



Predictive validity of attention-deficit/hyperactivity disorder from ages 3 to 5 Years

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Abstract

We investigated to what extent parent-rated attention-deficit/hyperactivity disorder (ADHD) and impairment at age 3 years predicted elevated ADHD symptoms at age 5 years, and whether teacher-rated ADHD symptoms improved these predictions. This study is part of the longitudinal, population-based Norwegian Mother, Father and Child Cohort Study. Parents of 3-year-old children ($n = 1195$) were interviewed about ADHD and impairment, and teachers rated child ADHD symptoms by the Strengths and Difficulties Questionnaire or the Early Childhood Inventory-4. At 5 years of age, the children ($n = 957$) were classified as ADHD-positive or -negative using Conners' Parent Rating Scale. Relying solely on parent-rated ADHD or impairment at age 3 years did moderately well in identifying children with persistent elevation of ADHD symptoms, but gave many false positives (positive predictive values (PPVs): .40–.57). A small group of children ($n = 20$, 13 boys) scored above cut-off on both parent-rated ADHD and impairment, and teacher-rated ADHD symptoms, although adding teacher-rated ADHD symptoms slightly weakened the predictive power for girls. For this small group, PPVs were .76 for boys and .64 for girls. Limiting follow-up to these few children will miss many children at risk for ADHD. Therefore, we recommend close monitoring also of children with parent-reported ADHD symptoms and/or impairment to avoid delay in providing interventions. Clinicians should also be aware that teachers may miss ADHD symptoms in preschool girls.

Keywords Attention-deficit/hyperactivity disorder · Children · Longitudinal · Sensitivity

Attention-deficit/hyperactivity disorder (ADHD) is characterized by age-inappropriate and impairing hyperactivity-impulsivity and/or inattention that is pervasive across settings [1]. ADHD often begins during preschool years [1] and occurs 1.6–1.8 times more frequently in preschool boys than girls [2, 3] with a preschool prevalence rate of 1.9–3.3% when estimated by a parent diagnostic interview [3, 4]. Studies report that greater symptom severity in early childhood predicts poor outcomes [5–8]; therefore, early detection is recommended [9]. Furthermore, during the last 20 years,

prospective clinical studies have found strong predictive validity, where $\geq 70\%$ of those who met criteria for ADHD from the age of 4 years old and over continued to fulfil criteria at 6- and 8-year follow-ups [5, 7, 10, 11]. Subsequently, the American Academy of Pediatrics extended their guidelines for the ADHD diagnosis to apply from the age of 4 years [9]. However, the fifth edition of the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-5) states that ADHD symptoms are difficult to distinguish from normative behaviours before this age [1].

Still, the few longitudinal studies that begin before the age of 4 years indicate that ADHD symptoms at this early age may be important to identify [12]. One community study found that ADHD diagnosed at the age of 3 years gave a significantly increased odds ratio (OR = 17.96) of ADHD at 6 years old [13], but was limited by the low number of children diagnosed with ADHD at age 3 years ($n = 11$). Another community study with 170 hyperactive 3-year-old children found significant continuity between early hyperactivity and ADHD after 14–25 years, but only in boys [14]. Another study including 3-year-old children with behavioural

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problems ($n = 168$), found that 58% of the children with behavioural problems continued to meet diagnostic criteria 3 years later [15]. None of these studies included impairment or used the recommended multi-informant, across-settings approach to assess ADHD at age 3 years [1, 9, 16]. However, one clinical study followed children (baseline, mean age = 5.2 years) with ADHD who were impaired in one ($n = 96$) or two ($n = 29$) settings (according to parent or teacher reports) annually for 3 years [17]. Both groups had increased risk of continuing to fulfil diagnostic criteria, and those who were impaired in one setting only had significantly lower risk than children with impairment across settings. Another study of hyperactive/inattentive pre-schoolers ($n = 104$, baseline mean age = 4.4 years) found that the predictive utility of parent-reported ADHD symptoms (≥ 90 th percentile on the ADHD rating scale) was significantly improved by the addition of teacher reports [18]. Again, these two studies included older preschool children, were limited by relatively few participants, and did not investigate the potential biases when parents and teachers rated boys' and girls' behaviour [19]. As mentioned above, the one study that investigated gender differences from the age of 3 years, found preschool hyperactivity to be a risk factor for long-term ADHD only in boys [14]. Given the assumed referral biases of clinical preschool studies, population-based longitudinal studies on very young children, have long been in demand [20].

