Eur Child Adolesc Psychiatry
DOI 10.1007/s00787-014-0634-8

ORIGINAL CONTRIBUTION

Long-term course of ADHD symptoms from childhood to early adulthood in a community sample

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Received: 29 April 2014 / Accepted: 15 October 2014

Abstract Comparatively little information is available from population-based studies on subgroup trajectories of attention-deficit/hyperactivity disorder (ADHD) core symptoms of inattention and hyperactivity-impulsivity (particularly as defined by DSM-IV and ICD-10). Recent report of a subgroup with high and increasing inattention symptoms across development requires replication. To identify the different trajectory subgroups for inattention, hyperactivity-impulsivity and total symptoms of ADHD in children and adolescents aged 7–19 years. Eleven birth cohorts from 2,593 families with children and adolescents who had parent ratings for the outcome measures of inattention, hyperactivity-impulsivity or total symptoms were considered. Data were analysed using an accelerated longitudinal design and growth mixture modelling was applied to detect subgroups. For all three outcome measures, three trajectories with low (78.3–83.3 %), moderate (13.4–18.8 %) and high (2.8–3.2 %) symptom levels were detected. Course within these subgroups was largely comparable across outcome domains. In general, a decrease in symptoms with age was observed in all severity subgroups, although the developmental course was stable for the high subgroups of inattention and total symptoms. About 3 % of children in a community-based sample follow a course with a high level of ADHD symptoms. In this high trajectory group, hyperactivity-impulsivity symptoms decrease with age from 7 to 19 years, whilst inattention and total symptoms are stable. There was no evidence for an increase in symptoms across childhood/adolescence in any of the severity groups.

Keywords Attention-deficit/hyperactivity disorder (ADHD) · Children and adolescents · Longitudinal study · BELLA study · Cohort

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Electronic supplementary material The online version of this article (doi:10.1007/s00787-014-0634-8) contains supplementary material, which is available to authorized users.

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Introduction

Attention-deficit/hyperactivity disorder (ADHD) as defined by DSM-IV and DSM-5 and hyperkinetic disorder (HD) as defined by ICD-10 are characterized by inappropriate

Published online: 14 November 2014

levels of inattention, hyperactivity and/or impulsivity. ADHD/HD is one of the most common neurodevelopmental disorders in childhood with an estimated worldwide prevalence for ADHD of about 5 % in children aged 18 years or younger [1]. In Germany, similar prevalence rates were found in a representative national sample of children and adolescents using parent ratings of ADHD/HD symptoms according to DSM-IV and ICD-10 [2]. ADHD has a substantial impact on affected children and their families in terms of academic, occupational, social, emotional and behavioural functioning [3, 4].

Attention-deficit/hyperactivity disorder symptoms often vary during development and may manifest differently over time. In particular, a decrease in symptom severity is often reported for the hyperactivity-impulsivity dimension [5, 6]. However, the results for inattention are less conclusive: some studies show a reduction in attention over time [5, 6] while others have reported these symptoms are relatively constant [7]. In contrast, one recent study reported an increase in inattention from middle childhood to adolescence [8]. Nevertheless, a reduction in core symptoms of ADHD does not mean that diagnosed children necessarily return to normal development. Severely affected children often maintain a high symptom level [9] and are at risk for several comorbid disorders in young adulthood [10].

Only a few studies have analysed and identified different developmental trajectories of ADHD symptoms in children and adolescents. Two trajectories of ADHD symptoms were identified in a high-risk sample of children aged 7–16 years [11]. One study in boys aged 6–15 years using teacher-rated hyperactivity found that the majority of youths followed either a low symptom trajectory or a moderate declining trajectory, whereas a small percentage of children (6 % of the sample) followed a chronic high hyperactivity trajectory [12]. Four developmental trajectories of ADHD symptoms were identified in a community sample of Dutch children aged 4–18 years using the DSM-IV scale of the CBCL/4–18 describing high, moderate, low and near zero developmental trajectories both for girls and boys [9]. Only one population-based study separately analysed the development of hyperactivity-impulsivity and inattention (as defined by 14 DSM-IV based items) and found two hyperactivity-impulsivity trajectories (low, high decreasing) and two inattention trajectories (low, high increasing) [8].

