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Environmental Exposure of Organophosphate Pesticides Mixtures and Neurodevelopment of Primary School Children In Tanjung Karang, Malaysia

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ABSTRACT

Objective: This study determined relationship between environmental exposure of organophosphate pesticides mixtures and neurodevelopment among primary school children in a paddy farming area.
Method: The study was conducted at Tanjung Karang, Selangor. Random sampling method was used to select the children (n=114) based on the inclusive criteria; healthy primary school children, aged 10 to 11 years old and with parental written permission. A set of questionnaire items were filled up by parents to obtain their children's background information. Data was analyzed using descriptive statistics. Finger prick technique was used to collect 0.01 ml blood samples in which blood cholinesterase concentration as an indicator of organophosphate pesticide exposure were then analyzed using a rapid test cholinesterase test kit Model LOVIBOND 412870 AF287. All seven tests of WHO Neurobehavioral Core Test Battery (NCTB) were used to measure the children's neurodevelopment.
Result: Findings showed poor neurobehavioral functions scores in term of motor steadiness (36.61), rapid coordination of eye and hand (46.17), attention or response speed (47.28), and perceptual motor speed (47.38). There were significant correlations between blood cholinesterase with the Trail Making Test score (p=0.003) and Pursuit Aiming Test score (p=<0.001). Trail Making Test scores (motor steadiness) were significantly related to the frequencies of these children playing near to the paddy field (p=0.039) whereas Time Reaction / Movement Test score (rapid coordination of eye and hand) was significantly related to the home location with respect to the paddy fields (p=0.042). There was a significant relationship between blood cholinesterase, home location (p=<0.001) and frequency of playing near to the paddy fields (p=0.039).
Conclusion: Home proximity and habits of playing near to the paddy fields were the main factors related to low blood cholinesterase which further resulted in poor motor steadiness as well as poor coordination of eye and hand among these children.

Keyword: Blood Cholinesterase, Neurodevelopment, Children, Organophosphate

1. Introduction

Agriculture is categorized into two distinct sectors in Malaysia, namely the co-existence of plantation farming and the smallholder's sub-sectors. Agricultural sector is predominately for food and industrial commodities. The food sub-sector includes crops such as paddy, vegetables, fruits, meats and fish while the industrial commodities are palm oil, rubber and cocoa. The engine of the Malaysian economic growth is partly driven by high export earnings from the agriculture sector (Zaim et al, 2012).

According to Zaim et al. (2012), there were about 300,000 farmers who depend on rice farming as their source of income and livelihood. Paddy planted areas are estimated to cover about 672,000 hectars throughout Malaysia and average national paddy production is about 3.660 metric tonnes per hectare.

1.1. Pesticides

The main concern of an agriculture sector is the use of pesticides. Pesticides are used in modern commercial agriculture. Pesticides are chemicals applied to control or kill pest species. Global pesticide production was valued to cost about $35.8 billion in 2006 and $39.4 billion in 2007. The quantity of pesticides produced was about 5.2 million tonnes in 2006 (Ismail et al, 2012). In 2007, the total value rose partly due to increased use of all types of pesticides.

In Selangor, pesticides are applied to paddy crops from December to March every year. Harvesting is usually carried out twice a year during the month of May till June and October to November. The period for cultivation of paddy in Tanjung Karang is presented in Table 1. The most commonly use insecticide are organophosphates and carbamates. Toxic exposure is a serious global public health problem with more than three million people poisoned and 200,000 deaths reported per year (Kwong, 2002).

