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ORIGINAL ARTICLE

Time trends and determinants of multiple development delays in Bavarian preschool children: a retrospective analysis from 1997 to 2010

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Abstract
Objectives The aim of this study was to identify the time trends of multiple developmental delays and to determine the strength of selected factors influencing preschool child's development.
Methods We reviewed the records of 13,876 preschoolers in a district of Lower Bavaria to determine prevalence and time trends of combined developmental delays from 1997 to 2010. The effect of age, sex and nationality on development was estimated by using regression models.
Results The largest increase was in the area of psychosocial development (1997:3.8 % versus 2010:13.8 %), followed by twofold combined delays in motor (2.6 versus 14.4 % in 2009) and twofold delays (1.3 versus 6.2 %) in cognition. Youngest children (4.26–5.49 years) had the highest risk for twofold delays in motor (4.78; 95 % CI 3.30–6.92), whereas strongest protection was observed for girls (0.28; 95 % CI 0.22–0.36) for threefold delays in motor and for a German nationality (0.30; 95 % CI 0.20–0.43) for fourfold delays in cognition.
Conclusions According to this study, multiple disabilities in development were increasing in preschool children. These children can be considered as a risk group who therefore require measures in Public Health.

Keywords Preschool children · Development · Combined delays · Prevalence · Time trends · Determinants

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Introduction

By the end of 1980s little was known about prevalence of different delays in development of childhood, especially in preschool children. The early 1990s saw the publication of a number of important studies documenting the prevalence of specific impairments in preschool children (Karch 1990; Wohlfeil 1991). Over more recent years, epidemiological studies have reported an increase in the prevalence of impairments in single specific areas of development (Boyle 2001; Flender 2005; Stich 2009; Stich et al. 2012).

Age, sex and nationality have been identified as strong correlations to the appearance of single developmental delays (Campell et al. 2003; de Moura et al. 2010; Karch 1990; Stich et al. 2012; Thompson et al. 2003; Wohlfeil 1991). Over the last decade we have seen in the literature a greater focus on assessing multiple or co-occurring delays both by specialists (Dewey et al. 2002; Kadesjö and Gillberg 2001; Landgren et al. 1996; Nicholoson and Fawcett 1994; Sachdeva et al. 2010; Tirosh et al. 1998; Valtonen et al. 2004; Viholainen et al. 2002; Webster et al. 2005; Yochman et al. 2006) and experts of Public Health (Bavarian Health and Food Safety Authority 2006, 2013; Robert Koch-Institute 2007).

A number of researchers have explored the prevalence of combined delays of motor, speech and other important subareas of development (Dewey et al. 2002; Kadesjö and Gillberg 2001; Landgren et al. 1996; Nicholoson and

Fawcett 1994; Sachdeva et al. 2010; Tirosh et al. 1998; Valtonen et al. 2004; Viholainen et al. 2002; Webster et al. 2005; Yochman et al. 2006). Children with multiple or combined delays may be considered a population at high risk of adverse outcomes relative to children with single developmental delays and distribution patterns for a number of combined delays have been documented (Eldred and Darrah 2010; Stich et al. 2014; Tervo 2003).

In many European countries school entry examinations are mandated before children can enter the first year of school. These examinations allow the screening of children for medical and developmental disorders and for early interventions to occur. In Germany, all preschool children are assessed by specialists from the local health departments using a standardized battery of screening tests. With a population of 12.7 million, Bavaria is the second largest state of Germany both in size and population (Bavarian State Office for Statistics 2016). The district of Dingolfing-Landau represents one of 71 administrative districts of Bavaria. The district has a population of almost 100,000, and its economy relies heavily on the automobile industry (Bavarian State Office for Statistics 2015). The focus of the school entry examinations is on assessing deficits or delays in motor, speech, cognition and psychosocial development by using standardized procedures (Task Force "School and Youth Health Care in the Public Health Services" 1997). We retrospectively analyzed data from a consecutive cohort of preschool children over 14 years. A quantitative approach was utilized to assess changes in the prevalence of combined developmental delays in preschool children over the time of the study period. The correlation between selected risk factors and the incidence of developmental delays of motor, speech, cognitive and psychosocial functioning was determined.

Methods

Study design

Before commencing primary school, all children in the federal state of Bavaria, Germany, are routinely examined by Public Health experts in a so-called "school-enrolment-examination" (Bavarian Law of Education and Instruction 2011). Since the assessments are compulsory, the corresponding data set was very comprehensive and access data for nearly all children could be achieved.

All the assessments were conducted by the "school-examination-team" from the local Public Health Medicine Service, which remained the same over the whole study period (one school doctor and one social medical assistant). The duration of one screening consisted in the average about 20 min and was carried out generally in the kindergarten.

Methodology of the examination and the criteria utilized for defining impairment remained unchanged over the period of investigation. The examination was conducted utilizing a modified manual for school entry examinations (Task Force "School and Youth Health Care in the Public Health Services" 1997), which is a recommendation for the whole state of Bavaria. This examination is standardized and assesses four defined domains of development: motor, speech, cognitive and psychosocial functioning.

The criteria and methodology identifying impairments using this examination are comparable the Denver Developmental Screening Test (DDST) (Frankenberg and Dobbs 1967).

Each of the developmental domains assessed in the examination is further subdivided into specific subareas (Table 1). Impairment in two standardized tests for motor development or in a single test for speech, cognitive or psychosocial development indicates a delay of development. It must be noted that the examination is a screening instruments only and while it has good psychometric properties, it is not a substitute for clinical assessments or comprehensive psychometric testing.

Results of the screening examinations for all children in the district of Dingolfing-Landau, Bavaria, in the years 1997–2010 were analyzed retrospectively ($N = 14{,}068$).

