	13(20)	5 (5)
National academic test fail rate[d], *n* (%)			
Any national academic test	104 (52)	55 (72)	49 (39)
Mathematics	81 (40)	42 (55)	39 (31)
Swedish	78 (39)	47 (62)	31 (25)
No of failed tests (range 0–17), mean (SD)	2.5 (4.1)	4.0 (5.1)	1.5 (3.2)

Note: Due to non-participation or missing information there was missing data for 22 participants for national academic tests, 20 for physician's assessment, 45 for neuropsychology, 44 for caregiver SDQ and 5 for teacher SDQ.

[a]Participants stratified according to the presence of clinically impairing neurodevelopmental problems (NDPs) defined as a Clinical Global Impression – Severity rating 4–7 (range 1–7).

[b]Strengths and Difficulties Questionnaire (SDQ, range 0–40).

[c]Measured with the Leiter-3 non-verbal IQ test, including psychologist's behaviour ratings.

[d]Fail rate on a national level is 21% for any test in the Swedish language and 35% for any test in mathematics.

neuropsychological composite measures of non-verbal IQ were comparable between the two groups.

3.6 | Academic achievements

Failed national academic tests were more common in the group with NDPs (Table 3) and the number of failed tests correlated positively with severity of NDPs rated with the CGI-S instrument (Spearman's $r=0.41$, $p<0.001$) slightly more in boys than girls (boys $r=0.48$, $p<0.001$, girls $r=0.34$, $p<0.001$). Overall rates of failed national academic tests were similar between boys and girls (51% in girls, 52% in boys), and the cohort performed worse than the population mean in both Swedish and mathematics. Following the national trend, boys fared better in mathematics tests (Table S2).

3.7 | Constellations of co-occurring symptoms

Based on clinical experience and the review of school healthcare records we selected commonly presenting complaints in school healthcare settings, such as pain, internalising symptoms and obesity, in participants with failed national academic tests in order to examine the interrelations and association with NDPs in this subgroup

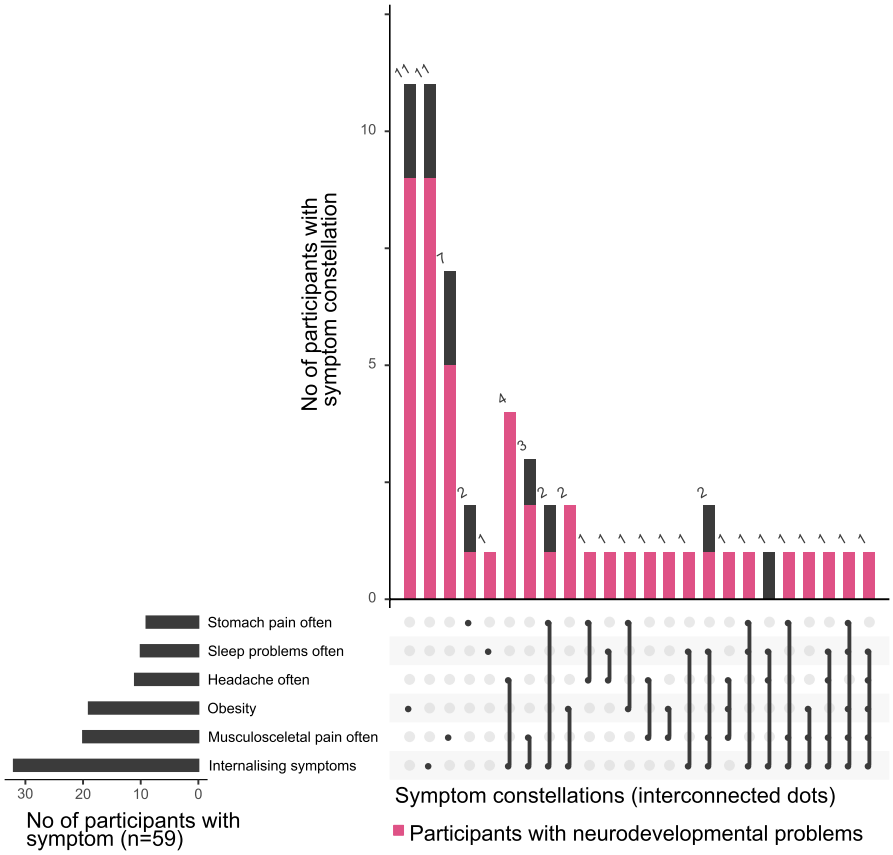

FIGURE 1 Upset plot for participants with failed national academic test ($n = 59$) and co-occurring symptoms and problems. The figure illustrates that neurodevelopmental problems (NDPs), obesity and somatic complaints often co-occurs with academic difficulties, which underlines the importance of a holistic clinical approach in practice. Of 91 participants with failed tests, 32 participants had no co-occurring symptoms and are omitted from the plot. Horizontal bars to the left denote the number of participants experiencing each symptom (symptoms reported as "often" in the physician's assessment, obesity defined as *z*-score of BMI >2 standard deviations from the reference mean, and internalising symptoms defined as low mood or anxiety reported by two or more informants (physician, psychologist, medical records, caregiver- or teacher ratings). The x-axis denotes the combination and the y-axis for vertical bars denotes the frequency of participants experiencing each combination. Pink colour indicates the proportion of participants with interfering neurodevelopmental problems (NDPs warranting some investigation).