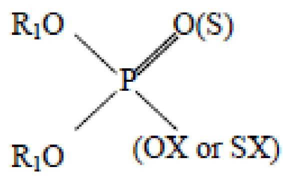
Table 1: Paddy crop cultivation in Tanjung Karang, Selangor

Month	Activities
November	Cut the rice straw or weed control
	Burn the rice straw (depends on situation)
	Ploughing using tractors and conditioning the fields
December	Weed control by applying herbicide
	Spread lime to balance the soil pH
	Rat control by applying pesticides
	Ploughing using tractors and conditioning the fields
January	Irrigate the paddy block
	Remove water from paddy block
	Sow the seed uniformly by using blower
	Fertilizing
February & March	Fertilizing, maintaining, and pest controlling Many type of pesticide used in this phase: herbicide, insecticide, mollucide.
April	Ripening of paddy
May	Harvesting

Source: Pejabat Pertanian Kuala Selangor Utara, 2009

1.2. Characteristics of Organophosphate (OP)

Organophosphates (OPs) are esters of phosphoric or phosphorothioic acid that exist in two forms: -thion (sulfur containing) and -oxon (oxygen containing). The -oxon OPs have a greater toxicity concentration than -thion OPs. However -thion OPs readily undergo conversion to -oxons once in environment). Majority of the OP pesticides used are dimethyl compounds (two [-O-CH_3] groups attached to the phosphorus) or diethyl compounds (two [-O-C_2H_5]) groups attached to the phosphorus) represented by R_1 in Figure 1 (LaDou, 2004).



Note: X is the leavening group

Figure 1: Chemical structure of organophosphate (OP) compounds
Source: LaDou, 2004

1.3. Mechanism of cholinesterase toxicity

Organophosphates are anti-esterase insecticides and cause overstimulation at cholinergic nerve terminals. This process occurs in both insects and humans. Acetylcholinesterase catalyzes degradation of the neurotransmitter acetylcholine in synapse (yellow panel in Figure 2). Organophosphate pesticides phosphorylate acetylcholine, thereby, reduce the ability of the enzyme to break down the neurotransmitter (red panel below in Figure 2). This causes accumulation of acetylcholine in the central and peripheral nervous systems, resulting in an acute cholinergic syndrome via continuous neurotransmission. The clinical onset of cholinergic over-stimulation can vary from almost instantaneous to several hours after exposure according to Pediatric Environmental Health Specialty Unit (PEHSU, 2007).

1.4. The Effect on Neurobehavioral Performance

Neurobehavioral test batteries have frequently been used to assess neurotoxicity of pesticide exposure in adult populations. Individuals with histories of toxic exposures to organophosphates were found to have a consistent pattern of deficits on measures of motor speed and coordination, sustained attention, information processing speed and learning ability (Rothlein et al, 2006; Nur Naqibah et al, 2015; Noor Aishah et al, 2015; Miswon et al, 2015). Children are also at greater risk of OP toxicity than adults because their brains are rapidly developing (Grandjean et al, 2006).

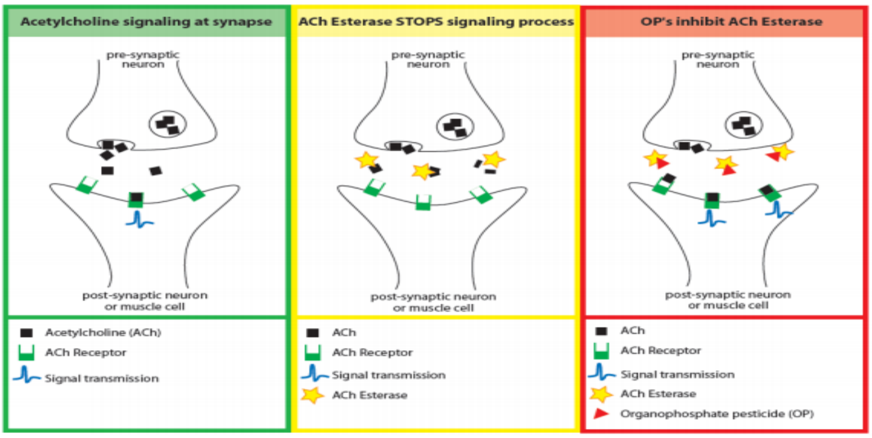


Figure 2: Mechanism of cholinesterase toxic

Source: Pediatric Environmental Health Specialty Unit (PEHSU, 2007).

