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Original Article

Secondhand Smoke Exposure in Toddlerhood and Cognitive Ability among Malaysian Adolescents

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Abstract

Background: Secondhand Smoke (SHS) exposure has been reported to cause a number of adverse health effects. Although studies have been conducted to identify the link between SHS exposure and cognitive functioning of children, its relationship is still unclear. This study aimed to identify the association of prenatal and postnatal SHS exposure with cognitive ability among adolescents.

Methods: A total of 370 adolescents aged 13-14 years old in two states in Malaysia participated in this study. A modified Global Youth Tobacco Survey questionnaire was used to assess exposure to SHS. Parental-administered questionnaire was used to obtain information on parental smoking and prenatal SHS exposure. Cognitive ability was objectively measured using Wechsler Nonverbal Scale of Ability.

Results: 75.4% and 24.6% adolescents were identified to have cognitive ability categorized as high (>90marks) and low (≤90marks), respectively. From the logistic analysis adjusting for confounders, adolescents with SHS exposure in toddlerhood (≤2years old) were three times more likely to have lower cognitive ability compared to those without exposure (Adjusted Odds Ratio (AOR), 2.89; 95% Confidence Interval (CI), 1.21-6.83). School absenteeism was associated with lower cognitive ability.

Conclusion: Exposure to SHS during toddlerhood was linked to lower cognitive ability among adolescents. The findings of this study emphasize the need for preventing involuntary toddlerhood SHS exposure from parents and indirectly encourage home smoking restriction practices among Malaysian citizens.

Keywords: Passive smoking, Adolescents, Cognitive ability, Youth, Tobacco smoke

Introduction

Second-hand Smoke (SHS) refers to the smoke exhaled by a smoker and the smoke from the burning tip of a cigarette (1). Approximately 30% of the world's population were reported to be exposed to SHS; and as of 2004, 603,000 premature deaths have been reported (2). Of all deaths attributed to SHS, more than one quarter occurred among children and young adolescents.

Evidence shows that involuntary exposure to SHS among children and young adolescents is linked to detrimental health consequences (3, 4). Apart from respiratory problems, such as night cough, wheezing, and asthma, which are among the most common SHS-related health effects, poor cognitive ability has been shown to be associated with SHS exposure (5). Cognitive ability refers to the capacity to understand complex ideas, to adapt effectively to the environment, to learn from experience, to engage in various forms of reasoning, and to overcome obstacles through thought (6). In other words, it refers to an individual's capacity to think, reason, and problem-solve, and is usually measured using tests of intelligence or cognitive skills.

A study conducted among 4,399 children and adolescents aged 6-16 years old in the United States provided a link between SHS exposure and a decrement in maths, reading, and block design test marks (7). Moreover, a study in Hong Kong also showed a linear association between SHS exposure and poor academic performance among non-smoking adolescents (8). In explaining the mechanism of SHS effects on the brain, a common pathway was associated with the release of carbon monoxide (CO) from incomplete combustions of cigarettes (9). CO from side stream smoke exhaled by smokers has been found to be five times higher than mainstream smoke inhaled by smokers themselves. The effects of SHS were linked to the higher CO affinity towards haemoglobin that depletes oxygen (O_2) supply to the brain; thus affecting cognitive performance.

Exposure to SHS can be either from indoor or outdoor sources. For children and young adolescents, parental smoking at home has been proven the main source of exposure, followed by exposures occurring outdoors (2, 10, 11). A study in Scotland, among 2,424 children, has further supported the outdoor exposure theory, by identifying SHS exposure in public places as another important source of SHS (12). Findings from these studies suggested that adolescents living with parent who smoke, and those who frequently spend their time in public areas where smoking is permitted, are more susceptible to higher SHS exposure.

Although studies have been conducted to establish a link between SHS exposure and cognitive ability, the factors have been controversial (5, 13). In Malaysia, no local study exploring the relationship has been performed before. The prevalence of Malaysian adult smokers has remained high; even as the percentage of smokers in the western world has dwindled (14). Moreover, more than 40% of adolescents lived with a smoking parent (15). As such, it is important to study SHS exposure, its effects, and other SHS-related factors. This study will provide an overview of the adverse effects of SHS exposure on cognitive ability; especially among local adolescents.