Statistical analysis

Variables for 12 possible impairments were defined in a binary form (0 = no delay versus 1 = delay). Point-prevalence of delays in percent were calculated for every year of school entry examination and differences between the annual prevalence rates were assessed by the χ^2 test using 1997 as year of reference and for all vintages together in the sense of proportions. The Mann–Whitney *U* test was used to calculate homogeneity between two consecutive vintages to identify differences of these cohorts.

The influences of age (youngest children versus middle-aged versus older; reference: older), sex (boy versus girl; reference: boy) and nationality (non-German versus German; reference: non-German) on the number of impairments in subareas of development (delay versus no delay; reference: no delay) was determined by the use of multinominal (for motor, speech and cognition) and binary (for psychosocial) regression models.

Univariate regression models were used to determine the crude odds-ratios (cOR) for delays in each year. Subsequently we used multivariate regression models to assess the effect of age, sex and nationality for the calculation of adjusted odds-ratios (aOR).

Table 1 Domains and subareas of developmental functioning assessed and corresponding standardized tests procedures of the modified "Bavarian Model" for school entry examinations in the District of Dingolfing-Landau, Germany, during 1997–2010

Domains of development	Subareas	Standardized test procedures
Motor	Gross motor skills	Free standing on one leg without putting the other foot to the ground (at least 10 s, both legs max. three trials, one trial max. 30 s)
		Jumping on one leg without stepping to the ground (at least 5 times on each leg, max. 15 times with each leg)
		Going like a rope dancer (20 steps forwards and backwards with both legs in a nearly straight line, max. 3 deviations from the straight line); Going with clapping hands (walk a 10 m walk and clapping hands at each step on nearly straight line)
	Fine body coordination	Finger-opposition test (touching with the thumb all other fingers from 2 to 5 forwards and backwards, 3 sequences per hand, max 3–4 s pro sequences per hand)
		Fist-palm test (one hand clenched to fist the other as palm and change of hands min. 7–10 times in 10 s)
		Thumb-palm test (as previous one but with the thumb and palm min. 7–10 times in 10 s)
	Graphomotor coordination	Drawing different figures by using a template with following forms (four shapes: circle, cross, triangle, square; proportions and the holding of the pen should be age-appropriate)
		Drawing of a person (head with eyes, mouth, ears, hairs, body and hands and legs; proportions and the positions of the body parts should be age-appropriate)
Speech	Pronunciation	Repeating words (8–10 words with specific consonants and vocals have to be repeated with about max 15 syllables)
	Grammar	Retelling a short story (five sentences, i.e., a "girl has a fish in a glass—the fish is growing and fits no more in the glass—girl gives the fish in a river")
		Retelling a short picture story (i.e., boys are playing football and one boy shoots a goal)
		Explaining rules of a well-known game (i.e., football)
	Rhythm of speech	Repeating sentences with specific sounds (i.e., blue flower, brown bear)
		Repeating sentences with 7–10 words including three adjectives (i.e., "I pluck three beautiful red roses from the bush")
Cognition	Memory and concentration	Repeating four single numbers in the correct sequence (i.e., "4–1–5–7")
	Perseverance	Discontinuity of capacity to attend during the examination
	Abstraction	Building pairs (i.e., knife and fork); finding out an object of various objects belonging together (i.e., five snowmen, four with a head and one hatless; four different specifications are presented, three requirements must be answered correctly)
	Visual perception	Reception and knowing of simple geometric figures or silhouettes of figures and animals (i.e., circle, flower, elephant; eight pictures are represented, six pictures should be named correctly)
	Arithmetic and amount detection	Counting from 1 to 10 in the correct sequence;
		Distinction and designation of frequencies between two different colored ball quantities (a quality detection until 4 is required)
Psyche	Behavior	Erratic; overly bonded with mother (no separation possible during examination); hostility towards examiner
	Emotionality	Major mood swings; crying
	Psycho-motor	Agitation; unable to sit calmly for a few minutes

The significance level was set at $\alpha \leq 0.05$. All analyses were made with software package SPSS 21.0.

Hypotheses

We predicted that the frequencies of single developmental delays would be much higher than multiple developmental delays. We were uncertain whether there would be any large change in incidence of delays over the 14 year study period. Generally we expected the rates to remain reasonably stable since we did not consider there to be any obvious socio-demographic changes in the population over the period and the study area remained nearly unchanged over the whole time period. Since we previously demonstrated that age, sex and nationality have an important impact on the occurrence of single developmental delays, we postulated that these factors similarly influenced the incidence of multiple impairments in preschool children.

Results

Socio-epidemiology

The children had an average age of 5.92 years (standard deviation ± 0.39) with a total range between 4.26 until 7.91 years (14 %: 4.26–5.49 years versus 79.6 %: 5.50–6.50 years versus 6.4 %: 6.51–7.91 years). There was a slight over representation of boys versus girls (51.6 % male:48.4 % female) and most children were of German nationality (88.2 versus 11.8 %: non-German).

Prevalence and time trends of impairments

For the whole study population the majority of the children (83.7 % of 13,975 children) demonstrated no delays in motor development. Over the 14 years of the study period, however, we saw a large increase in the prevalence of single and multiple motor delays (Tables 2, 3). The subgroup of preschool children with two areas of delay in motor development showed the largest increase in the prevalence (1997: 2.6 % versus 2010: 14.4 %; $\chi^2 = 197.12$). The prevalence for single motor delays (1997: 1.4 % versus 2010: 8.9 %) and threefold (1997: 1.4 % versus 2010: 5.3 %) impairments demonstrated a smaller but statistically significant increase. All prevalence differences proved to be statistically highly significant for the whole time period ($\chi^2 = 724.15$; $\alpha \leq 0.0001$).