In the present study, we followed a cohort of 3-year-old children until they were 5 years old ($n = 957$). Based on the diagnostic criteria [1] and data from the few studies on pre-schoolers, we hypothesized that the predictive utility of ADHD classified by the parent interview when the child was 3 years old would be significantly improved by the addition of impairment and teacher-rated ADHD symptoms. As studies of possible gender differences related to the predictive validity of ADHD symptoms, impairment and pervasiveness are limited, we had no a priori hypotheses about gender differences.

Methods

Participants

The Norwegian Mother, Father and Child Cohort Study (MoBa) is an ongoing prospective population-based cohort study of Norwegian-speaking pregnant women conducted by the Norwegian Institute of Public Health (41% participation rate) [21]. About 89% of the participating mothers were ethnic Norwegian, recruited from all over Norway from 1999 to 2008, and were predominantly white Caucasians [22]. The current paper is from a clinical substudy on ADHD described in previous publications [23, 24]. In short, this

study oversampled children at risk for ADHD using the MoBa questionnaire for 3-year-old children, which includes 11 items about ADHD; six items from the Child Behavior Checklist/1.5–5 (Can't concentrate, Can't sit still, Can't stand waiting, Demands must be met immediately, Gets into everything, Quickly shifts activities) [25], and five items from the revised fourth edition of the DSM (DSM-IV-TR) (Easily distracted, Difficulty waiting his/her turn, Difficulty sustaining attention, Talks excessively, Does not seem to listen) [26]. Children with scores ≥ 90 th percentile on these 11 items ($n = 2798$) were invited to participate, along with randomly selected children from MoBa ($n = 654$). Of these, 35% agreed to participate, and 1195 children took part in a 1-day clinical assessment that included a diagnostic interview with parents (almost all mothers) from 2007 to 2011. Ninety-five percent of Norwegian 3-year-olds attend preschool. When the children were 3 years old, their parents received the screening questionnaires by mail and gave theirs to the teachers, who mailed their responses to the study administrator. By the 5-year follow-up, 6 mothers withdrew from the MoBa-study, leaving 1,189 participants. Eighty percent ($n = 957$; 519 boys) of the mothers who participated when their child was 3 years old also completed questionnaires when their child was 5 years old.

Measures

Background variables

Length of parental (mothers' + fathers') education was obtained at the first MoBa assessment (about Week 17 of pregnancy) and reported in mean number of years.

To check how many children were referred for treatment, we included results on one item asked to mothers at child age 3 and 5 years: "Has your child been referred to Child and Adolescent Mental Health Services (CAMHS)? To check for comorbidities at age 5 years, we included two questions: (1) "Has your child ever had behavioural problems (difficult or oppositional behaviour)?" (2) "Has your child ever had emotional problems (sadness or anxieties)?"

At 3 years of age

Birth date and child gender were obtained from the Norwegian Medical Birth Registry.

The preschool age psychiatric assessment (PAPA) [27] was developed for children from 2 to 5 years old. The PAPA is interviewer-based, i.e., the interviewer asks questions until s/he can decide whether the symptoms described meet the definitions provided in a glossary. In a study of test–retest reliability of the PAPA interview, the test–retest intra-class correlations for ADHD classification was 0.80

[4]. In the present study, only ADHD symptoms persisting for ≥ 3 months were counted as present. Blinded to the questionnaire ratings, trained graduate psychology students conducted the interviews under the supervision of specialists in child psychology/psychiatry. An interrater reliability check was carried out by a second blind rater who rescored audiotapes of 79 randomly selected interviews. The average intra-class correlation for ADHD symptoms was 0.98.