This study aimed to identify an association between SHS exposure and cognitive ability among 13-14 year old adolescents, as well as other predictors that may affect the level of their cognitive ability.

Methods

This cross-sectional study was performed in two states in Malaysia among adolescents aged 13-14 years old. Data collection was carried out between the months of April and November 2013.

Participants

Participants were recruited from Form 1 and Form 2 students. They were randomly chosen from 18 secondary schools that best represented the local demographics of each state. Of the 898 students who received a survey envelope containing 1) a student information sheet, 2) a consent form, 3) a parental questionnaire, and 4) a student questionnaire, 600 students returned their completed consent form, thus giving a response rate of 66.8%. Respondents' participation was voluntary upon parental approval. Permission to conduct this research was granted by the Universiti Putra Malaysia's Medical Research Ethics Committee, the Ministry of Education, and the school's administration.

Assessment of SHS exposure

SHS exposure was measured via a self-administered questionnaire. Of 600 eligible participants, 438 students returned the questionnaire. Overall, 370 students completed their questionnaires. The questionnaire consisted of Malay back-translated and modified versions of a Global Youth Tobacco Survey (GYTS) by the World Health Organization (16). The questionnaire contained items on socio-demographic characteristics, household smoking habits, and outdoor SHS exposure. A panel of experts, teachers, and parents reviewed the self-administered questionnaire. Questionnaire completion sessions were conducted in a classroom setting, where all of the students involved gathered at the same place at the same time. This helped to ensure uniformity of information and instructions given to the students.

The parents were given a study information sheet, a consent form, and a self-administered questionnaire via their child. The questionnaire contained items on smoking habits and prenatal SHS exposure related to their child. Questions on exposure to SHS during toddlerhood (aged ≤ 2 years old) experienced by adolescents were also asked.

Assessment of cognitive ability

A total of 370 students took part in the cognitive ability test. The Wechsler Nonverbal Scale of Ability (WNV), which consisted of Matrices and Spatial Span subtests, was used to determine cognitive ability (17). The matrices' subtest measured general intelligence and problem solving skills by asking respondents to choose a missing portion from four or five response options to match into the incomplete figural matrix (18). The spatial span subtest assessed attention and short-term working memory; in which the respondents were required to repeat a sequence of tapped blocks in both the same and the reverse order, as demonstrated by the examiner (18).

In both WNV assessments, only pictures, movements, and body language were used to describe the tasks to be performed by the respondents, in order to participate actively in this study. WNV was used, because it operates nonverbally; which helped to reduce the variability that exists due to language barriers between researcher and participants, and to ensure the consistency of any instructions given (no verbal interaction was needed to explain both WNV subtests).

The outcome measurement for WNV was in the form of scoring number. A full-scale score for each respondent was derived from the sum of matrices and spatial span subtest scores; which was age-dependent. This sum was obtained using a specific calculation, as presented in the WNV Administration and Scoring Manual (18). For data analysis purposes, the final cognitive ability test scores were placed into two categories by the researcher, namely ≤90 marks - which represented the category of low cognitive ability and >90 marks - which represented the high cognitive ability category. Categorization was made based on the distribution of WNV scores obtained from the study's participants and according to the cut-off point by WNV.

Statistical analysis

Statistical data analysis was performed using SPSS Version 21 (SPSS Inc., Chicago, IL, USA) with the significant level set at $P<0.05$. Chi-square tests were performed to compare socio-demographic characteristics, parental smoking, and SHS exposure between adolescents with low and high cognitive abilities. Multi-level logistic regression analysis was performed to identify the significant predictors of low cognitive ability. Independent variables that were significant in the cross-tabulation tests, and proved to be significant in previous studies, were included and grouped into three different blocks according to their categories: Block 1=SHS exposure (pregnancy, toddlerhood, and current exposure); Block 2=gender; and Block 3=parental information and children school absence days. The model containing all three blocks was then analyzed using an enter method.