Within the area of language development we saw the largest changes over the duration of the study period. At the beginning of the observation period most children demonstrated no impairments of language (1997: 88.8 %); however, by 2006 we began to see an increase in the prevalence of one or more delay in language development (2006: 13.4 %; $\chi^2 = 66.74$). The prevalence of 2- and 3-fold delays in language development showed small fluctuations over the study period, but single delays in speech increased in the trend by more than half (8.9 % versus 1997: 15.5 % in 2010; $\chi^2 = 25.36$) (Tables 2, 3). All differences between the enrollment cohorts were highly significant between all cohorts ($\chi^2 = 241.03$; $\alpha \leq 0.0001$).

In the field of cognitive development few of 13,875 the preschool children showed disabilities in 1997 (7.2 %) but by 2010 this figure had increased considerably (21.4 %; $\chi^2 = 119.11$). The prevalence increased primarily for single and twofold delays in cognition over the 14 years. The incidence of 3-, 4- and 5-fold developmental delays remained reasonably stable over the period (Tables 2, 3). According to χ^2 test all differences between cohorts were considered as significant over the whole observation period ($\chi^2 = 408.05$; $\alpha \leq 0.0001$).

Impairments in the area of psychosocial development demonstrated a dramatic increase over the 14-year observation period (1997: 3.8 % versus 2010: 13.8 %; $\chi^2 = 63.11$). There were also fluctuations in prevalence over the investigation period. Initially, soon after the beginning of investigation period prevalence increased (1999: 7.9 %; $\chi^2 = 16.67$) followed by a small decrease in the subsequent years and then rose again from 2005 (6.3 %; $\chi^2 = 6.91$) until 2010 (Tables 2, 3). We saw statistically significant differences from year to year during 1997–2010 ($\chi^2 = 120.88$; $\alpha \leq 0.0001$).

Associations between number of delays and influence factors

We saw significant increases in delays in motor development over the period. For motor development highest risk with almost 380 % was noted for twofold delays in the group of younger preschool children, whereas risk for children in regular preschool age was only increased by 89 %. These crude risks did not differ significantly from the adjusted odds-ratios (Table 3). Being female and having German national identity were both associated with a lower risk for single and multiple developmental delays in motor development in both regression models (Table 4).

In the area of language development, only the influence of sex was identified as a significant factor in single and twofold developmental delays. The incidence of speech disorders in boys was twice that of girls irrespective of age and nationality (Table 4).

For cognitive development, being younger at the time of school entry was associated with and increased incidence (130 % risk increase) of single developmental delays. Girls had consistently reduced risk compared to boys for almost all delays in cognition, with almost identical effect estimates in both models (cOR 0.41–0.61 versus aOR 0.41–0.69). Children of German nationality were at reduced risk of demonstrating cognitive impairments, with an overall risk reduction of 70 %. This protective effect was very strong in 4- and 5-fold delays in cognition with marginal differences in regression models (cOR 0.30; 0.33 versus aOR 0.30; 0.34) (Table 4).

Differing patterns of impairment were seen in the area of psychosocial development. The youngest preschoolers had overall 70 % increased incidence of developmental delays (cOR: 1.81 versus aOR: 1.68), while middle-aged and older children had no altered risk of these impairments. Unlike the effect observed in the other three areas of development there was a higher prevalence of psychosocial delays for girls (cOR 35 % versus aOR 38 %) and for children of German nationality (cOR 81 % versus aOR 68 %) (Table 4).

Table 2 Prevalence and time trends of preschoolers without developmental impairments versus prevalence of numbers of combined delays in all four areas of individual development in the District of Dingolfing-Landau, Germany, during time period 1997–2003

Areas of development	Numbers of combined delays	Years of school entry examinations						
		1997 Prevalence (%)	1998	1999	2000	2001	2002	2003
Motor ($f = 192$)	No delay	94.6	94.7	90.3	87.1	86.6	87.6	85.3
	1	1.4	1.4	6.4	6.7	5.6	5.8	4.5
	2	2.6	2.2	2.2	3.6	5.7	5.6	8.3
	3	1.4	1.8	1.2	2.7	2.1	1.1	2.0
	χ^2	Reference year	1.13	**37.27**	**48.23**	**45.38**	**43.97**	**56.99**
	Mann–Whitney *U* test*	Significance between two enrollment years	**0.94****	$\leq$0.0001***	0.02	**0.71**	**0.47**	**0.09**
Speech ($f = 192$)	No delay	88.8	85.2	84.4	85.6	88.1	84.6	86.0
	1	8.9	11.4	11.2	10.5	10.6	10.9	11.4
	2	1.6	2.8	3.8	3.0	0.8	3.9	2.5
	3	0.6	0.5	0.7	0.9	0.4	0.5	0.1
	χ^2	Reference year	**7.95**	**13.14**	6.92	4.88	**13.52**	**9.83**
	Mann–Whitney U test*	Significance between two enrollment years	0.01**	**0.52*****	**0.41**	**0.07**	0.02	**0.31**
Cognition ($f = 193$)	No delay	92.8	84.8	83.3	83.1	89.9	89.2	87.3
	1	2.1	6.0	6.9	7.9	4.2	4.2	4.7
	2	1.3	4.5	6.0	5.7	4.2	4.6	4.9
	3	1.2	2.0	2.7	2.4	1.6	1.4	2.4
	4	0.5	2.0	1.1	0.9	0.2	0.5	0.8
	5	2.2	0.8	0.0	0.1	0.0	0.0	0.0
	χ^2	Reference year	**63.36**	**98.53**	**99.08**	**48.19**	**51.27**	**64.16**
	Mann–Whitney *U* test*	Significance between two enrollment years	$\leq$0.0001**	**0.45*****	**0.97**	$\leq$0.0001	**0.62**	**0.16**
Psycho-social ($f = 192$)	No delay	96.2	93.3	92.1	93.4	93.9	95.6	94.3
	1	3.8	6.7	7.9	6.6	6.1	4.4	5.7
	χ^2	Reference year	**9.34****	**16.67**	**8.46**	**5.91**	0.56	**4.39**
	Mann–Whitney *U* test*	Significance between two enrollment years	0.01	**0.29*****	**0.23**	**0.66**	**0.10**	**0.19**

In total: 14,068 preschool children

f missing

Level of significance for tests $p \leq 0.05$

χ^2: Chi-quadrat value for the particular vintage under reference to the index year 1997

* Mann–Whitney *U* test identifies homogeneity between two groups (school enrollment years). If the level of significance is higher than 0.05, there are significant

Differences in time trends of numbers of delays between the designated vintage and the previous year (i.e., 1998 versus 1997**; 1999 versus 1998***, etc.)