Among the few studies that have identified different developmental trajectories of ADHD symptoms in children and adolescents, some treated overall ADHD symptoms [9] while others treated the specific domains of inattention or hyperactivity/impulsivity [8, 11]. As there is an ongoing debate about the factorial structure of ADHD and no consensus on whether ADHD should be considered as a unitary concept or as having different domains [13, 14], we considered ADHD at both an overall and subdimensional level in our analyses.

Overall, to our knowledge, there have been no previous analyses of trajectories using a full set of DSM-IV or ICD-10 based symptoms of ADHD/HD in large community samples of children and adolescents, and the characteristics of children and adolescents in different trajectories have only rarely been studied. To address this research gap, our study aimed to examine the development of parent-rated inattention, hyperactivity-impulsivity and total symptoms as defined by DSM-IV and ICD-10 in a large community sample of children and adolescents, and to identify different trajectories. Given that the number of trajectories has varied in previous studies using global ratings for ADHD (e.g., CBCL) or DSM-based ratings, we expected to identify between two and four trajectories of ADHD symptoms in early childhood. We also anticipated that, except for inattention, there would be a general decline in symptom severity over time. For inattention, we examined whether a subgroup with high and increasing levels of inattention could be detected. We hypothesized that the majority of children and adolescents would exhibit constantly low levels of inattention, hyperactivity-impulsivity or total symptoms. We also expected to identify a small group of children with high ratings of ADHD symptoms that remained high from early childhood to late adolescence.

For the different trajectories identified, we aimed to examine child and family characteristics [child's externalizing problems, internalizing symptoms, quality of life and family socioeconomic status (SES)]. Based on previous findings in the literature, we expected children and adolescents in high trajectories of hyperactivity-impulsivity, inattention or total symptoms to have higher levels of other externalizing behaviour problems as well as internalizing problems [15–17], lower levels of quality of life [18, 19] and lower family SES [8].

Method

Study design and sample for analysis

The BELLA study aimed to investigate mental health issues of children and adolescents in Germany [20]. Study goals were to estimate prevalence rates for a broad range of mental health problems and to assess the risk and protective factors of mental health problems as well as their consequences. The BELLA study was the mental health module of the German National Health Interview and Examination Survey for children and adolescents (KiGGS) [21]. It had a cross-sequential design, which combined both

cross-sectional and longitudinal study aspects [22]; i.e., multiple age cohorts were considered at the same time at the first measurement (cross-sectional) and subsequently followed over time (longitudinal). For the current analysis, we used three of the four assessment points of the BELLA study (the main outcome measures were not available at fourth assessment point): at the first measurement point (baseline), eleven birth cohorts aged 7–17 years were examined; the two follow-up assessments were at 1 year (1-year follow-up) and 2 years (2-year follow-up) after the baseline assessment.

The nationally representative KiGGS sample included 17,641 families with children and adolescents aged 0–17 years from 167 sampling units across Germany [21]. For the BELLA study, a subsample of 2,942 families with children and adolescents aged 7 years or older was randomly selected from the KiGGS study sample. Out of these, a number of 2,863 families gave written informed consent and finally participated in the BELLA study [20]. The current analysis included 2,593 of these families with data available from at least one of the measurement points for at least one of the three outcome measures (inattention $n = 2{,}591$; hyperactivity-impulsivity $n = 2{,}588$; total symptoms $n = 2{,}587$). Missing data analysis revealed that attrition during the course of the study was increased for families with low SES and a migration background, using the complete BELLA baseline sample as the reference sample [23]. Further details about the design and the sample (including missing data analysis) of the BELLA study are reported elsewhere in this issue [23].

