

Full Length Research paper

Increasing prevalence of motor impairments in pre-school children from 1997-2009: results of the Bavarian pre-school morbidity survey

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Normal movement is essential for a child's healthy physical, cognitive and social development. Accurate data on the incidence of disorders of motor functioning in children is needed if appropriate public health initiatives are to be implemented. We used data from the Bavarian Pre-School Morbidity Survey (BPMS) to look at the rates of motor impairments in thirteen consecutive cohorts of children entering primary school, from 1997 to 2009. We explored prevalence rates of motor impairments and its sub domains over thirteen years. We utilised a retrospective cross-sectional study design to assess the prevalence of impairments over thirteen consecutive cohorts of German children beginning school, from 1997 to 2009. A total of 13088 children were assessed for physical impairment using a standardised medical assessment. We subdivided motor functioning into three separate sub-areas of functioning: gross motor, fine motor and graph-motor (drawing) skills. There was a dramatic increase in the rates of motor impairments in children over the thirteen year period. The prevalence of one or more motor impairments rose from 8.15 to 42.44% for boys and from 2.12 to 17.21% for girls over the study period. Mostly, children were having increasing difficulties with fine motor tasks and tasks involving writing and drawing, while gross motor functioning was less affected. The rapid and dramatic increases in motor problems over the 13 years are concerning and warrant further exploration. We suspect that children, increasingly exposed to modern technologies, may be losing certain fine motor skills, especially those relating to hand written language and drawing. Such changes may indicate significant changes in modern child development which warrant exploration and intervention. Alternatively, our results may indicate that traditional tests of motor functioning, which use drawing and pencils, may be outdated in a modern world where the need to use pen and paper is increasingly unnecessary. Tests of motor functioning may need to be updated and new norms developed.

Keywords: Child development; developmental impairment; motor skills; fine motor skills; pre-school.

INTRODUCTION

Movement is such a normal part of childhood development that its importance, at least in comparison to speech or cognition, is often over looked. Development of

motor functions, especially drawing and handwriting, are crucial for performance in school, autonomy in everyday life and the general human development (Rueckriegel, Blankenburg et al. 2008). Even minor abnormalities of motor development may place children at risk of subsequent problems including anxiety (Sigurdsson et al. 2002), speech delay (Webster et al., 2005), attention

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attention problems (Piek et al., 2004) and general developmental delay (Sugden and Chambers 2007). Detection and early intervention of motor delays or problems is therefore an important focus of public health measures.

Previous epidemiological studies have shown that pre-school children have high rates of motor developmental abnormalities (Smits-Engelsman et al., 2001; Tieman et al., 2005). A gender difference, with higher rates of motor disorders in male children has been a reasonably consistent finding (Marcon, 1999; Livesey et al., 2007; Darrach et al., 2009). Motor dysfunction has been associated with speech and behavioural problems (Piek et al., 2004) and may lead to poor outcomes in later childhood and early adulthood. To date epidemiological studies in the area of motor development have been hampered by methodological differences and a lack of agreed upon tools to measure motor development. Epidemiological studies have shown that children over recent years have changing patterns of obesity (Mond et al., 2007) and physical activity (Timmons, Naylor et al. 2007; Sigmund et al., 2009), and exposure to electronic entertainment (Li and Atkins, 2004). In contrast there has been insufficient literature exploring changes in the prevalence of problems in motor functioning in children, especially over the last decade.

Epidemiological studies show that over recent years there have been marked changes in the prevalence of many childhood illnesses such, asthma (van den Hazel et al., 2006), diabetes (Popkin, 2001) and ADHD (Gracey, 2003). In contrast, robust data on the changes in the prevalence of motor developmental impairments in pre-school children is currently lacking. Accurate data on the incidence and changes of prevalence rates of such impairments may help in planning interventions. Since motor development may be very sensitive to early environmental influences (de Barros et al., 2003), our concern is that, linked to these modern changes in the incidence of other disorders, we will find changes in motor functioning and motor development in young children.

Previously our group published data from the Bavarian Pre-School Morbidity Survey (BPMS), looking at rates of childhood impairments in consecutive cohorts of Bavarian children entering school from 1997 to 2005 (Caniato et al., 2009). In the survey, we found high prevalence rates of impairments in general motor functioning and a suggestion that rates were increasing over recent cohorts. We did not however, explore specific sub-domains of motor functioning, such as gross, fine and graph-motor skills.