Parents' classifications

In line with our earlier studies [23, 24], we used information from the PAPA interview, and defined ADHD by the DSM-IV-TR criteria [26], classifying the ADHD hyperactive/impulsive or inattentive presentations by the presence of at least six out of nine symptoms of either hyperactivity/impulsivity or inattention, and ADHD combined presentation by six out of nine symptom within both symptom presentations. In all, 172 children fulfilled the criteria: 76% hyperactive/impulsive ($n = 131$, 50 girls), 5% inattentive ($n = 8$, 6 girls), and 19% combined presentation ($n = 33$, 14 girls).

The ADHD section of the PAPA concluded with an impairment section [28]. Whenever a parent reported at least one ADHD symptom, impairment was scored for six functional domains: (1) family relationships; (2) friends; (3) learning; (4) play/leisure activities; (5) child's quality of life; and (6) family burden. For each domain, difficulties were scored on a four-point Likert scale (no, a little, some, a great deal; range 0–3). The functional domains gave a total impairment scale score (range 0–18), with Cronbach's $\alpha = 0.83$. A sum score of three was equivalent to the 75th percentile for the participants who responded to the questionnaire at 5 years, in line with an earlier study of all participants at age 3 years old, and was taken to indicate a moderate level of impairment [28]. Thus, an impairment score of ≥ 3 was chosen as the threshold for impairment to be present. Among the children who fulfilled ADHD symptom criteria according to the PAPA interview, impairment was present in 62% of boys and 50% of girls.

Oppositional Defiant Disorder (ODD) was defined by the presence of ≥ 4 DSM-IV ODD symptoms according to PAPA.

Teachers' classifications

The first 44% of the sample received the Norwegian version of the Strengths and Difficulties Questionnaire (SDQ) rated on a three-point Likert scale (not true, somewhat true, and certainly true; range 0–2) [29]. The psychometric properties of the teacher SDQ have been found satisfactory [30]. We used only the hyperactivity/inattention (HI) subscale (Cronbach's $\alpha = 0.86$), which we in a previous cross-sectional study at age 3 years found to discriminate PAPA classified

ADHD from non-ADHD significantly better than chance ($p < 0.001$) [23]. We used a cut-off of seven to categorize ADHD, in line with epidemiological studies [31–34].

The rest of the sample received the Norwegian version of the Early Child Inventory-4 (ECI-4) that contains 108 items corresponding to the symptom lists of the child psychiatric disorders in the DSM-IV [35]. The inventory was translated into Norwegian and back-translated into English by professional translators, and the translation was approved by the ECI-4 developers. We used only the teacher hyperactivity/impulsivity (H-I) and inattention (IA) subscales, each with nine items [35] rated on a four-point Likert scale (never, sometimes, often, very often; range 0–3). In a previous cross-sectional study, at age 3 years, we found these teacher-rated subscales to discriminate PAPA classified ADHD from non-ADHD significantly better than chance ($p < 0.001$) [24]. We used the dichotomized teacher symptom count where symptoms were scored as being not present (never/sometimes = 0) or present (often/very often $n = 1$). In line with the ECI-4 manual, the cut-off score was set to the minimum number of symptoms necessary for the DSM-IV ADHD diagnosis (≥ 6 on either the H-I or the IA subscales) [36]. Cronbach's α was 0.91/0.90 for the H-I/IA subscales. Pearson's correlation between the two subscales was high (0.78; $p < 0.001$).

Thus, for the entire sample, teacher ADHD was classified as present by an SDQ HI score ≥ 7 (first subsample) or by an ECI-4 H-I or IA symptom count score ≥ 6 (last subsample).

At 5 years of age

The mothers received the revised short form of the Conners' Parent Rating Scale (CPRS-R:S) including the 12 ADHD items comprising the ADHD index [37]. The CPRS items were rated on a four-point Likert scale (not true, somewhat true, often true, or very true; range 0–3), with Cronbach's $\alpha = 0.88$. The ADHD index has been found to have good validity for ADHD [38]. From all the responders to the five-year MoBa questionnaire ($n = 32,633$, 49% girls), we created cut-offs for ADHD to be present at the 95th percentile of the CPRS-R:S ADHD index scores: > 14.2 for boys and > 11 for girls. In our sample, 215 children (121 boys, 94 girls) reached the ADHD classification by these cut-offs, giving a 22.5% (215/957) occurrence rate.