Significant differences in χ^2 test and in Mann–Whitney *U* test are in bold

Discussion

A pooled data set of 14 consecutive school enrollment cohorts was analyzed to assess time trends and the impact of social epidemiological determinants on multiple developmental delays from 12 defined subareas.

Especially, a strength of our study instrument might be the strong standardization of school entry examinations (Petermann and Daseking 2011; Bellman et al. 2013), so that our results are largely not modified by systematic errors (bias). Further, expected by the same research instrument and the same examiners throughout the whole observation period, a comparison of vintages with each other might be permitted objectively by a strong internal validity. Critically, it must be noticed a methodological weakness for the modified "Bavarian model", because the DDST from 1967 (Frankenberg and Dobbs 1967) and the German version from 1973 (Flehmig et al. 1973) as the

Table 3 Prevalence and time trends of preschoolers without developmental impairments versus prevalence of numbers of combined delays in all four areas of individual development in the District of Dingolfing-Landau, Germany, during time period 2004–2010

Areas of development	Numbers of combined delays	Years of school entry examinations						
		2004 Prevalence (%)	2005	2006	2007	2008	2009	2010
Motor ($f = 192$)	No delay	85.0	81.4	78.1	75.9	76.2	69.9	71.4
	1	4.6	7.8	8.8	5.6	4.3	12.2	8.9
	2	7.6	8.4	9.9	14.2	15.1	15.2	14.4
	3	2.9	2.4	3.3	4.2	4.4	2.7	5.3
	χ^2	**56.12**	**96.69**	**132.11**	**150.05**	**147.14**	**228.89**	**197.12**
	Mann–Whitney *U* test*	**0.83****	0.05***	0.05	**0.19**	**0.99**	0.04	**0.92**
Speech ($f = 192$)	No delay	78.9	77.5	76.6	78.0	79.7	79.2	80.6
	1	17.8	19.4	20.5	18.5	17.7	16.7	15.5
	2	3.3	2.9	2.7	3.4	2.5	4.0	3.2
	3	0.0	0.2	0.1	2.0	0.0	0.1	0.8
	χ^2	**49.82**	**56.16**	**66.74**	**49.61**	**42.45**	**42.63**	**25.36**
	Mann–Whitney *U* test*	$\leq$0.0001**	**0.47*****	**0.67**	**0.57**	**0.32**	**0.32**	**0.50**
Cognition ($f = 193$)	No delay	87.3	81.5	78.9	80.9	81.9	78.8	78.6
	1	3.8	7.1	8.9	9.1	6.7	10.5	10.1
	2	5.1	7.9	7.9	4.8	7.2	6.5	6.2
	3	2.6	2.3	3.1	3.0	2.9	2.8	2.7
	4	0.8	1.2	0.9	2.0	1.0	0.9	1.8
	5	0.5	0.0	0.2	0.2	0.3	0.6	0.6
	χ^2	**48.76**	**119.79**	**140.52**	**109.13**	**97.72**	**124.52**	119.11
	Mann–Whitney *U* test*	**0.93****	0.001***	**0.16**	**0.28**	**0.64**	**0.15**	**0.87**
Psycho-social ($f = 192$)	No delay	94.5	93.7	92.7	92.2	91.2	88.9	86.2
	1	5.5	6.3	7.3	7.8	8.8	11.1	13.8
	χ^2	3.37	**6.91**	**12.49**	**15.34**	**21.64**	**40.36**	63.11
	Mann–Whitney *U* test*	**0.81****	**0.44*****	**0.38**	**0.63**	**0.47**	**0.09**	**0.10**

In total: 14,068 preschool children

f: missing

Level of significance for tests: $p \leq 0.05$

χ^2: Chi-quadrat value for the particular vintage under reference to the index year 1997

* Mann–Whitney *U* test identifies homogeneity between two groups (school enrollment years). If the level of significance is higher than 0.05, there are significant

Differences in time trends of numbers of delays between the designated enrollment year and the previous year (i.e., 2004 versus 2003**; 2005 versus 2004*** etc.)

Significant differences in χ^2 test and in Mann–Whitney *U* test are in bold

basics for the modification has no ability to differentiate between/within groups and both manuals are not validated (Macha et al. 2005). This might be having a strong influence on the validity of the "Bavarian model". In contrast, the stability, consistency and equivalence as an item for reliability which might be represented by the strength selectivity of the diagnosis with their dichotomous coding by a constant investigation team during the whole observation period, a moderate reliability should be given. But it must be noticed that an empirical proof of the reliability is still missing. Additionally, a methodological related limitation of our analysis is that only dichotomous outcomes (presence versus absence of delays) were studied and no information about the quality and severity of delays was collected.