We have decided to investigate if patterns of increased motor impairments observed in our earlier study, will continue in more recent cohort up until 2009. Specifically, we investigate if the pattern of increasing

impairments is part of a continuing pattern, or will plateau or even reverse. We also further analyse the different aspects of motor functioning, including gross motor, fine motor and graph-motor skills, to see which areas are most affected and to better understand any changes. Currently, there are no internationally agreed standards upon tools for detecting and assessing motor impairments in pre-school children (Rosenbaum et al., 2009). Accurate and rapid screening tools, as well as more comprehensive assessments, are both important aspects of developing processes to detect and remediate problems. Long term outcomes of childhood motor impairments also remain to be established.

The goal of the study is to investigate the prevalence rates of motor impairments among pre-school children in consecutive cohorts over a 13-year period, addressing various sub domains of motor functioning. We further aim to critically evaluate our current motor screening procedures, with a view to improving their reliability and utility.

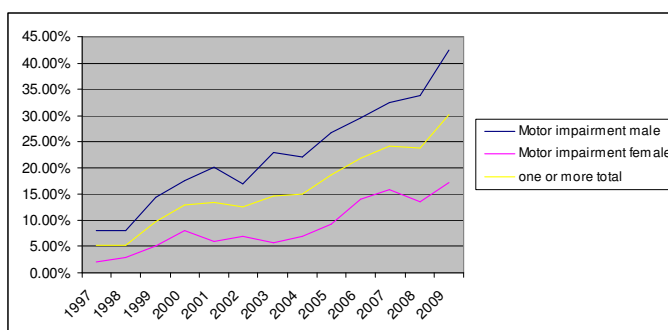
METHODS

Before entering primary school, all children in the federal state of Bavaria, Germany, are examined medically in the so-called school-enrolment-examination. The data for all children entering school in Bavaria has been collected over the last thirteen years to form the basis of the Bavarian Pre-school Morbidity Survey (BPMS). The assessment consists of a comprehensive physical, psychological and behavioural assessment that has been developed by the Public Health Service of Bavaria. The examination has been used extensively in Bavaria (Stich et al., 2006) and initially designed to provide information to the department of education for the purpose of facilitating changes in education policy. While the psychometric properties have not been well established, the examination represents a broad and comprehensive assessment by a qualified medical practitioner. The examination was designed to be simple, to have high reliability and to have strong face validity. There is no data currently with which to compare it to other standardised developmental motor assessments. The results are used to screen children for further assessment and in providing recommendations concerning the kind of school and specific educational needs of the child in primary school.

The medical examinations and documentations of findings were conducted by the "school-examination-team" from the local medical service, which remained the same over the study period. Based on examination manual, motor functioning is subdivided into three areas-gross motor, fine motor and graph-motor (see table 1). The manner of evaluation is standardised and manualised (Manual is available from the author on

Table 1. Summary of motor function testing utilised in the BPM-survey physical examination

Gross motor tests	1) standing on one foot. Both feet tested. Should be able to stand for over 10 seconds
	2) jumping on one foot- at least 5 times. Repeated for each foot
	3)clapping hands- repeating a simple clapping pattern/ task
Fine Motor	1) holding a pencil as shown with the dominant hand
	2) finger opposition test- index finger is opposed to each finger sequentially
	3) palm-fist opposition- fist of each hand is sequentially pressed into the opposite hand
Graph-motor	1) holding a pencil in the dominant hand while drawing- dynamic
	2) drawing shapes- square, triangle, circle and cross
	3)drawing a person test

**Figure 1:** Rates of one or more motor impairments

request). Over the 13 years all the examinations were carried out by a single medial practitioner. The assessment is was derived utilising the simplest elements from a number of assessment tests, including the MOT 4-6 (Motoriktest fur Vier- bis Sechjarige Kinder), the Peabody Developmental Motor Scales 2 and the Test of Gross Motor Development-2. The test however is designed to be faster and easier to administer, as it is used as a screening tool used on all children entering pre-school. No specific norms are yet available for the examination. The tests used in the examination (see table 1), are used in a number of other assessments and have high face validity. Tests of fine motor functioning, such as the finger opposition test, are well established screens of fine motor skills. Tests of graph-motor skills utilise three tests which all involve the use of a pencil to draw certain figures.