Results

Table 1 presents details of the socio-demographic characteristics of adolescents included in the study. Most of the adolescents were Malay (90.5%), females (52.4%), and lived in the same household as a smoking parent (67.0%). More than 50% of the adolescents reported that smoking restrictions were practiced at home (60.8%). A higher number of adolescents came from families with lower socio-economic statuses (70.8%) with parents that had a secondary level of education (62.2%). Table 2 shows the details of the socio-demographic characteristics of adolescents across cognitive ability test scores. Malay adolescents (*P*=0.039) and those who experienced SHS exposure during their toddlerhood (*P*=0.022) were more likely to score low marks in the cognitive ability test**.**

Table 1: Socio-demographical characteristics of study participants (n=370**)**

Variables		Total
Total (n = 370)		370 (100)
Gender		
	Male	176 (47.6)
	Female	194 (52.4)
Ethnicity		
	Malay	335 (90.5)
	Non-Malay	35 (9.5)
Parental education		
	Secondary	230 (62.2)
	Tertiary	130 (35.1)
	Missing	10 (2.7)
Household income		
	Low	262 (70.8)
	High	100 (27.0)
	Missing	8 (2.2)
Tuition		
	Yes	60 (16.2)
	No	310 (83.8)
Parental smoking		
	Yes	248 (67.0)
	No	122 (33.0)
ETS exposure (pregnancy)		
	Yes	82 (22.2)
	No	287 (77.6)
	Missing	1 (0.3)
SHS exposure (toddlerhood)		
	Yes	122 (33.0)
	No	240 (64.9)
	Missing	8 (2.2)
SHS exposure (hr/day)		
	≤ 1	139 (37.6)
	> 1	112 (30.3)
	No	119 (32.2)
Smoking restriction		
	Yes	225 (60.8)
	No	140 (37.8)
	Missing	5 (1.4)

Table 3 provides details on the mean of cognitive ability test scores. For the matrices subtest, the mean (standard deviation; sd) value was 20.06 (4.28); whereas, for the spatial span subtest, the mean was 16.25 (2.97). Summing up marks for both subtests for each participant, the mean for overall cognitive ability test score was 98.20 (12.24). The mean for cognitive ability tests score indicated that, on average, study participants had high cognitive ability (75% of the adolescents scored ≥90 for the cognitive ability test).

Table 4 shows the results of the multivariate analysis for predicting low cognitive ability among participants. The model, as a whole, explained 14% of the variance in low cognitive ability, and correctly classified 78.3% of cases. After adjusting for the individual differences, classrooms, schools, and states of the study participants, the results show that exposure to SHS during toddlerhood was the strongest predictor of low cognitive ability. Adolescents who experienced SHS exposure during their toddlerhood were three times more likely to have lower cognitive ability than those without toddlerhood SHS exposure (Adjusted Odds Ratio (AOR) 2.89; 95% Confidence Interval (CI) 1.21-6.83).

Table 2: Socio-demographical characteristics of study participants (n (%)) across low and high cognitive ability

Variables		Cognitive abilities scores, n (%) Low (≤ 90)	High (> 90)	χ^2	*P*
Gender (n=370)					
	Male	43 (24.4)	133 (75.6)	0.005	0.521
	Female	48 (24.7)	146 (75.3)		
Ethnicity* (n=370)					
	Malay	87 (26.0)	248 (74.0)	3.613	0.039
	Non-Malay	4 (11.4)	31 (88.6)		
Parental education (n=360)					
	Secondary	54 (23.5)	176 (76.5)	0.787	0.223
	Tertiary	36 (27.7)	94 (72.3)		
Household income (n=362)					
	Low	67 (25.6)	195 (74.4)	0.822	0.222
	High	21 (21.0)	79 (79.0)		
Tuition (n=370)					
	Yes	10 (16.7)	50 (83.3)	2.427	0.078
	No	81 (26.1)	229 (73.9)		
Parental smoking (n=370)					
	Yes	62 (25.0)	186 (75.0)	0.067	0.451
	No	29 (23.8)	93 (76.2)		
ETS exposure (pregnancy) (n=369)					
	Yes	24 (29.3)	58 (70.7)	1.204	0.170
	No	67 (23.3)	220 (76.7)		
SHS exposure (toddlerhood)* (n=362)					
	Yes	38 (31.1)	84 (68.9)	4.676	0.022
	No	50 (20.8)	190 (79.2)		
SHS exposure (hr/day) (n=360)					
	≤ 1	36 (25.9)	103 (74.1)	0.370	0.831
	> 1	28 (25.0)	84 (75.0)		
	No	27 (22.7)	92 (77.3)		
Smoking restriction (n=365)					
	Yes	53 (23.6)	172 (76.4)	0.383	0.309
	No	37 (26.4)	103 (73.6)		

Note: *P<0.05/Missing values were excluded from chi-square (χ^2) test

Another factor that was significantly related to lower cognitive ability test scores was adolescents' school absence days. Adolescents who reported a higher number of school absence days were significantly linked to lower cognitive ability (AOR 1.11; 95%CI 1.02-1.20).