At the beginning of the 1990s literature on child developmental tended to describe delays primarily based on medical approaches and definitions (Karch 1990; Wohlfeil 1991). Motor and language deficits in development were the main focus of interest in these early studies (Campbell et al. 2003; Eldred and Darrah 2010; Kadesjö and Gillberg 2001; Nicholoson and Fawcett 1994; Wohlfeil

Table 4 Regression models—influences of age, sex and nationality on numbers of developmental delays in the District of Dingolfing-Landau, Germany, during the time period 1997–2010

Areas of development	Numbers of combined delays	Independent factors		Univariate regression			Multivariate regression		
				Crude odds-ratio (cOR)	95 % CI	*p* value	Adjusted odds-ratio[c] (aOR)	95 % CI	*p* value
Motor[a]	1	Age	Youngest	**2.20**	**1.56–3.10**	**≤0.0001**	**2.47**	**1.74–3.51**	**≤0.0001**
			Middle-aged	1.12	0.82–1.54	0.481	1.19	0.86–1.65	0.284
		Sex	Girl	**0.40**	**0.35–0.47**	**≤0.0001**	**0.39**	**0.33–0.45**	**≤0.0001**
		Nationality	German	**0.67**	**0.49–0.68**	**≤0.0001**	**0.70**	**0.58–0.86**	**≤0.0001**
	2	Age	Youngest	**4.78**	**3.30–6.92**	**≤0.0001**	**5.35**	**3.68–7.78**	**≤0.0001**
			Middle-aged	**1.89**	**1.32–2.70**	**≤0.0001**	**1.98**	**1.39–2.84**	**≤0.0001**
		Sex	Girl	**0.32**	**0.28–0.37**	**≤0.0001**	**0.30**	**0.26–0.34**	**≤0.0001**
		Nationality	German	**0.58**	**0.49–0.68**	**≤0.0001**	**0.30**	**0.53–0.75**	**≤0.0001**
	3	Age	Youngest	1.48	0.91–2.40	0.114	1.67	1.03–2.73	0.039
			Middle-aged	0.97	0.63–1.49	0.886	1.02	0.66–1.58	0.920
		Sex	Girl	**0.28**	**0.22–0.36**	**≤0.0001**	**0.28**	**0.22–0.35**	**≤0.0001**
		Nationality	German	**0.63**	**0.47–0.83**	**≤0.0001**	**0.65**	**0.49–0.87**	**0.003**
Speech[a]	1	Age	Youngest	**1.54**	**1.21–1.96**	**≤0.0001**	**1.64**	**1.29–2.09**	**≤0.0001**
			Middle-aged	1.20	0.96–1.48	0.107	1.22	0.98–1.51	0.077
		Sex	Girl	**0.49**	**0.45–0.54**	**≤0.0001**	**0.49**	**0.44–0.54**	**≤0.0001**
		Nationality	German	0.98	0.84–1.13	0.763	1.02	0.88–1.18	0.828
	2	Age	Youngest	0.71	0.47–1.08	0.109	0.78	0.51–1.19	0.241
			Middle-aged	0.62	0.44–0.88	0.007	0.66	0.46–0.93	0.658
		Sex	Girl	**0.41**	**0.33–0.51**	**≤0.0001**	**0.41**	**0.33–0.51**	**≤0.0001**
		Nationality	German	0.85	0.63–1.13	0.260	0.87	0.65–1.16	0.338
	3	Age	Youngest	0.56	0.17–1.84	0.337	0.57	0.17–1.88	0.353
			Middle-aged	0.61	0.24–1.55	0.300	0.62	0.24–1.57	0.311
		Sex	Girl	0.63	0.36–1.11	≤0.0001	0.64	0.36–1.12	0.118
		Nationality	German	0.82	0.37–1.82	0.621	0.82	0.37–1.82	0.618
Cognition[a]	1	Age	Youngest	**2.29**	**1.63–3.20**	**≤0.0001**	**2.30**	**1.63–3.24**	**≤0.0001**
			Middle-aged	1.17	0.85–1.60	0.339	1.20	0.87–1.65	0.268
		Sex	Girl	**0.70**	**0.60–0.80**	**≤0.0001**	**0.68**	**0.60–0.79**	**≤0.0001**
		Nationality	German	**0.49**	**0.41–0.58**	**≤0.0001**	**0.51**	**0.43–0.61**	**≤0.0001**
	2	Age	Youngest	**2.46**	**1.74–3.49**	**≤0.0001**	**2.45**	**1.73–3.48**	**≤0.0001**
			Middle-aged	0.99	0.71–1.37	0.931	0.96	0.72–1.38	0.976
		Sex	Girl	**0.61**	**0.53–0.71**	**≤0.0001**	**0.60**	**0.51–0.69**	**≤0.0001**
		Nationality	German	**0.47**	**0.39–0.56**	**≤0.0001**	**0.50**	**0.41–0.61**	**≤0.0001**
	3	Age	Youngest	1.39	0.85–2.29	0.193	1.41	0.85–2.34	0.186
			Middle-aged	0.87	0.56–1.35	0.541	0.90	0.57–1.41	0.645
		Sex	Girl	**0.62**	**0.50–0.78**	**≤0.0001**	**0.60**	**0.48–0.76**	**≤0.0001**
		Nationality	German	**0.36**	**0.28–0.47**	**≤0.0001**	**0.37**	**0.28–0.48**	**≤0.0001**
	4	Age	Youngest	1.68	0.72–3.92	0.234	1.56	0.67-3.67	0.305
			Middle-aged	1.24	0.58–2.68	0.580	1.24	0.58–2.68	0.581
		Sex	Girl	**0.70**	**0.50–0.98**	**0.036**	**0.69**	**0.49–0.97**	**0.034**
		Nationality	German	**0.30**	**0.20–0.43**	**≤0.0001**	**0.30**	**0.21–0.44**	**≤0.0001**
	5	Age	Youngest	0.81	0.26–2.50	0.722	0.81	0.27–2.49	0.712
			Middle-aged	0.66	0.20–0.43	0.378	0.67	0.27–1.71	0.407
		Sex	girl	0.41	0.30–0.73	**0.003**	0.41	0.23–0.74	**0.003**
		Nationality	German	**0.33**	**0.18–0.61**	**≤0.0001**	**0.34**	**0.18–0.62**	**≤0.0001**