($n = 91$, excluding 12 individuals with failed academic tests but no data on self-reported symptoms). Of 91 participants with failed test results, 68 (75%) had NDPs and 41 (51%) had clinically impairing NDPs (CGI-S level 4–7). In total, 59 (65%) of those with failed tests had concurrent symptom areas, their constellations are visualised in Figure 1. Of the 59, 32 (54%) were symptomatic in one additional area, 17 (29%) in two areas and 10 (17%) in three or more areas, 30 (51%) also had a physical condition and 48 (81%) had NDPs warranting some clinical investigation.

4 | DISCUSSION

In this school-based study of 11-year-old children, half had one or more of weekly pain, internalising symptoms, physical conditions and failed national academic tests. Clinical level NDPs were noted in more than one-third and obesity in one-fifth of the cohort. Key findings were that NDPs correlated with the number of failed national academic tests and were even more common in children with obesity or pain in combination with academic difficulties. Only three individuals had been diagnosed with an NDD prior to school entry, whereas most participants with substantial NDPs initiated contact with psychiatry as school children, of whom just a few had been seen for NDPs by the school healthcare team.

Although there are few similar studies for comparison when interpreting the meaning of the findings of very high rates of clinically relevant NDPs and other symptoms reported herein, the representativeness of the cohort needs to be evaluated. The rates of self-reported bad sleep, low mood and anxiousness are in our study almost half of those reported in the recent national surveys, although asking questions in a slightly different manner render the results not entirely comparable.[3] National test results were markedly lower than those of the Swedish mean, which may indicate an oversampling of participants with academic difficulties. That participating schools had a socioeconomic index about 1 standard deviation below the population mean may partly explain the high prevalence of NDPs in the cohort, as lower parental income coincides with increased rates of, for example, ADHD and probably

other NDDs.[20] It is possible that the relationship between health and development and their correlation with test performance is different for more well-off populations. Prevalence studies and meta-analytic estimates of NDD prevalence often use national registers and diagnostic cut-offs for inclusion as a "case". Previous clinical Swedish population-based studies of NDDs have reported numbers in the 10%–15% range, which aligns with the number of individuals rated as CGI-S 5–7 in this cohort.[21–24] The concept that these characteristics might be viewed as common traits is congruent with the observation that some NDPs (CGI-S 2–4) were seen in the majority of individuals. The definitions used herein focusing on gestalt and degree of overall symptoms/impairment, irrespective of specific diagnostic status, are likely more inclusive and may contribute to higher prevalence estimates when including those with a CGI-S of 4. Nonetheless, 25% of 11-year-old who responded to a national survey reported having an illness that requires medicine or affects their school performance, a rate that has increased over the past decade and suggests that the rates in our study may merely be a slight overestimation.[3]

Of particular interest we believe were the results of the SDQ, for which the parent rated cohort mean scores were about 40% higher compared with population-based Swedish norms in the subscales and the total score.[25] In a classification study of the SDQ in distinguishing those referred to child psychiatry clinics from those not needing such services, the optimal cut-off in the parent-rated total difficulties score was 11 and the mean score in the clinic sample was 16, which is similar to the mean score of 14 in those deemed to have clinical level NDPs in this study.[26] Comparing these previous studies of the SDQ with the present study, the base rate of psychiatric symptoms seems to be increased in this cohort, whereas the sensitivity for raised clinical suspicion was not.

