Risk factors affecting visual-motor coordination deficit among children residing near a petrochemical industrial estate

P Aungudornpukdee[1] and N Vichit-Vadakan[2]

[1]College of Public Health Sciences, Chulalongkorn University, Bangkok, Thailand, [2] aculty of Public Health, Thammasat University, Patumthani, Thailand

Corresponding author: Piraya Aungudornpukdee, College of Public Health Sciences, Chulalongkorn University, Bangkok, Thailand; e-mail: janchai_a@hotmail.com

ABSTRACT

Thailand has been changed to rapid urbanization and industrialization since 1980s. During 1992 through 1996, the number of industrial factories in Rayong province increased very sharply. The major types of industries are petrol-chemical and plastic production. However, after the petrochemical industry boomed, the higher demand led to an industrial area expansion. The establishment of factories in this area leads to serious environmental and health impacts. The study aims to investigate the factors that affect visual-motor coordination deficit among children, 6-13 years of age, residing near the Petrochemical Industrial Estate, Map Ta Phut, Rayong province. A population-based cross-sectional study was employed for collecting data on neurobehavioral effects using the Digit Symbol Test. The study found one-third of 2,956 children presented with visual-motor coordination deficits. Three factors were identified that caused children to have a higher risk of visual-motor coordination deficits: gender (adjusted OR 1.934), monthly parental income (range of adjusted OR 1.977 - 2.612), and household environmental tobacco smoke (adjusted OR 1.284), while age (adjusted OR 0.874) and living period (adjusted OR 0.954) in study areas were reversed effects on visual-motor coordination deficit among children. The finding indicated that children with visual-motor coordination deficit were affected by gender, monthly parental income, age of children, length of living period, and household environmental tobacco smoke.

Keywords: Visual-motor coordination deficit, digit symbol test, children, petrochemical industrial estate, Thailand.

INTRODUCTION

Rapid urbanization and industrialization led to health impact among people worldwide. It also has been taking place in Thailand since the 1980s. Rayong province (total area 3,552 square kilometers) is located on the east coast of Thailand and is the site of a Gas Separation Plant and Map Ta Phut Industrial Estates. The major types of industries are petrol-chemical and plastic production. These industries produce sulphur dioxide (SO_2) and organic solvents especially VOCs (Benzene, Vinyl chloride, Styrene etc.), leading to serious environmental and health impacts. The health impacts include both acute problems (irritation; headaches; nausea/vomiting; dizziness; fatigue; epistaxis) and chronic problems (cancer; loss of coordination; damage to liver, kidney, and central nervous system), including mental health effects.[1,2]

Students and teachers at a secondary school were reported to have been affected by chemical vapors released from the factories in the estate in 1997. They were hospitalized for breathing in toxic air and suffered from various health effects, both physical and mental.[3] The study for benzene in blood, hippuric and mandelic acid in urine in Muang district, Rayong province, found that subjects had high blood benzene and low white blood cell count.[4] The Thailand Environment Institute[5] reported that the sources of air pollution were 15 factories in the Map Ta Phut which emitted VOCs from fuel combustion, leakage from manufacturing processes, storage, and incineration. This evidence has heightened public concern about gaseous emissions from the petrochemical industry.

There were numerous studies revealing that VOCs can cause birth defects among pregnant woman living near an industrial area, in particular a petrochemical industry or oil refinery.[6-10] Moreover, there were numerous epidemiological studies investigating the health impacts of air pollution worldwide. They found that pollution may lead to neurobehavioral deficits, which are a major risk factor for mortality, neurological impairment, and disability, with high associated costs of care in hospital. The symptoms experienced after contact with these agents are related to the function of the central (CNS) or peripheral nervous system (PNS). The acute health effects of solvents on the central nervous system include eye, nose, throat irritation, headache, dizziness, and light

Table-1: Comparison between children with and without visual-motor coordination deficits by socio-demographics