Table 4 continued

Areas of development	Numbers of combined delays	Independent factors		Univariate regression			Multivariate regression		
				Crude odds-ratio (cOR)	95 % CI	*p* value	Adjusted odds-ratio[c] (aOR)	95 % CI	*p* value
Psychosocial[b]	1	Age	Youngest	**2.07**	**1.53–2.79**	**≤0.0001**	**2.02**	**1.50–2.73**	**≤0.0001**
			Middle-aged	0.92	0.70–1.22	0.573	0.92	0.70–1.22	0.923
		Sex	Girl	**0.74**	**0.65–0.84**	**≤0.0001**	**0.73**	**0.64–0.83**	**≤0.0001**
		Nationality	German	**0.55**	**0.47–0.66**	**≤0.0001**	**0.60**	**0.50–0.71**	**≤0.0001**

Significant associations are in bold

Reference no delays

Age youngest (4.26–5.49 years); middle-aged (5.50–6.50 years); Reference: older (6.51–7.91 years)

Sex Reference: boy nationality: Reference: non-German 95 % CI: 95 % confidence interval

[a] Multinomial logistic regression

[b] Binary logistic regression

[c] Age, sex and nationality

1991) and less was known about the prevalence of other developmental impairment in preschool children. A critical examination of the literature observed that the frequency of single (Bavarian Health and Food Safety Authority 2013; Boyle 2001; Robert Koch-Institute 2007; Stich 2009; Stich et al. 2012; Tirosh et al. 1998) and combined (Bavarian Health and Food Safety Authority 2013; Dewey et al. 2002; Kadesjö and Gillberg 2001; Tirosh et al. 1998; Valtonen et al. 2004; Webster et al. 2005; Yochman et al. 2006) developmental delays were very different. This was considered to be in largely attributable to the different definitions of these delays and to the different methodological approaches utilized.

In 1991, Wohlfeil investigated single developmental delays in preschool children and estimated a prevalence of 10 % for performance deficits. Boyle (2001), some ten years later, found a prevalence of 6–7 % for various speech and language disorders in children starting school. According to the data for the German state of Bavaria in 2008/2009 (with a cohort of 107,880 preschool children) 16.4 % of girls and 25.3 % of boys had speech articulation disorders and 7.3 and 10.6 % for word- and sentence-formation disorders, respectively, (Bavarian Health and Food Safety Authority 2013). This data has also shown a trend of increasing prevalence of impairments from 2004 onwards (Bavarian Health and Food Safety Authority 2013). Utilizing the same 12 defined subareas of development and with almost the same methodology, in the investigation area of the present study, over the period 1997–2009 the highest prevalence of single delays were seen in "pronunciation" (13.8 %) and "fine motor skills" (12.2 %) and the lowest in "arithmetic" (3.1 %) (Stich et al. 2012). In a similar study regarding the school entry years 1997–2007, a significant increase in motor and cognitive developmental delays were identified in subsequent cohorts over the duration of the study period (Stich 2009). Results of these two studies corresponded to those of simple developmental delays in the present study, which was to be expected.

With respect to multiple impairments in children, Kadesjö and Gillberg (2001) noted that 6.1 % of children in their study population had combined delays in both motor coordination and attention. In several further studies, children with specific developmental disorders were assessed for further impairments (Gaines and Missiuna 2007; Stich 2009; Stich et al. 2012; Tebruegge et al. 2004; Zimmer 2002). Generally, these studies provided evidence for a clustering of developmental delays, but their results are not directly comparable with the current study, which utilized a normal, unselected population. In addition, the cited studies assessed only a narrow spectrum of developmental delays. Clustering of multiple developmental delays to identify distribution patterns was not investigated in these studies.

Eldred and Darrah (2010) used cluster analysis to study developmental delays, but only considered the subareas of gross motor coordination. In the investigation area of our present study we previously found a high correlations between 6 of 12 defined subareas of developmental delay ("fine body coordination" and "grapho motor coordination" versus "memory and concentration" and "perseverance" versus "abstraction" and "visual perception") (Stich et al. 2014). In the interpretation of time trends for combined impairments it must be noted that there was no overlapping between the categories of multiple developmental delays. The individual sum variables were counted only once for multiple existing developmental delays for each category of 2-, 3- 4- and 5-fold delays. That is to say those children with four delays for instance were only counted once in the category of fourfold delays and were not also counted in the categories of 3-fold, 2-fold or single impairments.

Previously published studies on child development have not used such a strictly quantitative methodological approach as in the present study, so our results are not directly comparable with data from these other authors. However, many of these authors have also noted an increase in the frequency of multiple developmental delays in preschool children in recent cohorts, which coincided with the results of our analysis. This supports the underlying conclusion of our results, indicating that there has been an increase in developmental delays in preschool children over the last 15 years. The cross-sectional nature of our study does not allow us to explore possible etiological causes or associations for these results.

Karch (1990) considers developmental delays to be present when "… a delay or a too rapid development is based on our ideas about the normal development and its variants in childhood". This means in terms of preschool children that they should have an age-appropriate level of development (in the Federal Republic by an average of 6 years). Consequently, younger preschoolers would not be expected to have the level of development of older children. However, older children must have these skills compared to the age group of children in regular school age, so as not to have a development-related diagnosis. Thus, a child's age is a significant factor influencing the occurrence and the diagnosis or label of developmental delays. With these criteria in mind, the impact of age on the prevalence of developmental delays in current study is hardly surprising. Younger preschoolers in our study had a significantly increased risk for developmental delays compared to the reference group of older children for both single and multiple developmental delays.