As mentioned, only eighty percent ($n = 957$) completed the CPRS-R:S ADHD index when their child was 5 years old, we therefore checked for differences in rates of ADHD among responders and non-responders. Of the missing participants ($n = 232$), 22% of children fulfilled symptom criteria for ADHD at 3 years old, which is nearly the same as for those who continued to participate (22.5%). However, the non-responders had significantly higher parent-reported ADHD symptom scores at 3 age years old (mean = 4.76,

SD = 3.96) than the responders (mean = 3.84, SD = 3.83; $t = 3.25$, $p = 0.001$), while there was no significant difference in teacher-reported ADHD symptoms. The parents of the responders were significantly better educated (mean = 14.97 years, SD = 2.20) than the parents of non-responders (mean = 14.47, SD = 2.29, $t = 2.91$, $p = 0.004$). There were more boys (54%) than girls among the responders, and vice versa among the non-responders (45% boys), a significant difference ($\chi^2 = 6.62$, $p = 0.01$). At age 3 years, only 16 children (1.3%) had been referred to CAHMS. All inter-correlation coefficients between the parent and teacher variables when the child was 3 years old and CPRS-R:S when the child was 5 years old were low to moderate (range 0.27–0.61) (Table S1).

Ethics

Informed consent was obtained from participants upon recruitment to the MoBa and the ADHD substudy. Both studies had licenses from the Norwegian Data Inspectorate. The present study was approved by the Regional Committee for Medical Research Ethics.

Analytic plan

Internal consistencies were analysed using Cronbach's α , differences between means of continuous variables with t tests and correlations with Pearson's r . For the defined categories (parent-rated ADHD, impairment, and teacher-rated ADHD), we estimated sensitivity (the probability that a measure correctly classified a child with ADHD at age 5 years) and specificity (the probability that a measure

correctly identified a child without ADHD at age 5 years). We calculated the positive predictive values (PPVs, the probability of a child being correctly classified with ADHD at age 5 years given a positive test), negative predictive values (NPVs, the probability of a child being correctly classified without ADHD at age 5 years given a negative test), positive likelihood ratios (+LRs; the probability of a child being classified with ADHD at age 5 years testing positive divided by the probability of a child being classified without ADHD at age 5 years testing positive), and negative LR (–LRs; the probability of a child being classified with ADHD at age 5 years testing negative divided by the probability of a child being classified without ADHD at age 5 years testing negative). LR between 0 and 1 argue against the presence of the disorder [39]. Because LR are derived from sensitivity and specificity and are independent of the proportion of the disorder in the sample, they are more likely than PPV/NPV to generalize results outside the sample [40].

Results

Children classified with ADHD at 5 years had significantly higher mean parent and teacher symptom scores at 3 years than those who were not classified with ADHD (Table 1).

The parent-classified ADHD and impairment at 3 years gave similar sensitivity (43–45%) and specificity values (81–91%) for detecting elevated ADHD symptoms at 5 years old in boys and girls. In boys, the teacher-classified ADHD gave sensitivity and specificity values of 27% and 88%, respectively, while the sensitivity of the teacher classification was particularly low (14%) in girls. For boys, the

Table 1 t -test Comparisons of the 3-Year-Old Measures for Boys and Girls Categorized With and Without ADHD at 5 Years Old

	n	ADHD 5 Years Mean (SD)	n	No ADHD 5 Years Mean (SD)	t -test	p -value
Boys, 3 years ($n = \text{ADHD/no ADHD}$)	121	54/67	398	48/350		
p-PAPA ADHD symptoms	121	7.17 (3.97)	398	3.20 (3.33)	9.97	<.001
p-PAPA impairment scores	121	3.21 (3.69)	398	1.18 (2.10)	5.77	<.001
t-SDQ HI	44	5.43 (2.73)	182	3.64 (2.72)	3.92	<.001
t-ECI H-I	66	8.94 (6.59)	191	5.64 (4.88)	3.73	<.001
t-ECI IA	65	8.57 (6.09)	185	5.51 (4.22)	3.75	<.001
Girls, 3 years ($n = \text{ADHD/no ADHD}$)	94	40/54	344	30/314		
p-PAPA ADHD symptoms	94	6.97 (2.56)	344	2.54 (2.97)	9.39	<.001
p-PAPA impairment scores	94	2.81 (3.04)	344	.80 (1.41)	6.22	<.001
t-SDQ HI	37	4.30 (2.99)	149	2.49 (2.47)	3.91	<.001
t-ECI H-I	53	6.11 (4.38)	174	4.12 (4.11)	3.73	<.001
t-ECI IA	53	6.30 (5.58)	173	3.77 (4.22)	3.75	<.001