Studies (Nur Naqibah et al, 2015; Grandjean et al, 2006) which assessed neurobehavioral deficits in children with parental occupational pesticides exposure history, were consistent with deficits for motor speed (Finger Tapping), motor coordination (Santa Ana Form Board), visuospatial performance (Standford-Binet Copying) and visual memory (Copying Recall).

2. Methods

This is a cross-sectional study conducted in paddy farming areas of Tanjung Karang, Selangor. There were 114 children who lived near to paddy fields. Random sampling method was used to select children from name lists provided by teachers based on the inclusion criteria: healthy, age ranged between 10 to 11 years old and with parental written permission. A take home questionnaire was given to each child to be filled by their parents. The questionnaire comprised 4 sections – social demographic, knowledge of pesticide, information on the children's health, activities and home location.

2.1. Cholinesterase Test Kit

The blood cholinesterase concentration was analyzed using rapid test cholinesterase kit Model LOVIBOND 412670 AF267. The test was carried out with finger prick as it requires only 0.01ml of blood samples from each children and it can be completed in less than 4 minutes. The cholinesterase test kit is based on colorimetric concept whereby the change of color depends on pH variations when blood cholinesterase liberates acetic acid. There were two types of reagent used in this test; the indicator solution consisting of bromothymol blue water soluble dissolved in 250 ml of deionized water and substrate solution of 0.25g acetycholine perchlorate dissolved in 50ml of deionized water. When the solutions were mixed with children's blood, the mixture become acidic, and turns the solution color from blue to yellow. The color appeared were compared to the comparator kit. The cholinesterase activity was expressed in percentage of activity in the blood. Table 2 shows the exposure category of cholinesterase in blood.

Table 2: Exposure category of cholinesterase activity in blood

Percentage (%)	Indicator
100.0 -75.0	Normal
74.9- 50.0	Over exposure
49.9-25.0	Serious over exposure
24.9-0.0	Very serious and dangerously over exposure

2.2. Neurobehavioral Core Test Battery (NCTB)

Neurobehavioral tests were conducted to monitor the neurodevelopment of the children. These neurobehavioral tests with their related functions are shown in Table 3.

Table 3: Neurobehavioral Core Test Battery (NCTB)

Test	Function
Benton Visual Retention	Visual perception / memory
Time Reaction Movement	Attention/ response speed
Santa Ana Manual Dexterity	Manual dexterity
Trail Making	Motor & visual coordination / steadiness
Pursuit Aiming	Motor steadiness
Digit Symbol	Perceptual motor speed
Digit Span	Short-term memory capacity

To ensure the effectiveness of this equipment, WHO Guideline of NCTB was followed and the researcher was trained thoroughly to minimize error variance. The room used to conduct the test must be comfortable, free from distracting noise and intrusion with adequate lighting, suitable table and seats (an examiner and children can see face to face or a 90% angle with regard to each other). During each test session, an examiner was present to read the instructions, answer questions, and reinforce responding when necessary.

3. Results

3.1. Response Rate

A total of 120 primary school children had been selected to participate in this study. However, only 114 students participated giving a response rate of 95%.

3.2. Socio-demographic Information

This study was conducted in two schools; Sekolah Kebangsaan Berjaya and Sekolah Kebangsaan Dato' Manan in Tanjung Karang, Selangor. The variables assessed were age, gender, BMI, parent's education and occupation, house location, common mode of transportation, distance from house to school, habits of playing near paddy field, and habits of washing hand before eat (Table 4).

3.3. Reported Sign and Symptoms

The health symptoms observed were cough (55.3%) followed by running nose (38.6%), headache (25.4%), and excessive sweat (7%). Breathing difficulties (2.6%) and watery eye (6.1%) conditions were the least reported to occur among children.

3.4. Classification of Blood Cholinesterase Concentrations

The blood cholinesterase concentrations were classified according to the four categories ranging from 100% to 75% (normal), 74.9% to 50% (over exposed), 49.9% to 25% (serious over exposed), and 24.9% to 0% (very serious and dangerously over exposed). The classifications are shown in Table 5. The majority of the school children (49.1%), was in the range of normal exposure concentration. On the other hand, about 43.9% of them were over exposed, while only 7% were seriously over exposed.