With regard to physical conditions, the rates of, e.g., asthma, migraine and birth defects were on par or slightly higher than rates reported in previous cohort studies.[27–29] This is consistent with a previous Swedish population-based twin study showing an association between NDDs and a wide array of physical conditions.[29]

We draw two main conclusions based on the results obtained in this study. First, there was a high rate of symptoms commonly connected with stress (i.e., poor sleep, worry, aches) and academic difficulties associated with NDPs in this study, which is in line with previous studies connecting, e.g., pain and NDPs.[30,31] There may be social forces in the broader community accounting for these findings that were beyond the scope of our assessment. Still, it raises the question of whether aspects of the school environment itself result in NDP "subthreshold cases" becoming stressed and in some cases impaired sufficiently to "cross" diagnostic boundaries. Nonetheless, stress-related symptoms can also cause externalising symptoms and attention problems that are mistaken for NDPs. Both would be consistent with evidence suggesting that although the environmental "contribution" to an NDD diagnosis of, e.g., autism, has been stable over time, fewer symptoms now seem to be required for services to make "clinical diagnoses" of autism and ADHD. Consequentially, cases that in the recent past were considered "sub-threshold" receive a clinical diagnosis today.[32–35] Candidate drivers of such trends have been suggested, such as requirements for an NDD diagnosis for receiving educational support (although not by law, but in practice), and a national curriculum that increasingly emphasises executive function and abstract reasoning for a pass grade—precisely the abilities for which deficits are salient across the NDDs.[36,37] This points towards a mismatch between individual children's abilities on the one hand, and the social and academic demands of the school environment on the other.[38] The discrepancy creates a seedbed for stress-related symptoms—especially in children whose trajectory of maturation is slower compared to age peers. In view of the current school system in which 13% of children are predicted to not "pass" 9-year primary school, this is not an issue necessarily resolved by healthcare, but by reconsidering the appropriateness of the school system.[10]

Second, if the school environment elicits (or at least coincides temporally with the onset of) both NDPs and stress-related symptoms on such a scale, current healthcare structures for school children, for which the school principal has primary responsibility in Sweden, seem inadequate to manage the panorama of clinical issues encountered. Studies focusing on specific aspects of health in isolation (e.g., psychiatric disorders, physical conditions, academic achievements, obesity, social stressors) fail to communicate the prevalence and complexity of the health challenges in school-aged children faced by clinicians and school healthcare teams.[39] Therefore, rather than trickle-down healthcare-seeking by parents or referrals between the different authorities (e.g., teacher, school healthcare, primary care, paediatrics, child psychiatry, social services) a child-centred approach would assemble supportive structures close to the primary point where symptoms are elicited and interventions needed, which is the school–family environment. Assessments and school accommodations that resolve issues as they arise, rather than adopting a passive approach, may reduce the demand for referrals to specialist care (restricting it to severe cases) and better serve the needs of children than current practice. At a minimum, this would require a dedicated school physician (i.e., paediatrician, child psychiatrist, or general practitioner, all specialised in students' health), nurse and psychologist, who together with the teaching faculty could assist in identifying children with NDPs, suggest early interventions and adaptations, as well as managing the associated physical conditions. In its most optimal organisational structure, school healthcare could probably be conceptualised as an ESSENCE team.[40] As a clinical paradigm, ESSENCE promotes organising expertise in NDDs based on their coexistence observed in clinical practice.[41] In this child-centred form of medical care, experts gather around the child/family, not the other way around. In the preschool years, ESSENCE teams ideally operate within primary care/child healthcare and later most efficiently embedded within the school healthcare setting. For example, in a child presenting with stomach symptoms, a school physician already connected with the child's family and school environment could efficiently assess the situation, whereas today the situation

would require both an in-school evaluation by staff (whether school-environment contributes to the symptoms) and a referral to primary care/paediatrics (to assess signs of gastrointestinal disease).

The strengths of the study are the multiplicity of data sources and the face-to-face assessments, which allow for estimations of prevalence of clinical levels of morbidity. Limitations were the high-attrition rate and absence of structured psychiatric interviews, which would have enabled more precise diagnoses. The high prevalence of NDPs may indicate some selection bias of participants with previously unrecognised NDPs, whose parents may have seen participation as a way to get a clinical referral. This is consistent with the fact that boys (56%) were overrepresented in the study compared to girls (44%), as boys displayed both more academic difficulties and NDPs. A longer follow-up time would allow for the validity of the CGI-S ratings of NDPs to be evaluated, which may follow different trajectories for individuals, increasing or decreasing in impact over time.

In conclusion, NDPs and other health issues were common in 11-year-old children and from a child's point of view would likely be best primarily attended to by a highly competent and appropriately staffed school healthcare service. Children with NDPs appear to be placed at a disadvantage by the current school curriculum.

AUTHOR CONTRIBUTIONS

M Landgren conceptualised the study. V Landgren, L Svensson, M Johnson and M Landgren collected the data. V Landgren had primary responsibility for preliminary data analysis and writing the manuscript. All authors contributed to case reviewing of participants, writing and revising the manuscript for important intellectual content.

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CONFLICT OF INTEREST STATEMENT

Authors declare no conflicts of interest.

ORCID

Valdemar Landgren https://orcid.org/0000-0003-3249-8221
Christopher Gillberg https://orcid.org/0000-0001-8848-1934
Rajna Knez https://orcid.org/0000-0003-1278-4554

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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