Assessments

The main outcome measures were ADHD symptoms of inattention, hyperactivity-impulsivity and total symptoms (inattention and hyperactivity-impulsivity combined). These were rated by parents using the ADHD Symptom Checklist (Fremdbeurteilungsbogen für Aufmerksamkeitsdefizit-/Hyperaktivitätsstörung [FBB-ADHS]), which is part of the German Diagnostic System for Psychiatric Disorders in Children and Adolescents (DISYPS) [24, 25]. This checklist assesses the 18 symptom criteria for ADHD according to DSM-IV-TR and 18 criteria for HD according to ICD-10, covering a total of 20 items to account for differences between the two sets of criteria. For the total symptoms score (FBB-ADHS-Tot), each of the 20 items are rated on a 4-point scale (0–3), with higher scores indicating more severe symptoms. Scores for the two subscales of inattention (FBB-ADHS-Inatt, with 9 items) and hyperactivity-impulsivity (FBB-ADHS-HypImp, with 11 items) were also obtained. The scale scores (range 0–3) represent the mean of the individual item scores. The scales have been shown to have factorial validity and good internal consistency with Cronbach's α coefficients of 0.81 for inattention, 0.87 for hyperactivity-impulsivity and 0.88 for the total symptom score [26].

Further measures used to assess characteristics of the different subgroups (i.e., externalizing behaviour, emotional symptoms, quality of life and family SES) are described in the online supplement.

Analysis

Normative developmental change of inattention (FBB-ADHS-Inatt), hyperactivity-impulsivity (FBB-ADHS-HypImp) and total symptoms (FBB-ADHS-Tot) in the total group was analysed using growth curve modelling [27, 28]. Subgroups of children and adolescents with different developmental trajectories of inattention (FBB-ADHS-Inatt), hyperactivity-impulsivity (FBB-ADHS-HypImp) and total symptoms (FBB-ADHS-Tot) were identified by applying growth mixture modelling [29, 30]. In contrast to growth curve modelling, growth mixture modelling does not assume that individuals come from a single homogeneous population with a common set of parameters, but allows for subgroups with different developmental trajectories. Growth curve modelling and growth mixture modelling analyses were conducted using Mplus, Version 7 [31]. Three different model specifications were considered: (1) fixed linear models, (2) random linear models, and (3) fixed quadratic, random linear models. For all models, intercepts were random. For growth curve modelling of the total group, model selection was based on model fit indices and parameter estimates. As the models were nested, they were compared using the chi-square difference test. For the subgroup analyses based on growth mixture modelling, model selection was based on clinical expectation and statistical criteria [Bayesian information criterion (BIC)]. Missing data were handled using full information maximum likelihood estimation [32]. To estimate trajectories over the entire age range of the study (7–19 years), the data were analysed using an accelerated longitudinal design [33, 34]. The different subgroups for inattention (FBB-ADHS-Inatt), hyperactivity/impulsivity (FBB-ADHS-HypImp) and total score (FBB-ADHS-Tot) were further compared according to child variables of sex, externalizing behaviour, emotional symptoms, quality of life and family SES (all assessed at baseline) using chi-square tests for categorical variables and univariate analyses of covariance (ANCOVA) for continuous variables (covariates: sex, age, externalizing or internalizing symptoms, quality of life and family SES unless they were the dependent variable). Where results were significant, pairwise comparisons were performed

Table 1 Means, standard deviations and sample size of the main outcome measures inattention ($n = 2{,}591$), hyperactivity-impulsivity ($n = 2{,}588$) and total symptoms ($n = 2{,}587$) when analysed using an accelerated longitudinal design