If the examination identified any distinctive impairment in either two standardized tests for motor development, it is interpreted as a delay of development and counted as an "impairment". In this analysis we retrospectively analysed the results of the screening examinations for all children in the district of Dingolfing-Landau, Bavaria, between 1997 and 2009 ($n=13088$). Our study continues on from a previous report which published data from the

cohort of 1997 to 2005.

Statistical analysis

Prevalence rates were compared by χ^2 -test for categorical variables of gender. Differences of continuous variables between groups (i.e.age) were carried out by the use of t-test. Associations between prevalence rates of impairments and time were calculated by logistic regression models which were adjusted for age and gender. All analyses were conducted with the statistical program STATA 11.0.

RESULTS

Study Population

A total of 13088 children with an average age of 5.94 years ($SD \pm 0.37$) were assessed over the 13 year period (girls: 5.9 $SD \pm 0.4$; boys: 6.0 $SD \pm 0.4$). In this sample, male children had significantly higher rates of motor impairments than females (figure 1). In both groups we saw an increase in prevalence rates over the 13 years

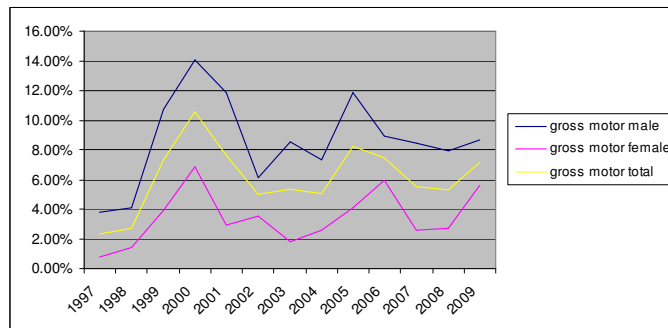


Figure 2: Rates of Gross Motor Impairments

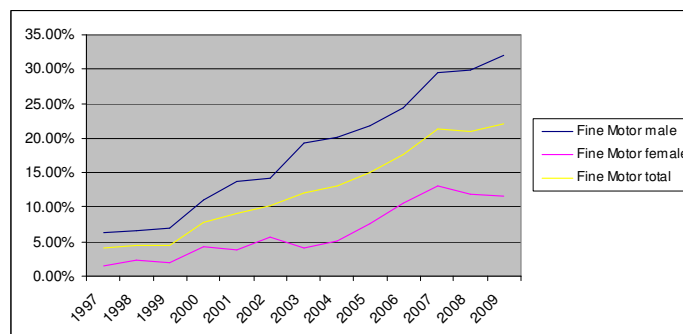


Figure 3. Rates of fine motor impairment

period. For males rates increased from 8.15 % to 42.44% while females increased from 2.12% to 17.25 % by 2009.

Gross motor skills

There did not appear to be a consistent change in gross motor impairments, with marked variations over the thirteen years (figure 2). For both boys and girls, a peak incidence occurred in the cohort of 2000, with 14.05 % of boys and 6.85% of females having gross motor impairments. The mean rates over the study period where 8.61% for males and 3.43 % for females, but with large variations between years

Fine Motor Skills

We found a steady increase in rates of fine motor problems, from a mean of 4.07% in 1997, to a peak of 22.05% in 2009. Males had higher rates in all cohorts with the gap between boys and girls increased in the later cohorts (figure 3)

Graph-motor skills

We saw a similar pattern of increasing rates of impairments, though it was not a linear as the changes in fine motor skills (figure 4). Lowest rates were found in the 1999 cohort with 3.26% males and 1.75% females having impairments. For males the rates peaked in 2009, at 32.67 %, while for females they peaked at 12.56 % in 2008 before dipping slightly.

DISCUSSION

We found a high prevalence of impairments in all areas of motor functioning. In all areas we assessed, males were significantly over represented. Overall, over the 13 year period, a clear increase in rates total motor, fine motor and graph-motor impairment, but no clear pattern of changes in gross motor function was observed.