The classification were then simplified into 2, consisting of normal and low blood cholinesterase which made up of over exposed and seriously over exposed. The results are given in Table 6.

Table 4: Children's socio-demographic background

	Frequency (n)	Percentage (%)
Age		
10 year old	60	52.6
11 year old	54	47.4
Gender		
Male	50	43.9
Female	64	56.1
Body Mass Index (BMI)		
Underweight (<18.5)	73	64.0
Normal (18.5-24.9)	41	36.0
Fathers' Education		
Primary	59	51.8
Secondary	42	36.8
Tertiary	13	11.4
Mothers' Education		
Primary	50	43.9
Secondary	42	36.8
Tertiary	22	19.3
Fathers' Occupation		
Farm Workers	78	68.4
Non-farm Workers	36	31.6
Mothers' Occupation		
Farm workers	51	44.7
Non-Farm workers	63	55.3
Transportation to School		
Walk	-	-
Bicycle	5	4.4
Motorcycle	84	73.7
Car	25	21.9
Distance of Home to Paddy Fields		
<100m	30	26.3
>100m	21	18.4
>500m	22	19.3
>1000m	41	36.0
Play near Paddy Field		
Yes	63	55.3
No	51	44.7
Wash Hand		
Yes	67	58.5
No	47	41.2

N=114

Table 5: Classification of blood cholinesterase concentrations

	Frequency (n)	Percentage (%)
Normal	56	49.1
Over Exposed	50	43.9
Serious Over Exposed	8	7.0
Very seriously over exposed	0	0

N= 114

3.5. The association of Blood Cholinesterase Concentration with House Location and Health Symptoms

Table 6 shows the association of children's blood cholinesterase concentrations with socio-demographic factor (house location) and health symptoms. House location near to paddy field (*p*=<0.001) and headache (*p*=0.049) were found to have significant association with the blood cholinesterase concentrations.

Table 6: Association of blood cholinesterase concentration with house location and health symptoms

	Blood Cholinesterase		χ^2	P
	Normal	Low		
Home Location [a]				
Near to paddy field	36	55	16.502	<0.001
Far from paddy field	20	3		
Health Symptoms [b]				
With headache	19	10	6.047	0.049
Without headache	36	43		

Na = 114, Nb = 108
Chi-Square Test
***significant at p<0.001
*significant at p<0.05

3.6. Neurobehavioral Performance Score

A set of seven NCTB tests were performed on school children to obtain the neurodevelopment score as shown in Table 7.

Table 7: Scores of NCTB test

	Range	Mean	SD
Benton Visual Retention Test	36-70	53.90	7.195
Digit Span Test	24-82	47.38	9.210
Digit Symbol Test	34-67	50.83	7.858
Santa Ana Manual Dexterity Test	23-69	50.12	10.422
Trail Making Test	33-67	46.17	7.964
Pursuit Aiming Test	7-65	36.61	9.954
Time Reaction / Movement Test	15-67	47.28	9.779

3.7. Correlation Blood Cholinesterase Concentration and Neurobehavioral Performance

Table 8 shows that there were strong direct correlation between blood cholinesterase with Trail Making Test (*p*=0.003) and Pursuit Aiming Test (*p*=<0.001).

Table 8: Correlations between blood cholinesterase and neurodevelopment scores.

	Blood Cholinesterase Concentration	
	r_s	p
Benton Visual Retention Test	-0.014	0.220
Digit Span Test	0.024	0.801
Digit Symbol Test	-0.058	0.543
Santa Ana Manual Dexterity Test	-0.113	0.231
Time Reaction / Movement Test	0.132	0.161
Trail Making Test	0.272	0.003**
Pursuit Aiming Test	0.386	<0.001***

N= 114
Spearman's Rho Test
**significant at p<0.01
*significant at p<0.05

3.8. Variables Influencing Blood Cholinesterase Concentration

The results in Table 9 shows that home location (to paddy field (p=<0.001), and playing near to the paddy field (p=0.039) had significant relationship with the blood cholinesterase.