Age (in years)	Inattention		Hyperactivity-impulsivity		Total symptoms	
	n	Mean (SD)	*n*	Mean (SD)	*n*	Mean (SD)
7	244	0.71 (0.43)	242	0.43 (0.37)	242	0.56 (0.36)
8	452	0.71 (0.48)	449	0.43 (0.39)	450	0.56 (0.39)
9	626	0.73 (0.52)	620	0.41 (0.41)	616	0.55 (0.41)
10	640	0.73 (0.52)	634	0.41 (0.44)	634	0.55 (0.43)
11	588	0.69 (0.49)	587	0.36 (0.36)	583	0.51 (0.38)
12	557	0.68 (0.48)	550	0.35 (0.35)	548	0.50 (0.37)
13	536	0.65 (0.47)	529	0.32 (0.37)	530	0.47 (0.38)
14	526	0.66 (0.50)	519	0.33 (0.38)	520	0.48 (0.39)
15	520	0.65 (0.46)	519	0.32 (0.35)	516	0.47 (0.35)
16	500	0.60 (0.44)	498	0.28 (0.31)	496	0.42 (0.33)
17	474	0.58 (0.46)	472	0.28 (0.32)	472	0.42 (0.35)
18	229	0.52 (0.42)	226	0.27 (0.32)	226	0.38 (0.30)
19	101	0.52 (0.43)	102	0.25 (0.35)	101	0.37 (0.34)

Sample sizes for the respective age groups vary as a function of the number and size of the contributing cohorts and dropout. Inattention = Subscale of the ADHD Symptom Checklist (FBB-ADHS-Inatt); Hyperactivity-impulsivity = Subscale of the ADHD Symptom Checklist (FBB-ADHS-HypImp); Total symptoms = Total symptom score ADHD Symptom Checklist (FBB-ADHS-Tot)

SD standard deviation

using the least significance difference method. Further details about the analyses are provided in the online supplement.

Results

Observed values and average symptom course for the total group

Table 1 presents the means, standard deviations and available sample sizes for the three outcome measures of inattention (FBB-ADHS-Inatt), hyperactivity-impulsivity (FBB-ADHS-HypImp) and total symptoms (FBB-ADHS-Tot) when data for the total group were analysed from the accelerated longitudinal design. On a descriptive level, a decrease in ADHD symptoms was observed from ages 7–19 years for all three scales. Growth curve models confirmed the symptom decline with increasing age was statistically significant (for details see online supplement). The average trajectory of inattention, hyperactivity-impulsivity and total symptoms in the total group are shown in Fig. 1.

Detection of subgroups

From the growth mixture modelling to detect subgroups, the three-class solution of the fixed linear model was preferred for the data on inattention (FBB-ADHS-Inatt), hyperactivity-impulsivity (FBB-ADHS-HypImp) and total symptoms (FBB-ADHS-Tot) (for details see online supplement). The results are shown in Figs. 2, 3 and 4, respectively.

Size and course of the subgroup trajectories were comparable across the three outcome domains and were labelled as low, moderate and high based on their overall symptom levels over time. For inattention (FBB-ADHS-