p parent, t teacher, SDQ Strengths and Difficulties Questionnaire, HI Hyperactivity Inattention subscale, $ECI-4$ Early Childhood Inventory-4, $H-I$ Hyperactivity-Impulsivity subscale, IA Inattention subscale, $CPRS-R$ S Conners' Parent Rating Scale

ADHD at 5 years was classified as ≥ 95 th percentile on the CPRS-R:S ADHD index sum scores in the MoBa population (> 14.2 for boys and > 11 for girls)

highest +LR of being classified with ADHD at 5 years was found for the children with parent-rated ADHD, impairment, and teacher-rated ADHD (+LR = 10.79), but the sensitivity was low (12%) for this combination. For girls, the combination of the parent-rated ADHD and impairment gave a +LR of 7.98 and adding teacher-rated ADHD symptoms slightly weakened the predictive power (see Table 2). Only a small group of 3-year-old children (13 boys, 7 girls) fulfilled ADHD criteria according to both parent and teacher reports, and were impaired. These children had high probabilities of being categorized with elevated ADHD symptoms at 5 years (PPVs = 0.76 in boys, 0.64 in girls).

Overall, adjusting the thresholds for the different teacher measures at 3 years did not improve predictions.

Figure 1 illustrates the improved PPVs in boys when impairment and teacher assessments were added to parent scores, with an increase from 53 to 76%. This effect was not found in girls. However, the highest PPVs were only valid for a small group of children. By demanding a combination of criteria, the percentage of children classified with ADHD at 3 years dropped dramatically (Fig. 2).

ODD at age three gave a sensitivity of 53% for detecting ADHD at age 5 years in both genders, with corresponding specificity values of 71% and 66%, and +LRs of 1.83 and

Table 2 Prediction Values for ADHD Classified at 5 Years Old

Predictors, 3 years	N/n*	Se (%)	Sp (%)	PPV	NPV	+LR	-LR
Boys							
Parent-rated ADHD	519/54	45	88	.53	.84	3.70	.63
Parent-rated impairment	519/53	44	81	.42	.83	2.36	.69
Teacher-rated ADHD	488/31	27	88	.40	.80	2.24	.83
Parent-rated ADHD and impairment	519/35	29	93	.57	.81	4.43	.76
Parent-rated ADHD, impairment, and teacher-rated ADHD	488/13	12	99	.76	.79	10.79	.89
Girls							
Parent-rated ADHD	438/40	43	91	.57	.85	4.88	.63
Parent-rated impairment	438/42	45	88	.49	.85	3.57	.63
Teacher-rated ADHD	417/13	14	94	.42	.80	2.55	.91
Parent-rated ADHD and impairment	438/24	26	97	.69	.83	7.98	.77
Parent-rated ADHD, impairment, and teacher-rated ADHD	417/7	08	99	.64	.79	6.18	.94

Parent-rated ADHD (DSM-IV criteria) and impairment (scores ≥ 3) were classified by PAPA. Teacher-rated ADHD was measured using the Strengths and Difficulties Questionnaire hyperactivity/inattention subscale scores ≥ 7 or the Early Childhood Inventory-4 hyperactivity/impulsivity/inattention subscale scores ≥ 6

ADHD at 5 years was classified as ≥ 95th percentile on the Conners' Parent Rating Scale (CPRS-R:S) ADHD index sum scores in the MoBa population (> 14.2 for boys and > 11 for girls). The proportion of children who fulfilled ADHD criteria in the sample according to the CPRS-R:S was 22.5%

Se Sensitivity, Sp specificity, PPV/NPV positive/negative predictive values, +LRs/-LRs positive/negative likelihood ratios