We found very high rates of motor abnormalities, which peaked in 2009 at 42.44 % for boys and 17.21% for females. Of note is that the examination utilised is a primarily a screening tests tool and should not be

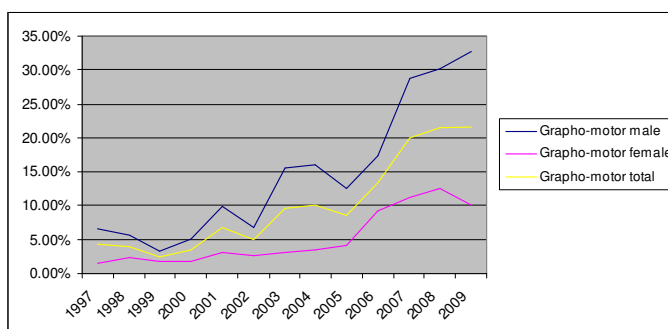


Figure 4: Rates of graph-motor impairment

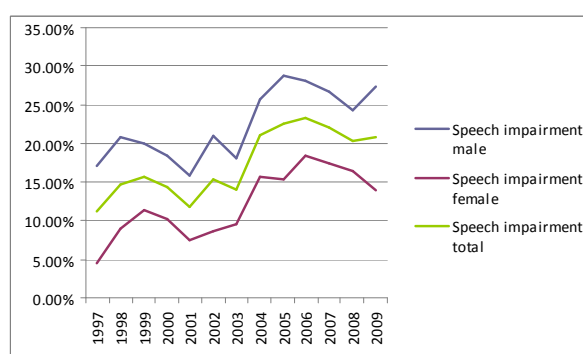


Figure 5: Rates of speech impairments

considered comprehensive motor examinations. The marked increase over previous cohorts however suggests concerning changes have been occurring. To our knowledge, we know of no other study that has found such dramatic and recent changes in rates of motor impairment. A previous survey in Lower Saxony detected a far smaller increase in motor disorder, from 13.7% in 1996, to 15.8% in 2000 (Niedersachsiches Ministerium fur Frauen, 2000). We know of no international study looking at changes in rates of motor impairments with which to compare our data.

The rate of motor impairments we detected in our earlier pre-2000 cohorts was similar to that of other German health reports (Baden-Wurtemberg, 2000; Niedersachsiches Ministerium fur Frauen, 2000). International studies have utilised very differing methodologies, but on face value at least, seem to have produced comparable rates to our pre-2000 cohorts. A Swedish study of seven year old children, for instance, detected moderate motor disorders in 4.9% and severe motor disorders in 8.6% of the children assessed (Kadesjo and Gillberg 1999). A Chinese survey found motor problems in 9.9% of children from 3 to 5 years of age (Chen et al., 2003).

Of note is that our study measured gross motor, fine

motor and graph motor skills, with other epidemiological studies often focussing far more on gross motor skills. A recent study of Dutch children, utilising some similar assessments of fine motor and graph motor skills, found that 34% of the group displayed serious handwriting problems (Smits-Engelsman et al., 2001). The high rates of fine motor impairments we found may therefore be comparable to other cohorts of children in the Western world. We were not able to locate comparable international cohort studies to which to compare our findings. Many authors have noted cultural differences in motor development (Victora et al., 1990). Currently used tests for motor functioning may not be appropriate for different cultural groups (Tripathi, Joshua et al. 2008).

The most consistent and dramatic increases in our study was in fine motor skills. Of note is that the testing of these skills involves primarily utilising a pencil to draw or write. One possible explanation might be a change in motor activities in children in recent years, especially those involving the written language. Over the last decade we have seen a dramatic increase in the exposure that children have to computers and other electronic media. We wonder if children in the recent cohorts have a dramatically reduced exposure to written activities, which have been replaced by computer media.

A study of American children in 2001 found that 53% had a computer at home and that 23% played on it on a daily basis (Li and Atkins, 2004). This is a marked change from even a decade earlier, and one suspects that children in 2009 would have even higher rates of computer use and exposure.

Children today grow up in a social and technological environment very different to their predecessors of even a few years before. Recent epidemiological studies certainly indicate that children are less physically active (Sigmund, Sigmundova et al. 2009) and spend more time playing video games (Okely et al., 2009), have higher rates of obesity (Lakdawalla et al., ; Mo-Suwan et al., 1993; Livingstone, 2001; Popkin, 2001), are exposed to greater pollution (Gracey 2003), and have very different diets to their predecessors of even a few years ago. Since we know that motor development is strongly sensitive to environmental influences (de Barros et al., 2003), our data may indicate that the any or all of these changes in the childhood environment over recent years may have impacted on the development of fine motor and graph-motor skills.