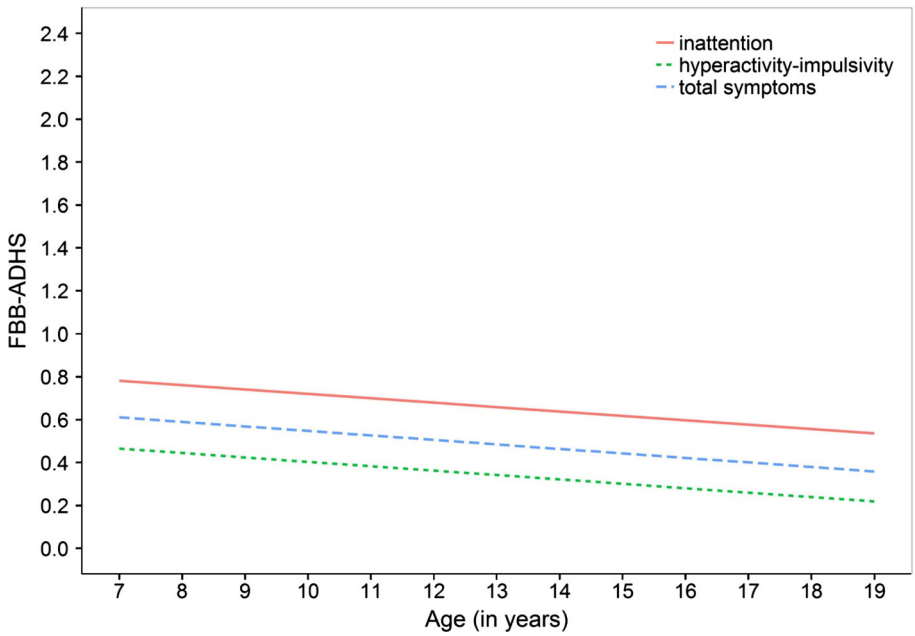

Fig. 1 Average trajectory of inattention ($n = 2{,}591$) hyperactivity-impulsivity ($n = 2{,}588$) and total symptoms ($n = 2{,}587$) in the total group using the ADHD Symptom Checklist (FBB-ADHS)

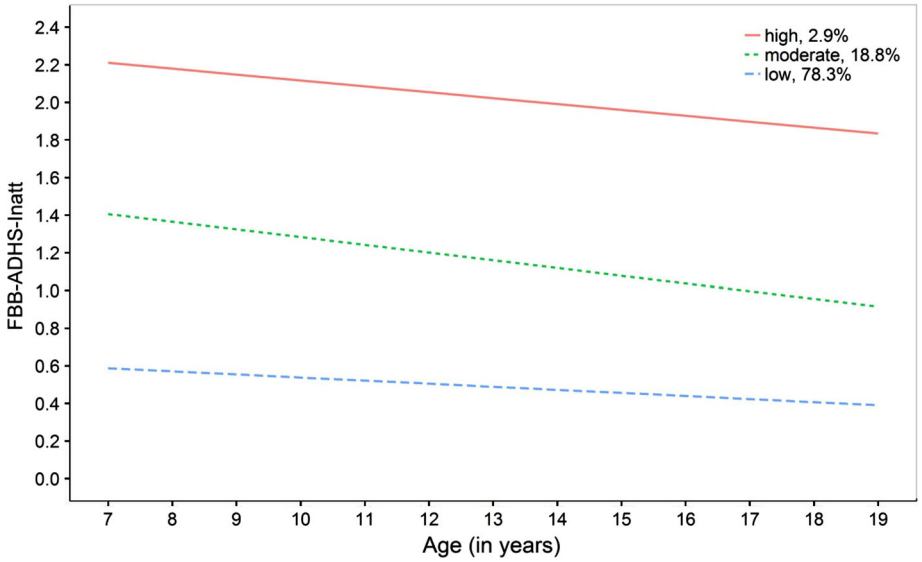

Fig. 2 Three-class solution of the fixed linear model for inattention ($n = 2{,}591$) using the respective subscale of the ADHD Symptom Checklist (FBB-ADHS-Inatt)

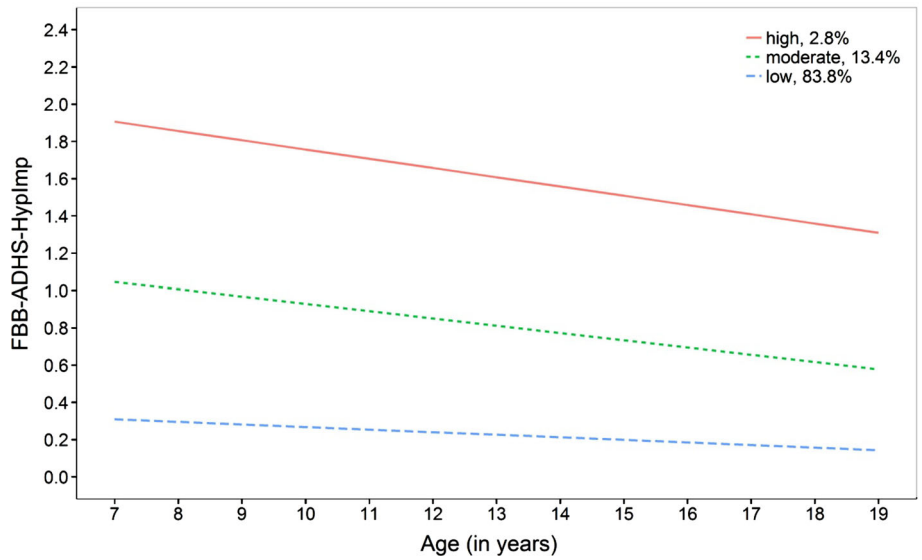

Fig. 3 Three-class solution of the fixed linear model for hyperactivity-impulsivity ($n = 2{,}588$) using the respective subscale of the ADHD Symptom Checklist (FBB-ADHS-HypImp)