Factors	No visual-motor coordination deficit	Visual-motor coordination deficit	*P-value*[a]
Total (n = 2,949)	N (%)	N (%)	
Gender			
Male	906 (45.4)	585 (61.3)	< 0.001
Female	1,089 (54.6)	369 (38.7)	
Age of child in years, mean (S.D.)	9.7 (2.0)	9.1 (2.1)	< 0.001
Education			
Pre-school	44 (2.2)	49 (5.2)	< 0.001*
Primary school	1,698 (85.5)	827 (87.1)	
Secondary school	244 (12.3)	70 (7.4)	
Not meet the criteria for the school	1 (0.1)	3 (0.3)	
Household registration			
Yes	1,055 (53.9)	437 (46.8)	< 0.001
No	903 (46.1)	497 (53.2)	
Living period in study areas in years, mean (S.D.)	6.6 (3.6)	5.8 (3.4)	< 0.001
Parental income (Baht / month)			
No income	90 (4.8)	33 (3.7)	< 0.001
Less than 5,000	77 (4.1)	40 (4.5)	
5,000-10,000	530 (28.4)	314 (35.3)	
10,001-15,000	407 (21.8)	236 (26.5)	
15,001-20,000	316 (17.0)	156 (17.5)	
20,001-30,000	256 (13.7)	63 (7.1)	
30,001-40,000	80 (4.3)	24 (2.7)	
More than 40,000	107 (5.7)	24 (2.7)	

* = Non-parametric Chi-square Analysis

a = Values determined using Chi-square for categorical variables and T-test for continuous variables; values significant at p<0.15

headedness progressing to unconsciousness, seizures, and death.[11,12] A number of long-term adverse effects of solvents have been described including leukemia in benzene-exposed workers, scleroderma (mixed solvents), and renal cancer in those exposed to chlorinated hydrocarbons.[13-15] Chronic exposure or acute exposure can produce long-term effects, cognitive and neurobehavioral effects. The study on neurobehavioral effects among Japanese painters compared to non-exposed worker found that statistically significantly more often on neurobehavioral effects among exposed subjects than among the referents such as being easily depressed without reason, coldness of hands and legs, loss of appetite, dizziness, and unsteadiness.[16] Numerous studies in Korean found that exposure of organic solvents could induced neurobehavioral changes such as poorer performance among painter and printer.[17,18] Moreover, Tsai[19] studied on neurobehavioral effects among Taiwanese workers using neurobehavioral test. This study found significant associations between increased exposure to solvent mixtures and performance. Globally, many studies explored effects on neurobehavior related to air pollutants such as heavy metal and VOCs among workers. These are important for preventing further harm to the individual worker. However, there is no any studies reporting an association between air pollution and neurobehavioral effects among general population. The hypothesis of this study was that children living closer to the Petrochemical Industrial Estates have a higher risk of visual-motor coordination deficits than children residing more distant. This study aimed to explore the factors that affect to visual-motor coordination deficits among children 6 to 13 years of age in the Map Ta Phut sub-district.

MATERIALS AND METHODS

Study site

The study was carried out in Map Ta Phut sub-district, comprised of 25 communities, within the Rayong province, Thailand. These communities are located near Petrochemical Industrial Estates which are known to release VOCs. Thus children in the study areas have a large chance of having been exposed to VOCs due to the proximity of the industrial areas and their homes. There were 40,999 registered residents in 2006 and over 74,502 non-registered residents.[20]

Table-2: Comparison of children with and without visual-motor coordination deficits by maternal exposure / history of delivery

Factors	No visual-motor coordination deficit N (%)	Visual-motor coordination deficit N (%)	*P-value*[a]
Pregnancy in study areas	753 (56.4)	371 (50.3)	0.008
Smoking during pregnancy	33 (1.8)	28 (3.2)	0.025
History of delivery			
Normal delivery	948 (93.9)	502 (93.3)	0.597
Preterm delivery	30 (3.0)	14 (2.6)	
Low birth weight delivery	32 (3.2)	22 (4.1)	
Breasts feeding	1,595 (86.0)	785 (87.3)	0.354

a = Values determined using Chi-square for categorical variables and T-test for continuous variables; values significant at p<0.15

Study population

All children 6 to 13 years of age residing in the study areas were recruited with the consent of their parents. The study was approved by the research ethical committee of Thammasat University. Prior to the data collection, the parents/guardians of participants were briefed on details of the study and asked to give a signature in an informed consent form, and children were also informed before being interviewed.

Sampling method and Sample size

A population-based cross-sectional study was employed for collecting data on neuropsychological test as the primary data using the standardized tools. Ninety-four percent of children were enrolled in primary school,[21] thus the data collection was administered in school. Non-school children were recruited in communities instead. To gather data on the health impact of air pollution as well as socio-demographic and exposure factors, secondary data on the population-based study in the Map Ta Phut collected by N. Vichit-Vadakan and team (Faculty of Public Health, Thammasat University) was used. To assess ambient air pollutant exposure, the study attempted to geocode participant's residences in the communities. Geocoding, latitude and longitude coordinates, was conducted and performed using GIS (Geographical Information System) software and mapping. The total sample size was 2,956 subjects.