It has been well established that preschool boys demonstrate a higher prevalence of developmental delays than girls (Wohlfeil 1991). Multiple studies have demonstrated a higher risk for boys for single (Boyle 2001; Campbell et al. 2003; de Moura et al. 2010; Stich et al. 2012; Thompson et al. 2003) and multiple (Webster et al. 2005; Yochman et al. 2006) delays of development. In an earlier subpopulation of our present study population, for the school entry years of 1997–2009 (Stich et al. 2012), we found that male sex demonstrated a higher incidence of all single developmental delays. In this group of 13,182 preschool children the highest relative risk of impairment for boys (versus girls) was for the subareas "fine motor coordination" (OR = odds-ratio 3.22), "grapho motor coordination" (OR 3.11) and the lowest for "arithmetic" (OR 1:38), "psycho-social development" (OR 1:42) and "memory and concentration" (OR 1:44) (Stich et al. 2012). Considering these strong associations for single development delays it was not surprising that boys in our current cohort demonstrated an increased incidence of multiple delays as well. Obviously it follows that being female proved to be a strong protective factor against the presence multiple impairments. This association became stronger for increasing numbers of delays in subareas of domains.

The Child and Adolescent Health Surveys (KiGGS) (Robert Koch-Institute 2007) reported on the impact of migration status on the development opportunities of children and young people. Utilizing standardized tests (one-leg, lateral jumping back and forth, descendants of a line, sit ups and inserting pins) for motor performance in the age group of 4- to 10-year-old children and adolescents (in total 14.478), the researchers found that children with an immigrant background demonstrated higher rates of motor delays. Similar results were seen for "emotional problems" and "behavior problems" (Robert Koch-Institute 2007). This could indicate that immigration represents a stressor impacting on healthy child development. Standardized norms for German children may, however, not necessarily apply to other populations, so our results need to be interpreted with great caution.

An association was identified in Bavarian preschool children of immigrant backgrounds for phonation disorders (20.9 versus 20.3 %) and word- sentence- formation problems (11.8 versus 22.7 %), whereas children without a migration background (20.9 versus 6.1 %) were less affected (Bavarian Health and Food Safety Authority 2013). In this context it should be mentioned that in comparison to the enrollment year 2004/2005 a relatively significant increase in the migration-specific prevalence in the phonation disorders (17.0 versus 15.7 versus 17.5 %) and word-sentence- formation disorders (8.8 versus 16.6 versus 5.4 %) became apparent (Bavarian Health and Food Safety Authority 2006). In the above-mentioned subpopulation of 13,182 preschool children, the independent variable "nationality" (German versus non-German) was used as a crude indicator of migration background. Children of non-German nationality showed a greater risk of developmental impairments for children, especially in the subarea of motor skills ("grapho motor coordination" with OR 1.69; "fine motor coordination" with OR 1:49, "gross motor skills" with OR 1.35) and cognitive skills ("abstraction" with OR 2.70; "visual perception" with OR 2.64; "arithmetic" with OR 2.61, etc.) (Stich et al. 2012). With the exception of language development (German nationality as a risk factor), a German nationality in was associated with a reduced prevalence of multiple development delays in preschool children. This observation might indicate that preschool children with a migration background represent a risk group for multiple developmental delays in motor skills, cognition and psychosocial development, but that development in speech might be independent of migration background.

The data from our current study seems generally consistent the results of comparable or similar studies in children's development. The small difference between crude and adjusted risk estimates for multiple development delays in our study may indicate that these are independent variables.

Conclusions

Our research highlights that the detection and the increasing of multiple impairments should occur at the earliest opportunity. Screening followed by comprehensive assessments in at-risk children, should be available to all children. Most importantly, intervention programs must be available to provide remedial and treatment-based interventions which minimize the risk of impairment and morbidity in these at-risk children.

Within Germany, and ever within Bavaria, there remains difference in the methodology and data collection for school enrolment examinations, which makes comparisons between different regions imperfect. There is now an ever increasing need for standardized, reliable and valid manuals for diagnosing developmental impairments during the childhood before school. In the future we hope that comparable tools will be used for all children throughout Germany, and even Europe and in other international locations.

Having detected at-risk children, it is equally important to be able to develop and implement evidence-based multidisciplinary for children identified through screening. Among children identified through screening, further assessment will be necessary to identify those most at risk and ultimately those who will most benefit from interventions. It remains unclear as to what percentage of children identified through screening, demonstrate clinically significant impairments or specific diagnoses after comprehensive assessment. The long-term developmental trajectories of children with these impairments also are not yet established so further research is needed.

Experts in kindergarten and teachers in primary schools should be empowered to manage delays in school children and education services must provide resources to help teachers focus on at-risk children. From the perspective of education policy, we believe that schools should implement curricula and teaching methods which optimize the individual development opportunities for children most at risk.

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Compliance with ethical standards The authors declare that the study complies with the current laws of the country in which the investigation was performed.

References

Bavarian Health and Food Safety Authority (2006) Health of preschool children in Bavaria. Results of school entry examination for the school year 2004/2005. Statistical-epidemiological report. Volume 1 of the series school entrance examination in Bavaria. (**German**)

Bavarian Health and Food Safety Authority (2013) Health of preschool children in Bavaria. Results of school entry examination for the school year 2008/2009. Statistical-epidemiological report. Volume 4 of the series school entrance examination in Bavaria (**German**)

Bavarian Law of Education and Instruction (2011) Bavarian Law of Education and Instruction (BayEUG) of March 9, 1960. BayRS 2230-1-1-UK. (**Last amended on July 20, 2011**)

Bavarian State Office for Statistics (2015) Statistics municipal 2014. District of Dingolfing-Landau 09 279. A selection of important statistical data. (**German**)

Bavarian State Office for Statistics (2016) Bavaria in numbers. J Stat Edition 01/2016. (**German**)

Bellman M, Byrne O, Sege R (2013) Developmental assessment of children. Br Med J 346:e8687. doi:10.1136/bmj.e8687