3.9. Selected Variables which Influenced the Neurodevelopment of the Children

Multiple regression statistics was carried out in order to determine the factors influencing neurodevelopment scores among children after controlling all the confounders such as gender, parents' education, housing location, hand washing before eat, playing near paddy field and blood cholinesterase concentrations. Among all the 7 tests, only Trail Making Test and Time Reaction/Movement Test showed significant relationship with the predictor of the neurodevelopment. From Table 10, blood cholinesterase (p=0.049) and playing near paddy fields (p=0.039) showed significant relationship with the Trail Making Test. Table 11 shows that house location (p=0.042) and blood cholinesterase (p=0.049) had significant relationship with the Pursuit Aiming Test.

Table 9: Selected variables that influenced the blood cholinesterase concentrations in children

	B	S.E.	PR	95% C.I.	p-value
Gender	0.196	0.429	0.209	0.525-2.823	0.647
Fathers' education	0.589	0.387	2.321	0.845-3.846	0.128
Mothers' education	-0.046	0.438	0.011	0.405-2.252	0.917
Home location	-2.659	0.704	14.254	0.018-0.278	<0.001***
Wash hand before eat	0219	0.512	0.184	0.456-3.399	0.668
Playing near paddy fields	1.096	0.531	4.264	1.057-8.475	0.039*
Home distance to school	0.44	0.182	0.058	0.731-1.494	0.810
Constant	0.479	1.244	1.469		0.700

N=114, B: Regression Coefficient, S.E: Standard Error, 95% C.I: 95% Confidence Interval, *Significant at p<0.05, ***Significant at p<0.001

Table 10: Selected variable that influenced the Trail Making Test of children

	B	S.E.	PR	95% C.I.	p-value
Gender	0.186	0.418	0.197	0.531-2.731	0.657
Fathers' education	0.148	0.358	0.172	0.575-2.340	0.678
Mothers' education	-0.302	0.426	0.503	0.321-1.703	0.478
Home location	-0.728	0.624	1.362	0.243-0.483	0.243
Wash hands before eating	0.525	0.516	1.032	0.614-4.650	0.310
Playing near paddy fields	1.095	0.531	4.251	1.056-8.458	0.039*
Blood cholinesterase	0.898	0.456	3.886	1.005-5.999	0.049*
Constant	-0.430	1.150	0.140		0.708

N=114, B: Regression Coefficient, S.E: Standard Error, 95% C.I: 95% Confidence Interval, *Significant at p<0.05

Table 11: Selected variable that influenced the Pursuit Aiming Test of children

	B	S.E.	PR	95% C.I.	p-value
Gender	-0.233	0.421	0.307	0.347-1.808	0.579
Father's education	0.468	0.357	1.724	0.794-3.212	0.189
Mother's education	0.157	0.413	0.144	0.521-2.628	0.704
Home location	1.217	0.598	4.150	1.047-1.640	0.042*
Wash hand before eat	0.547	0.515	1.128	0.630-4.743	0.288
Playing near paddy fields	-0.098	0.542	0.032	0.313-2.624	0.857
Blood cholinesterase	0.943	0.479	3.879	1.005-6.558	0.049*
Constant	-1.360	1.126	1.460		0.227

N=112, B: Regression Coefficient, S.E: Standard Error, 95% C.I: 95% Confidence Interval, *Significant at p<0.05

4. Discussion

4.1. Socio-demographic of Children

In this study, 114 school children from two schools located near the paddy field were involved, based on inclusive criteria. Healthy children with the age ranged between 10 to 11 years old with parental written permission were included in the study. The numbers of female children (56.1%) were higher than that of male children (43.9%).Majority of the children (68.4%), have father who is working as a farmer while most mothers' were non-farmers, (55.3%). Based on the feedback from questionnaire, most of the mothers were housewives.