Neurobehavioral test method

To assess the visual-motor coordination deficits the Digit Symbol Test, a sub-test of Wechsler Intelligence Scale for Children third edition (WISC III), was adopted. WISC is a standardized tool for children 6 to 16 years of age (developed by Wechsler, 1949), recommended by WHO. The Digit Symbol test aims to predict a fine movement, learning skill, and capacity of individual skills between symbol and number that are related to cognition and vision, regardless of whether the child can complete the test within a limited time period (120 seconds). The raw score ranges from 0-119. The raw score has been scaled to a 19 point score. The cut point of the scaled score in this study is 10, meaning that 10 and over refers to children without visual-motor coordination deficits.

Data analysis

Data on socio-demographic, maternal exposure, indoor exposure, and outdoor exposure variables were compared among children with and without visual-motor coordination deficits using univariate analysis, by Chi-square for category data and by T-test for continuous data. A *P-value* $\leq$ 0.15 was considered a statically significant for finding potential factors. A binary logistic regression was performed to study the relationship between potential factors and visual-motor coordination deficit which defined in terms of poor vs. normal. A *P-value* $\leq$ 0.05 was considered a statically significant.

Table-3: Comparison between children with and without visual-motor coordination deficit by individual / indoor exposure

Factors	No visual-motor coordination deficit N (%)	Visual-motor coordination deficit N (%)	*P-value*[a]
Household Environmental Tobacco Smoke	975 (49.1)	547 (57.8)	< 0.001
Using mosquito and insect repellent	1,150 (58.0)	526 (55.5)	0.199
Using fertilizer in residential areas	393 (19.8)	173 (18.3)	0.326
Using pesticide / insecticide in residential areas	292 (14.7)	140 (14.8)	0.966
Using fresh air spray in residential areas	345 (17.4)	120 (12.7)	0.001
Using painting / lacquer in residential areas	145 (7.3)	61 (6.5)	0.398
Exposed to hair spray / deodorant / hair color	39 (2.0)	9 (0.9)	0.041

a = Values determined using Chi-square for categorical variables and T-test for continuous variables; values significant at p<0.15

Table-4: Comparison between children with and without visual-motor coordination deficit by outdoor exposure

Factors	No visual-motor coordination deficit N (%)	Visual-motor coordination deficit N (%)	*P-value*[a]
Approx. motor vehicles on the road in regular 1-2 per hour , n (%)	1862 (94.0)	875 (92.5)	0.124
Experience in living within 500 meters of the road, n (%)	1,734 (87.6)	788 (83.0)	0.001
Gas station is located within 500 meters of reside ntial areas, n (%)	1,532 (77.9)	692 (73.9)	0.016
Car repair shop is located within 500 meters of residential areas, n (%)	966 (48.8)	424 (44.9)	0.044
Distance to Industrial Park from residential areas, mean (S.D.)	5.3 (1.8)	5.3 (1.8)	0.457

a = Values determined using Chi-square for categorical variables and T-test for continuous variables; values significant at p<0.15

RESULTS AND DISCUSSION

The socio-demographics of children with and without visual-motor coordination deficits are presented in Table-1. It shows 954 and 1995 children with and without visual-motor coordination deficits. More than half of the children with visual-motor coordination deficit were boys. More than 80.0% of the children studied in primary school. Among children with visual-motor coordination deficits, a larger proportion among non-residents as compared to residents. One-third of the children with visual-motor coordination deficits were those whose parents earned a monthly income of 5,000–10,000 Baht.

In terms of maternal exposure, this study focused on an exposure during pregnancy, including history of delivery and breast feeding as shown in Table-2.

The percentage of children with mothers who smoked during pregnancy was higher in the visual-motor coordination deficit group than children without visual-motor coordination deficit. There was no difference between children with and without visual-motor coordination deficit in their history of delivery and breast feeding.

According to individual / indoor exposure, the data analysis suggested that more than half of children with visual-motor coordination deficit exposed to household ETS. Table-3 also shows there were no different between both children with and without visual-motor coordination deficit on mosquito / insect repellent, fertilizer, pesticide and insecticide uses. In addition, using fresh air spray and hair spray / deodorant / hair color affected to visual-motor coordination deficit in comparison between children with and without visual-motor coordination deficit.

Table-5: Adjusted logistic regression model to examine potential factors compared between children with and without visual-motor coordination deficits.