*n = Total number of boys and girls with the measure, n = number of true positives according to the CPRS-R:S

Fig. 1 Percentages of the positive predictive values for boys and girls classified with ADHD at 5 years for the 3-year categories: parent-classified ADHD (P), parent-classified ADHD and impairment (I), and parent-classified ADHD, impairment, and teacher-classified ADHD (T)

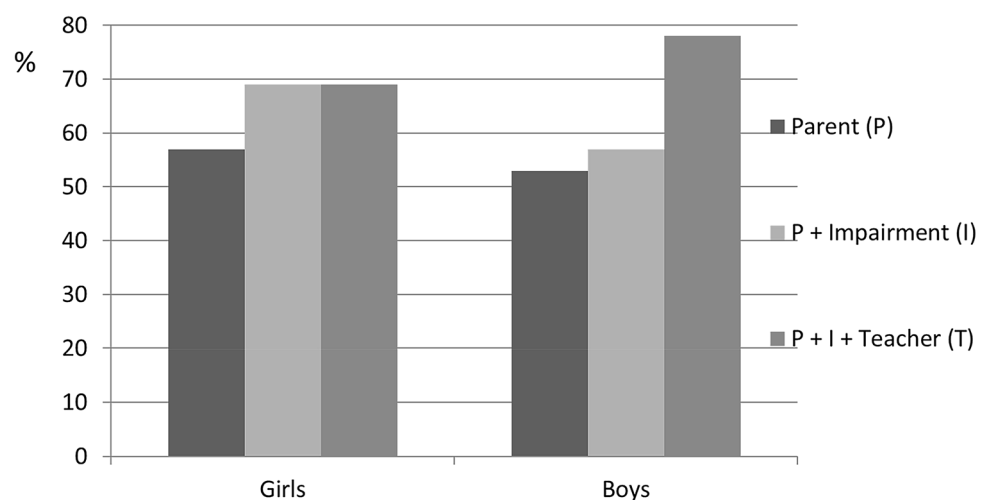
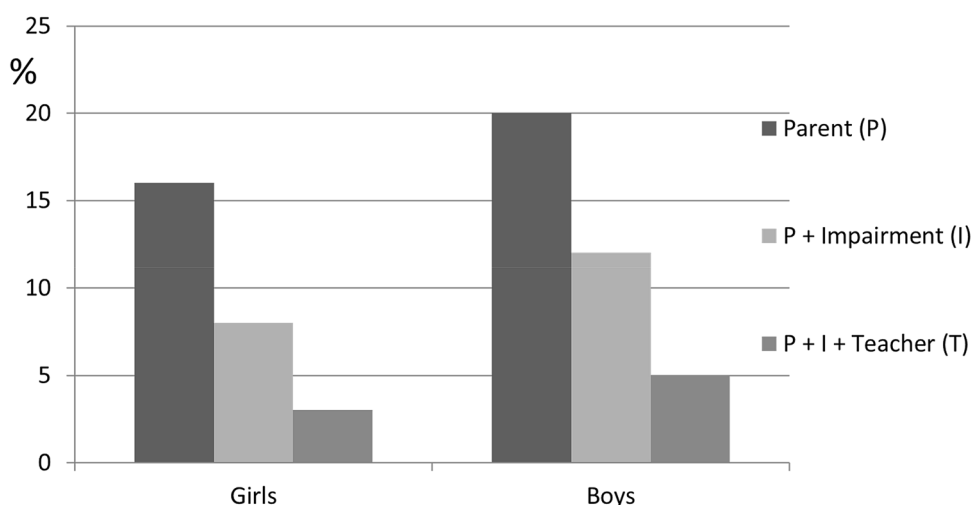


Fig. 2 Percentages of the boys and girls who met the criteria for ADHD at 3 years according to three different categories: parent-classified ADHD (P), parent-classified ADHD and impairment (I), and parent-classified ADHD, impairment, and teacher-classified ADHD (T)



1.55, in boys and girls, respectively. Adding ODD to the parent ADHD, impairment and/or teacher ADHD did not improve detection of ADHD classified at age 5 years.