Inatt), hyperactivity-impulsivity (FBB-ADHS-HypImp) and total symptoms (FBB-ADHS-Tot), the majority of children and adolescents were in the low subgroup, with 78.3, 83.8 and 82.7 % of children and adolescents, respectively, falling into that subgroup. In contrast, about three percent of children and adolescents fell into the high subgroup (2.8, 2.9 and 3.2 % for the outcome domains of hyperactivity-impulsivity, inattention and total symptoms, respectively). In general, a symptom reduction over time was observed in all three subgroups for all three outcome domains. The only exceptions were the high groups for inattention (FBB-ADHS-Inatt) and total symptoms (FBB-ADHS-Tot), where significance was missed, although the mean α of the slope (inattention high: $\alpha = -0.031$, $p = 0.10$; total symptoms high: $\alpha = -0.035$, $p = 0.10$) was numerically larger than that of the corresponding low group (inattention low: $\alpha = -0.016$, $p < 0.01$; total symptoms low: $\alpha = -0.015$, $p < 0.01$). One reason for this finding might have been a lack of power in the high subgroup due to its much smaller size. Overlap among subgroups of inattention (FBB-ADHS-Inatt) and hyperactivity-impulsivity (FBB-ADHS-HypImp) was further investigated by computing joint frequencies and conditional probabilities. These results are reported in the online supplement.

Description of subgroups

Chi-square tests revealed that sex was not equally distributed among the severity groups for inattention (FBB-ADHS-Inatt), hyperactivity-impulsivity (FBB-ADHS-HypImp)

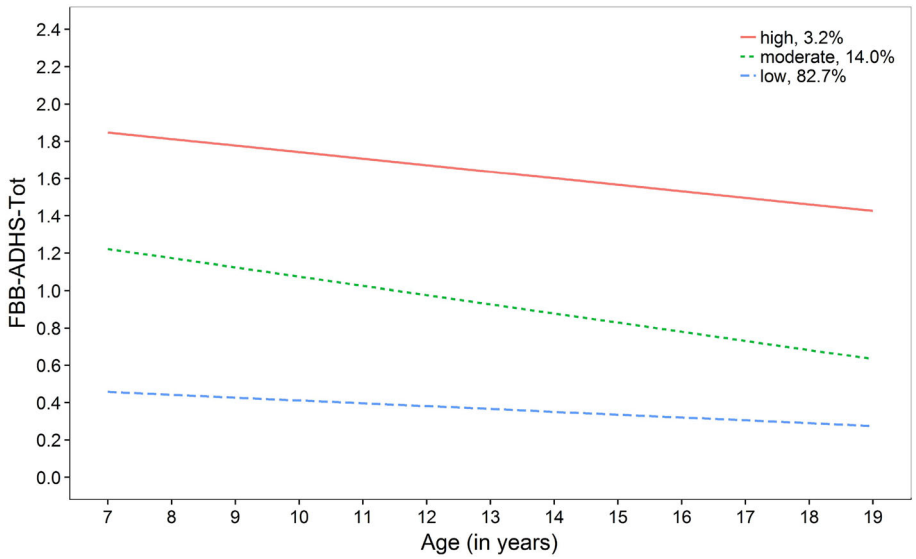

Fig. 4 Three-class solution of the fixed linear model for total symptoms ($n = 2{,}587$) using the respective scale of the ADHD Symptom Checklist (FBB-ADHS-Tot)