Boyle J (2001) Speech and language delays in preschool children. Br Med J 343:d5181. doi:10.1136/bmj.d5181

Campbell TF, Dollaghan CA, Rockette HE, Paradise JL, Feldman HM, Shriberg LD, Sabo DL, Kurs-Lasky M. (2003) Risk factors of speech delay of unknown origin in 3-year-old children. Child Dev 74:346-357. doi: 0009-3920/2003/7402-0002

de Moura DR, Costa JC, Santos IS, Barros AJ, Matijasevich A, Halpern R, Dumith S, Karam S, Barros FC (2010) Risk factors for suspected developmental delays at age 2 years in a Brazilian cohort. Paediatr Perinat Epidemiol 24:211–221. doi:10.1111/j.1365-3016.2010.01115

Dewey D, Kaplan BJ, Crawford SG, Wilson BN (2002) Developmental coordination disorder: associated problems in attention, learning, and psychosocial adjustment. Hum Mov Sci 21:905–918

Eldred K, Darrah J (2010) Using cluster analysis to interpret the variability of gross motor scores of children with typical development. Phys Ther 90:1510–1518. doi:10.2522/ptj.20090308

Flehmig I, Schloon M, Uhde J, Bemuth Hv (1973) Denver Development Scales. Club of Spastics in Harburg, Hamburg **(German)**

Flender J (2005) Early detection of children with defined disturbances. Kinder- und Jugendarzt 36:154–159 **(German)**

Frankenberg WK, Dobbs JB (1967) The Denver developmental screening test. J Pediatr 71:181–191

Gaines R, Missiuna C (2007) Early identification: are speech/language-impaired toddlers at increased risk for developmental coordination disorders? Child Care Health Dev 33:325–332. doi:10.1111/j.1365-2214.2006.00677.x

Kadesjö B, Gillberg C (2001) The comorbidity of ADHD in the general population of Swedish school-age children. J Child Psychol Psychiatry 42:487–492. doi:10.1017/S0021963001007090

Karch D (1990) Treatment of developmental disorders—principles, methods, and indication. Offentl Gesundh Wes 52:491–495 **(German)**

Landgren M, Pettersson R, Kjellman B, Gillberg C (1996) ADHD, DAMP, and other neurodevelopmental/psychiatric disorders in 6-year-old children: epidemiology and co-morbidity. Dev Med Child Neurol 38:891–906

Macha T, Proske A, Petermann F (2005) Validity of developmental tests. Kindh Entwickl 14:150–162. doi:10.1026/0942-5403.14.3.150 **(German)**

Nicholoson RI, Fawcett AJ (1994) Comparison of deficits in cognitive motor skills among children with dyslexia. Ann Dyslexia 44:145–164. doi:10.1007/BFO2648159

Petermann F, Daseking M (2011) Screening and diagnostic in school entry examinations. Gesundh Wes 73:635–636. doi:10.1055/s-0031-1287784 **(German)**

Robert Koch-Institute (2007) Results of the child and youth health survey. Bundesgesundheitsbla 50:529–908 **(German)**

Sachdeva S, Amir A, Alam S, Khan Z, Khalique N, Ansari MA (2010) Global developmental delay and its determinants among urban infants and toddlers: a cross sectional study. Indian J Pediatr 77:975–980. doi:10.1007/s12098-010-0151-9

Stich HL (2009) Disorders in preschool children. A differentiated analysis of prevalences of developmental delays over a ten-year period. Kinder- und Jugendmedizin 9:42–88 **(German)**

Stich HL, Baune BT, Caniato RN, Mikolajcyk RT, Krämer A (2012) Individual development of preschool children- prevalences and determinants of delays in Germany: a cross- sectional study in Southern Bavaria. BMC Pediatr 12:188. doi:10.1186/1471-2431-12-188

Stich HL, Krämer A, Mikolajczyk RT (2014) Clustering of developmental delays in Bavarian preschool children- a repeated cross- sectional survey over a period of 12 years. BMC Pediatr 14:18. doi:10.1186/1471-2431-14-18

Task Force "School and Youth Health Care in the Public Health Services" (1997) The school entry examination. (**German**)

Tebruegge M, Nandini V, Ritchie J (2004) Does routine child health surveillance contribute to the early detection of children with pervasive developmental disorders?—an epidemiological study in Kent, UK. BMC Pediatr 4:4

Tervo R (2003) Identifying patterns of development delays can help diagnose neurodevelopmental disorders. Pediatr Perspec 13:2–6

Thompson T, Caruso M, Ellerbeck K (2003) Sex matters in autism and other developmental disabilities. J Learn Disabil 7:345–362

Tirosh E, Berger J, Cohen-Ophir M, Davidovitch M, Cohen A (1998) Learning disabilities with and without attention-deficit hyperactivity disorder: parents' and teachers' perspectives. J Child Neurol 13:270–276

Valtonen R, Ahonen T, Lyytinen P, Lyytinen H (2004) Co-occurrence of developmental delays in a screening study of 4-year-old Finnish children. Dev Med Child Neurol 46:436–443

Viholainen H, Ahonen T, Cantell M, Lyytinen P, Lyytinen H (2002) Development of early motor skills and language in children at risk for familial dyslexia. Dev Med Child Neurol 44:761–769

Webster RI, Majnemer A, Platt RW, Shevell MI (2005) Motor function at school age in children with a preschool diagnosis of developmental language impairment. J Pediatr 146:80–85

Wohlfeil A (1991) Developmental delays in children starting school with the resultant performance deficits. Offentl Gesundh Wes 53:175–180 **(German)**

Yochman A, Ornoy A, Parush S (2006) Co-occurrence of developmental delays among preschool children with attention-deficit-hyperactivity disorder. Dev Med Child Neurol 48:483–488

Zimmer R (2002) Health promotion in kindergarten. Bundesgesundheitsbla 45:964–969 **(German)**