Based on BMI, majority of the school children are underweight (64%). BMI was measured because the dose of pesticide per body weight is likely to be larger in children and children have a reduced capacity for detoxifying xenobiotic (London et al, 2012). Among the health symptoms asked, the most frequent symptom were coughing (55.3%) followed by running nose (38.6%), headache (25.4%), and excessive sweat (7%). Some of the children also experience breathing difficulties and watery eye. Adverse effects of pesticide exposure range from mild symptoms of dizziness and nausea to serious, long-term neurological, developmental and reproductive disorders (US EPA, 2012). According to a study, the most common effects are irritation of the eyes, nose, and throat such as tearing, stinging, burning and coughs, skin irritation and rashes. Almost 76% of all acute poisonings in Asian countries are caused by organophosphate (Thomas et al, 2002).

OP pesticides causes broad range of non-specific symptoms following high exposures such as headache, dizziness, fatigue, weakness, nausea, chest tightness and difficulty in breathing (Kamel et al, 2003). The study found that exposure to organophosphate pesticides can lead to acute health problems, including headache, nausea, dizziness, vomiting, abdominal pain, skin or eye problems, and had been implicated in chronic morbidities such as dermatitis, fatigue, respiratory problems, sleep and memory disorders, anxiety, cancer, neurological deficits, miscarriages and birth defects.

4.2. Blood Cholinesterase Concentration

Study by Lu (Lu, 2007) evaluated the degree of exposure in children showed that activity of cholinesterase enzymes in blood can be utilized as a biomarker for the effect of organophosphate. The exposed person would show abnormally low concentrations of cholinesterase enzymes activity measured in the serum or in the red blood cell.

Low blood cholinesterase concentrations indicated high exposure to pesticide. According to the Cholinesterase Test Kit Instruction, the normal range for blood cholinesterase concentration is 100-75%, followed by 74.9-50% for over exposed, 49.9-25% for serious over exposed, and 24.9 to 0% for very serious over exposed. In this study, the classification were further simplified to normal and exposed with the blood cholinesterase which consisted of the over exposed and seriously over exposed group. It was found that 49.1% of 114 children's were normal, while the remaining 50.9% were over exposed.

4.3. Neurobehavioral Performance Functions

The assessment of neurobehavioral tests was aimed to determine the existence of neurotoxic problem among the school children. In this study, the children were classified according to their performance in each function test and the percentage of good and poor functions were also assessed.

A number of neurobehavioral tests have been used to identify more subtle adverse health effects of a wide range of toxicants including OP pesticides in both adults (Anger, 1986) and children (Nur Naqibah et al, 2015; Noor Aishah et al, 2015; Miswon et al, 2015; Dietrich and Bellinger, 1994). Based on the result obtained, most children showed poor neuropsychological function in term of motor steadiness (36.61), rapid coordination of eye and hand (46.17), attention or response speed (47.28) and perceptual motor speed (47.38).

Children had poor performance in motor steadiness probably due to reduction in their ability to make quick and accurate movements with hand. They also have low rapid coordination of eye, hand and attention or response speed probably due to low focus attention. The indication of low perceptual motor speed on the other hand, may be linked to having problems in learning the association of certain element in appropriate time. Neurotoxic effects of environmental chemical exposures vary along a continuum from minor subclinical deficits in sensory memory, motor or cognitive functioning to mental retardation and clinical disease (Nur Naqibah et al, 2015; Noor Aishah et al, 2015; Miswon et al, 2015; Landrigan, 2004).

4.4. Correlation between Blood Cholinesterase concentrations with Neurobehavioral Performance Score

Based on the results, the blood cholinesterase significantly influenced the score deficit in Trail Making and Pursuit Aiming Test among school children. A study (Abdel Rasoul et al, 2008) on cholinesterase activity was correlated with performance on the Digit Span and Trail Making Test. The accumulation of pesticide in human body inhibits the function of acetyl-cholinesterase in transmitting information. Continuous exposure might defect the motor and visual coordination or steadiness as excessive acetylcholine in the synaptic cleft could cause neuromuscular paralysis.