and total symptoms (FBB-ADHS-Tot), with comparatively more boys in the high subgroups for all three outcome measures (for details see online supplement). For all dependent variables, ANCOVAs revealed significant main effects for the subgroups of inattention (FBB-ADHS-Inatt), hyperactivity-impulsivity (FBB-ADHS-HypImp) and total symptoms (FBB-ADHS-Tot). On average, children and adolescents in the low subgroups demonstrated the least externalizing and internalizing symptoms, the highest quality of life and their family had the highest SES, compared with either or both of the other two subgroups (moderate, high). Furthermore, for all three outcome domains, the high subgroups demonstrated more severe externalizing and internalizing symptoms and had a lower quality of life (only true for inattention) when compared with the corresponding moderate subgroup. Family SES could not distinguish between the moderate and high subgroups for any symptom domain. For further details about the results of this analysis, please see the online supplement.

Discussion

This study gives new insights into the development of ADHD symptoms in children and adolescents in the general population. To our knowledge, this study is the first to explore different trajectories of symptoms of inattention, hyperactivity-impulsivity and total symptoms as defined by the full set of DSM-IV and ICD-10 symptom criteria from childhood to adolescence. In the first step of the analysis for the total group, we found a linear decline in the course of these symptoms across the age range of 7–19 years. This replicates previous findings of a normative decline in ADHD symptoms across development both in clinical samples and in general population samples [5, 9, 35].

Based on empirical fit indices and in agreement with our a priori expectations derived from previous empirical studies, the second step of the analyses identified three developmental trajectories that corresponded to low, moderate and high symptom levels for each of the outcome domains of inattention, hyperactivity-impulsivity and total symptoms. A decrease in symptomatology across childhood and adolescence was observed in all trajectories except for the high inattentive and high total symptoms subgroups, in which the numerical decline was non-significant most likely due to a lack of power.

Children and adolescents with low symptom scores represented by far the largest subgroup for all three outcome domains (ca. 80 %). Although they showed some signs of ADHD symptoms, these can be considered as normative and age-appropriate. Children and adolescents with a low symptom course have been reliably detected across different studies, with reported group sizes varying between 62 % [36] and 91 % [8]. In some other studies, instead of a single group with low symptoms, two subgroups with minor symptoms labelled ‘near zero’ and ‘low’ were identified [9]. The low subgroups reflect the large proportion of children and adolescents in the general population that is not seriously affected, not only with respect to ADHD symptoms, but also on other variables including comorbid externalizing and internalizing symptoms, quality of life and family SES.

About 3 % of the sample followed high symptom trajectories. For hyperactivity-impulsivity, the high subgroup showed decreasing scores with age until late adolescence. This is consistent with previous research on this symptom domain [5, 6] and confirms the stability of this finding across different study settings. For inattention, previous results were conflicting and a recent study using the same statistical approach for more severely affected children

found an increase in symptom level from middle childhood to adolescence [8]. In our high inattention subgroup, symptom scores seemed to decrease with age, but statistical significance was missed and, therefore, the inattention symptoms must be considered as stable over time (the same is true for the high subgroup of total symptoms).

At the end of adolescence, however, the high subgroups continued to have more severe ratings for inattention ($\approx$2.0), hyperactivity-impulsivity ($\approx$1.5) and total symptoms ($\approx$1.6) on the corresponding scales of the ADHD Symptom Checklist (FBB-ADHS); i.e., on average every item was rated between "somewhat problematic" and "considerably problematic". Children and adolescents following these high trajectories may reflect patients typically diagnosed with ADHD and there is a correspondence between the estimated group size and reported prevalence rates for ADHD [1].These results extend the findings of previous studies with global ADHD rating scales or DSM-III-R-based ratings, which identified between 4 % [9] and 9–14 % [8] of children in high ADHD or inattention/hyperactivity-impulsivity trajectories.