If our results are replicated, and are indeed due to a reduced exposure to written tasks in young children, some very important questions arise. Firstly, in a world where hand written language may be seen as increasingly anachronistic, are reduced skills in drawing and written language for children really a problem. Modern children are more likely to need to type and use computer than to use hand written notes. It may be that tests of motor function that utilise drawing or writing tasks are out of date in the modern world. Many tests of motor function have been found to demonstrate cultural differences (Victoria, Victoria et al. 1990). We wonder if our testing procedures have become culturally insensitive to a new generation of children, and need to be urgently updated.

A further consideration is the longitudinal pattern of the deficits we have demonstrated. A key question if these deficits will resolve, especially with activities in school or kindergarten, or if the deficits persist. If the deficits are merely due to a lack of exposure to writing, we may well see a prompt improvement in the kindergarten environment, merely from exposure to writing and drawing. However, some research in childhood development suggests that motor problems detected in early childhood do not spontaneously resolve, without specific interventions (Sugden and Chambers, 2007). Indeed some research suggests that motor problems may predispose to a range of other childhood problems, including speech and language (Bishop 2002; Webster et al., 2005) and anxiety problems (Sigurdsson et al., 2002). The long term developmental trajectories of motor problems in children remain poorly understood. Currently we do not yet have information on the longitud-

inal outcome of our cohort. It will be essential to plot the longer term developmental trajectories and outcomes of our group. Research indicates such motor problems may be very responsive to remedial interventions (Case-Smith, 1996). Early detection and treatment may therefore represent highly cost effective and productive intervention.

A number of studies have indicated that motor development is age dependant (Livesey et al., 2007) and is, to a great degree, a maturational process (Savion-Lemieux et al., 2009). It may therefore be that the changes we have seen represent maturational delays which may resolve spontaneously with time. Upon entering school, the motor deficits we have detected may resolve spontaneously, with no intervention needed. Alternatively, the delay in the acquisition of these motor skills may represent a missed window of opportunity, after which it is difficult or even impossible for motor development to catch up. Ultimately, the long term repercussions remain unknown. Vigilance and further research is essential to clarify and ultimately remediate the problems.

The marked gender differences detected in our study are concerning aspects of our report. Gender differences in prevalence of motor problems are reasonably well documented in the literature (Stich et al., 2006). The gender differences we detected are therefore to some degree expected. What is concerning is the widening gap between boys and girls in terms of fine motor and graph motor development. It may be that boys especially are more susceptible to the environmental changes that have brought on the changing rates of impairment. This has implications for detection and remediation of motor delays.

Our study clearly has a number of important limitations. The medical examination of the BPMS is primarily a screening examination, for which norms have not yet been developed. Criteria such as developmental delay or impairment lack clearly outlined definitions and normative values are not well established. The tests, even if standardised, are strongly subjective and even with manualisation, many of the assessment criteria are difficult to standardise. Certain tests, such as hand clapping, finger-opposition test seem qualitative and subjective. In our study, however, all the examinations were carried out by a single practitioner. This is one of the strengths of our research. The data is therefore best used in a comparative sense between the different years within our cohort, rather than representing accurate absolute rates of motor delay, that can be compared to other cohorts.

Our hypothesis is that these or a combination of other social, environmental, technological or biological factors may be responsible for the changes seen in our study. The cross-sectional nature of our sample does not allow

us to test or explore any hypothesis on aetiological factors. Our study was not designed to detect or assess potential aetiological factors, only to document changes. Multivariate analysis looking at these factors could be helpful in identifying causative factors. A longitudinal study would also have allowed us to better assess the natural history of the identified deficits. Our study also used rating tools specific to Germany, and these may not be easily comparable to assessments in other jurisdictions.

Despite its limitations, this is, to our knowledge, the longest and largest cross-sectional cohort study of motor impairments school-beginners. Our study indicates that there may be changes occurring in the physical and developmental well being of our children over the last decade which warrant careful monitoring.

CONCLUSIONS

Our research suggests that patterns of motor skills in children, especially fine motor and drawing skills, have been changing over the last thirteen years. The data suggest that children at pre-school age are progressively losing certain fine motor abilities, especially those related to using hand written tools. While these changes may be natural and predictable changes of a changing technological world, they may alternatively indicate a serious and pathological change in the childhood development. Vigilance and caution in monitoring these changes is warranted. At the very least our tools for assessing child development must adapt to the changing technological environments that our children grow up in. Ongoing monitoring of these patterns is essential in predicting the long term consequences and in remediating any negative effects.

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