Discussion

Consistent with our hypothesis, the predictive power improved when impairment and teacher-rated ADHD were added to parent-rated ADHD, but only in boys. Relying on only one source of information to find children categorized with ADHD at 5 years old gave much uncertainty due to many false positives (PPVs = 0.40–0.57). In the small group of 3-year-old children (13 boys, 7 girls) who fulfilled ADHD criteria according to both parent and teacher reports, and were impaired, the probability of finding children categorized with ADHD at 5 years was high (PPVs = 0.76 in boys, 0.64 in girls). For girls, the highest PPV (0.69) was reached by combining information about parent-rated ADHD and impairment.

Our finding of increased risk for persistent elevation in ADHD symptoms even in children with only parent-rated symptoms and/or impairment is in accordance with a community study that found that children diagnosed with ADHD by parent interview at 3 years old were highly likely to meet ADHD criteria at 6 (OR = 17.96), 9 (OR = 5.53), and 12 years old (OR = 6.80) [13, 41]. That study only identified 11 pre-schoolers with ADHD at the age of 3 years old (about 2%), and reported increased occurrence rates at school age (13.1% and 16.4% at ages 9 and 12 years, respectively) [41]. This increase may have been due to ADHD symptoms becoming more apparent in school. It might also be that the use of telephone interviews when the children were 3 years old did not detect all children who had ADHD already at that age [41]. The increased occurrence rates in that study may

have inflated their ORs, in contrast with our study where about 20% were categorized with ADHD at both time points.

The moderate diagnostic stability of ADHD when relying on one source of information is not unique for 3-year-old children. As pointed out by Law et al., community samples using checklists to ascertain ADHD diagnoses have reported about 50% stability in <7-year-old children after a 2-year period [7]. Studies of clinical/high-risk samples that include some form of standardized diagnostic assessments have demonstrated higher stability (> 70%), suggesting that more narrow study selections and broader clinical assessments improve prediction [7, 10, 15]. This may explain why the stability for the few children with parent-rated ADHD, impairment, and teacher-rated ADHD in the present study was similar to that of children in these clinical studies. However, limiting follow-up to these few children will miss many children at risk for ADHD. Therefore, we recommend close monitoring of children with parent-reported ADHD symptoms and/or impairment, in line with a recent review emphasizing that pre-schoolers with subthreshold ADHD are more likely to develop the disorder over the next few years than to outgrow it [12].

Impairment in the present study had similar sensitivity and specificity values to the ADHD symptoms measures, in accordance with a study of school children that found impairment of ADHD at baseline significantly predicted persistence of ADHD 11 years later [42]. Our finding was also consistent with that of a preschool study, which found that impairment gave an increased risk of fulfilling diagnostic criteria over the next 3 years [17].

As in previous studies [43–46], we found low to moderate correlations between parent- and teacher-rated ADHD symptoms in 3-year-old children. An earlier study underlined the importance of a multi-informant approach, showing that the predictive power of parent-reported ADHD was significantly improved by adding teacher reports [18]. This was consistent

with our results only for boys because teacher-rated ADHD symptoms had a particularly low sensitivity for girls (14%). This gender difference contrasts to our earlier finding that preschool teachers were inaccurate in identifying 3 years old boys at risk, compared with a parent diagnostic interview [23], and also with a follow-up study of school-children reporting that the combination of parent and teacher checklist information improved predictive power most clearly in girls [47].