Factors	Adjusted OR	95% CI of OR	*P-value*[b]
Gender: female	1		
Gender: male	1.934	1.635, 2.288	< 0.001
Parental income: more than 40,000 Baht / month	1		
Parental income: 30,001 - 40,000 Baht / month	1.241	.649, 2.374	0.515
Parental income: 20,001 - 30,000 Baht / month	1.024	.601, 1.743	0.931
Parental income: 15,001 - 20,000 Baht / month	1.977	1.208, 3.234	0.007
Parental income: 10,001 - 15,000 Baht / month	2.423	1.498, 3.918	< 0.001
Parental income: 5,000 - 10,000 Baht / month	2.418	1.504, 3.886	< 0.001
Parental income: Less than 5,000 Baht / month	2.501	1.367, 4.575	0.003
Parental income: No income	2.612	1.397, 4.886	0.003
Age (years)	.874	.836, .914	< 0.001
Living period in study areas (years)	.954	.930, .978	< 0.001
Household Environmental Tobacco Smoke: no	1		
Household Environmental Tobacco Smoke: yes	1.284	1.084, 1.521	0.004
Distance to Industrial Park from residential areas	1.027	.979, 1.077	0.280
Constant:			0.122

b = Values significant at p<0.05.

To assess ambient air pollutant exposure from the industrial sources, the study attempted to geocode participant's residences in the communities using GIS (Geographical Information System) software and mapping. For ambient air pollutant exposure from other sources a questionnaire was used. Table-4 shows that more than two-third of children with and without visual-motor coordination deficits had lived near a road that has 1-2 motor vehicles/hour, lived within 500 meters from the road, and lived within 500 meters of a gas station. Less than 50.0% of both groups lived within 500 meters of a car repair shop.

The study showed that male children have a higher risk of visual-motor coordination deficit when compared with female children (adjusted OR 1.934). Vermeir *et al*[22] studied neurobehavioral investigations in adolescents exposed to environmental pollutants, battery heavy metals, and PCBs using a computerized neurological test. It was found that heavy metals impaired symbol-digit distribution test results in boys. In addition, Kraft and Nickel[23] studied cognitive ability and found sex-related differences favoring girls in the rate of brain maturation, derived from the fact that during the initial testing girls showed a significant advantage over boys on both verbal fluency and production scores. For monthly parental income, this study found that children whose parents earned a lower income have a higher risk for visual-motor coordination deficits when compared to children whose parents earned higher incomes (adjusted OR 1.977, 2.423, 2.418, 2.501 and 2.612 respectively). It was found that adjusted OR of visual-motor coordination deficit was slightly increased for children whose parents had lower income. These results might be affected by educational opportunity and quality of life that relates to learning ability. Waber *et al*[24] found that low-income children exhibited more externalizing problems and a lower social competence rating than children of parents with a high income. A similar study found that children are more likely to have a low response if they have a low socioeconomic status.[25] An inverse association was also found between visual-motor coordination deficit and age (adjusted OR 0.874). The younger children have more brain impairment than older children. A study on audiospatial and visuospatial working memory in 6–13 year old school children found that the performance speed (auditory and visual working memory) improves with age, suggesting functional maturation of underlying cognitive processes and brain areas.[26] In terms of exposure, children who were exposed to household environmental tobacco smoke have a higher risk on visual-motor coordination deficit when compared to children who were not exposed (adjusted OR 1.284). Yolton *et al*[27] studied exposure to environmental tobacco smoke and cognitive abilities among U.S. children and adolescents (aged 6-16 years) using neuropsychological tests and measured serum cotinine as a biomarker of ETS exposure. The study found the estimated environmental tobacco smoke associated cognitive deficits among children even at extremely low levels of exposure. Moreover, it was found that visual-motor coordination deficits decrease when the length of living period in the study areas increases by 1 unit (adjusted OR 0.954). This finding was contrasted with a study on the effects on neurobehavioral development in infants and young children residing within a specific community. It was found that residence in a community with high exposure was associated with poorer neurobehavioral development of the child.[28] This might be related to household ETS and community location. Among children with visual-motor coordination deficit, the results showed that children residing in this area within one year with a smoker in the household have twice as many visual-motor deficits as children residing here more than five years. In terms of home distance, children residing at the study area for only one year are located closer to the Petrochemical Industrial Estates than children residing for more than five years.

The limitation of this study is that a geocode (GIS) was used for assessing ambient air pollutant exposure in participants' residences instead of personal exposure. Therefore, local sources, wind direction and wind speed may have an effect on the level of air pollutant concentration in this area. Based on the data presented in our current study we recommended further investigation of the inverse associations between neurobehavioral effects and some factors such as living period and age.

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