Consistent with a previous study [8], children and adolescents with high symptom trajectories had lower SES, higher rates of male gender and higher comorbidity scores on internalizing and externalizing problems, compared to children and adolescents from the low symptom group. Moreover, we also found lower quality of life in the high trajectory subgroup for inattention and total symptoms. These findings in longitudinally defined groups extend the results of cross-sectional epidemiological studies demonstrating higher rates of boys and low SES as well as higher comorbidity rates and lower quality of life in children and adolescents with ADHD [2].

We additionally considered a total score in our analyses because psychometric research of bifactor models has shown that covariation among ADHD symptoms is often well explained by a general factor [13, 14]. Because the subgroup solutions were similar with respect to group size and course for all three outcome domains, it could be argued that consideration of the total score alone would be sufficient. However, when we inspected subgroup combinations for inattention and hyperactivity-impulsivity using conditional probabilities (for results see online supplement), high values were obtained only among the low subgroups. This was not true for the moderate and high subgroups, which might indicate that it is useful to consider separate domains instead of a single general construct. Furthermore, bifactor models also include specific factors, and therefore, they are also important for understanding covariation among ADHD symptoms. More research is needed on this topic.

Our study has some limitations. First, only parent reports were used. Parents are the main informants for assessment of psychopathology in their children and adolescents, but behaviour at school may be especially informative and parents may not be aware of their child's behaviour in this setting. However, studies have reported moderate correlations between parent and teacher ratings [37]. Second, for each of the eleven birth cohorts, data for analysis was only available for a limited observational period of 2 years. We used an accelerated longitudinal design to estimate trajectories that cover the age range from 7 to 19 years and cohort differences are a common threat to the validity of this design [34]. Furthermore, missing data analysis showed that families with a low SES and migration background were more likely to drop out of the study [23]. Our results, therefore, may not reflect "true" longitudinal change and may be misleading in terms of insufficient recognition of birth cohort differences and selective drop out. Indeed, for both the normative trajectories and the subgroup trajectories, we obtained some indication of varying longitudinal courses depending on the birth cohort (for details see online supplement). Although their predictive power was considered to be minor, our results have to be replicated in a representative sample also addressing ADHD symptoms as defined by DSM-IV and ICD-10. Third, the analysis of similarities and differences among subgroups was cross-sectional in nature and, therefore, the explanatory power is limited and the causality of any observed differences cannot be established.

Overall, this study of children and adolescents in a community sample identified three subgroups for each of the outcomes of inattention, hyperactivity-impulsivity and total symptoms. For each outcome measure, about 3 % of individuals had high ratings in childhood that remained remarkably elevated in late adolescence. The majority of children and adolescents only demonstrated minor symptoms (low ratings) that can be considered as normative and age-appropriate. In particular, we obtained no evidence for a subgroup with emerging symptoms across childhood and adolescence. Therefore, the results indicate that children with ADHD can be reliably detected in school-age and, correspondingly, children with a low symptom level during this age period are not at risk for a subsequent development of serious ADHD symptoms.

Keypoints

- In the BELLA study, three trajectory groups with low, moderate and high symptom levels were detected for inattention, hyperactivity-impulsivity and total symptoms.
- About 80 % of all children and adolescents demonstrate a low level of ADHD symptoms (inattention, hyperactivity-impulsivity, total symptoms) over time.

- About 3 % of all children and adolescents followed a course with severe clinical symptoms.
- Except for the high subgroups of inattention and total symptoms, there was a decrease of symptoms in all severity subgroups over the age period from 7 to 19 years.
- Children and adolescents following different trajectories can be distinguished on several dimensions including sex, comorbid internalizing and externalizing problems, quality of life and family SES.

Acknowledgments The authors thank the Robert Koch Institute for their ongoing support and co-operation. We kindly thank Deirdre Elmhirst (Elmhirst Medical Writing Services) and Christina Dose (University Hospital of Cologne) for carefully reading the manuscript. The BELLA study has been financially supported by various grants: Baseline, 1-year follow-up and 2-year follow-up of the BELLA study were financed by the Stifterverband für die Deutsche Wissenschaft. The 6-year follow-up was funded by the German Federal Ministry of Health (BMG).

Conflict of interest None of the authors has a conflict of interest to disclose.

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