The strengths of our study included the population-based cohort design and the use of a parent diagnostic interview when the children were 3 years old, but it also had limitations. There were selection biases due to attrition [21, 48], however, one MoBa-study reporting on ADHD found differences to be small and assumed limited effects on generalizability [49]. We specifically checked for biases in the present study, and found the parents of the responders significantly better educated than the parents of non-responders, as well as more boys (54%) than girls among responders, and vice versa among non-responders (45% boys). Although these differences were statistically significant, they were small, indicating that attrition at 5 years has not biased our results substantially. Also, we found significantly higher parent-reported ADHD symptom scores at 3 years old among non-responders than the responders, indicating that if the non-responders had been retained, the prediction of ADHD at age 5 years might have been stronger, at least for parent-reported symptoms and impairment. About 1% and 5% of the sample had been referred to CAHMS before ages 3 and 5 years, respectively. Among the children classified with ADHD according to Conners at 5 years, about 14% ($n = 31$) had been referred to CAHMS, significantly more than among the children not classified with ADHD at age 5, of whom 2% ($n = 17$) had been referred. Although we cannot entirely rule out that treatments received may have influenced whether the children continued to fulfil criteria at age 5 years, few had been referred, particularly for those who were not classified with ADHD at 5 years. Also, according to the Norwegian prescription database, very few children in Norway are medicated for ADHD before age 5 years, with a variation in medication rate from 0.02/1000 to 0.1/1000 during a fifteen-year period (2004–2019) (<http://www.norpd.no/>). These rates are in line with a study from the five Nordic countries reporting annual prevalence of ADHD drug use under age 6 years in 1/1000 boys and 0.3/1000 girls [50]. About 9% and 5% of the sample were reported to have had behavioural or emotional problems, respectively. As expected, there were significantly more children with a life-time history of these problems among children classified with ADHD compared to those not classified with ADHD at age 5 years (behavioural: 24% versus 4%; ($p < 0.001$); emotional: 12% versus 3% ($p < 0.001$), in line with studies reporting high comorbidity rates to ADHD [51, 52]. Our

diagnostic outcome was based solely on the CPRS ADHD index scores, and is not equivalent to clinical ADHD diagnoses, but this index was found to have good validity for ADHD [38]. We created cut-offs based on the ADHD 95th percentile scores in the large MoBa population, indicating that we may have a group of high ADHD scorers compared with their peers. Also, using a cut-off based on scores in the general population from which the children were drawn, reduces the problem of cross-cultural differences if using US cut-off scores, as discussed in a previous paper [24]. Unfortunately, we only had parent-reported ADHD symptoms at age 5 years and cannot rule out that teacher-reported ADHD at this age might have altered our results somewhat.

There was a larger proportion of girls than boys with ADHD inattentive presentation at age three (6 girls of 8 children), but most of the children had hyperactive/impulsive or combined presentations (91% girls and 98% boys). Therefore, this gender difference can hardly explain why teachers were poor at identifying girls later categorized with ADHD. Because most of our sample had the hyperactive/impulsive presentation at age 3 years (76%), and we only had CPRS ADHD index at age 5, we were unable to investigate ADHD subtype stability/instability. Likewise, we did not fully address the role of comorbidity for this stability/instability, but we found that ODD, the most common comorbid disorder to ADHD, did not improve prediction of ADHD classified at age five years. Our at-risk sample had a higher proportion of children classified with ADHD at 5 years (22.5%) than did the general population, increasing the probability of finding true cases given a positive screen result. However, this should not affect LR-estimates, which may generalize to other samples.

Implications and future directions

In the present study, children where only the parent-reported child ADHD symptoms or impairment at age 3 years constitute a high-risk group, as about 50% continued to be categorized with ADHD at age 5 (according to parent report). We also identified a few children with combined parent- and teacher-reported ADHD and impairment with high probability of persistent elevation of ADHD symptoms to age 5 years. However, limiting follow-up to these few children will miss many children at risk for ADHD. Therefore, we recommend close monitoring also of children with parent-reported ADHD symptoms and/or impairment to avoid delay in providing interventions, in line with ADHD guidelines [9]. Clinicians should also be aware that preschool teachers may have more difficulty detecting ADHD in girls than in boys. Future studies should investigate whether the predictive validity of preschool subthreshold ADHD will be as

likely as above-threshold ADHD to develop into ADHD at school age. The gender differences in the predictive validity of teacher reports in the present study need to be replicated.

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Authors' contributions Dr. Overgaard contributed with acquisition of data, conception and design, drafting of the initial manuscript and revisions. Dr. Oerbeck conceptualized the study, and critically revised the manuscript for important intellectual content. Professor Emeritus Friis contributed with analyses and interpretation of data, as well as revising the manuscript critically. Dr. Pripp, the study statistician, contributed with the interpretation of data, and critically revised the manuscript. Drs Aase and Zeiner designed the ADHD study, contributed with acquisition of data, and revised the manuscript critically. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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Declarations

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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