A study conducted on neurobehavioral performance among preschool children found significantly poorer performance on measures of response speed (Finger Tapping) and latency (Match-to-Sample) in agriculture children compared to the non-agriculture children. Specifically, children exposed to OP pesticides had a deficit in inhibitory motor control (Kofman. 2006). Children demonstrated a dose–response relationship for functional cognitive effects, where these functions were positively correlated with increased years of exposure to OP pesticides (Noor Aishah et al, 2015; Miswon et al, 2015).

This deficit in neurodevelopment and the existence of more neurological symptoms in the applicators were consistent with the previous studies that examined adult pesticide workers in Egypt. There were significant deficits in complex visual-motor processing and executive function, verbal abstraction, attention and short-term memory and problem solving or perception (Farahat et al, 2003).

Von Osten et al. (2004) found that there was a significantly lower activity concentration of AChE in the exposed children compared to the control. All studies found AChE to be significantly lower in the exposed participants than the controls [Nur Naqibah et al, 2015; Noor Aishah et al, 2015; Kofman, 2006).

Roldan-Tapia (Roldan-Tapia et al, 2005) found that there was a significant correlation between the AChE concentrations and neurobehavioral performance, especially with the Information, Digit Span and Trail Making Tests.

4.5. Relationship between Selected Variables and Blood Cholinesterase concentration

In this study, the few variables were selected to identify if there was any influence on the blood cholinesterase concentration. Based on the results, there were significant relationship between blood cholinesterase concentration with home location and frequency of playing near to the paddy fields. From the questionnaire response, about 79.8% of the children lived in the vicinity of less than 100 meters from the paddy field area. The homes were located close to the paddy field area which used OP pesticides. This findings were supported by a study (Patil and Govindwar, 2003) in which the aerial drift of pesticides caused health symptoms and lowered cholinesterase concentrations in a population living near sprayed cotton field.

High exposure to the OP pesticide decreases the activity of cholinesterase in the synaptic cleft. AChE inhibitors play a significant role in the biochemical processes of human body due to the physiological importance of AChE. Inhibition of AChE also plays an important role in nerve agent toxicology (Roldan-Tapia et al, 2005).

4.6. Relationship between Selected Variables and Neurobehavioral Scores

Most children often plays out-door near to paddy field and this might influence their manual dexterity owe to pesticide exposure. The pesticide may have been brought into home on shoes or sandals, clothing, or on the skin. Potential for exposure to OP pesticides exists if contaminated hands are put near face. This type of exposure can occur through skin absorption, eating, drinking without prior hand washing.

Housing area near to paddy field was a factor influencing the coordination of eye and hand and motor steadiness among children. Similar to a study (Keifer et al, 1996), which stated that children of agricultural workers are considered to have a higher risk of exposure to pesticide compared to the general population because of the close proximity of their homes to fields where pesticides are applied and also from the take home exposure of their parents.

This decrement of neurobehavioral scores, and reporting of more neurological symptoms in the exposed children, were consistent with a previous study which examined adult pesticide workers in Egypt which were found to have significant deficits in complex visual-motor processing and executive function, verbal abstraction, attention and short-term memory and problem solving or perception (Abou Salem et al, 2008).

5. Conclusion

In conclusion, the frequency of playing near to paddy field and home location were the main risk factors related to the low blood cholinesterase which consequently influenced the deficit in neuro-development of these children. The poor functions in term of motor steadiness were indicated by the low Pursuit Aiming Test scores while the slow and inaccurate movement with the hands, visual motor, and scanning as well as attention span were indicated by the low Trail Making Test. The organophosphate pesticide significantly impaired the motor steadiness, speed, and accuracy of these children.

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ETHICAL CONSIDERATIONS

The study was approved by the Ethics Committee of the Faculty of Medicine and Health Sciences, University Putra Malaysia, Selangor, Malaysia.

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