Table 3: Mean of Wechsler Non-Verbal Cognitive Ability test score (n=370)

Subtests	Mean±SD[a]	Range (min-max)
Matrices	20.06±4.28	10.0-33.0
Spatial Span	16.25±2.97	7.0-26.0
Overall test	98.20±12.24	57.0-132.0

Note: [a]standard deviation

Discussion

This study aimed to examine the effect of SHS exposure, as well as other possible risk factors, in predicting a low level of cognitive ability among adolescents aged 13-14 years old in two states in Malaysia. From this study, adolescents reported that SHS exposure in toddlerhood (≤2 years old) was more likely to result in lower cognitive ability than those without toddlerhood SHS exposure. This higher likelihood of having lower cognitive ability was linked to higher school absence days (as reported by the adolescents).

This study had a number of limitations. Even though this study was performed in schools identified as national schools, a larger number of the study participants were Malay. In fact, the distribution of ethnicities in Peninsular Malaysia is comprised of approximately 55% Malays, 30% Chinese, and 15% Indians. Furthermore, the time at which the WNV test was conducted played a role in determining the students' attentiveness in completing the test. Thus, the tests were done mostly after recess (after 11am) as the students were more active and able to concentrate better after having their meals. Because WNV takes about 10-15 minutes to complete, there may have been a tendency for students to lose focus and interest in completing the test. For this reason, a token of appreciation was given after they completed the test.

Despite these limitations, the general cognitive ability of the adolescents was objectively measured using the established WNV subtests that were able to provide full-scale scores of cognitive ability for each participant. Since the test was nonverbally conducted, it ensured the uniformity of the instructions given. Only the pictorial direction provided by WNV was used to explain the task's demands. In addition, every student had to go through a demonstration for each of the subtests, in order to ensure that they understood the demands of the task prior to the actual test items being administered. If the students failed to provide a correct response during the trial items, they needed to repeat until correct scores were obtained.

The most important finding of this study was that the reported exposure to SHS among adolescents during toddlerhood was associated with lower cognitive ability; as measured from the WNV test. Unlike other studies, no other SHS assessment parameters, such as reported current and prenatal exposure, were able to show any significant link to cognitive outcome (19, 20). With further analysis, it was found that approximately 80% of parents (either father or mother) reported exposure to SHS during toddlerhood of their child were also a smoker (father) or the spouse of a smoker (mother). A skewed distribution of smokers, where smoking is favoured by males is generally specific to the Asian population (21, 22). This may be a likely reason why SHS-linked outcomes in this study were associated with exposure occurring in early childhood, instead of prenatal exposure being mostly linked with maternal smoking; as has often been observed in western studies (23, 24).

Table 4: Logistic regression for predictors of low cognitive ability

Variables	Block 1				Block 2				Block 3			
	[a]B[b](S.E)	[c]Wald	OR	95%CI	B(S.E)	Wald	OR	95%CI	B(S.E)	Wald	OR	95%CI
Block 1												
Parental smoking	-0.56(0.43)	1.74	0.57	0.25-1.32	-0.56(0.43)	1.73	0.57	0.25-1.32	-0.64(0.45)	1.99	0.53	0.22-1.28
SHS exposure (pregnancy)	-0.24(0.48)	0.25	0.78	0.30-2.02	-0.24(0.48)	0.25	0.78	0.30-2.02	-0.44(0.51)	0.74	0.65	0.24-1.75
SHS exposure (toddlerhood)	0.86(0.42)	4.25	2.36	1.04-5.33	0.86(0.42)	4.23	2.36*	1.04-5.33	1.06(0.44)	5.75	**2.89***	**1.21-6.83**
SHS exposure (hrs)		0.02				0.02				0.21		
≤1 hr/day	-0.07(0.47)	0.02	0.94	0.37-2.35	-0.06(0.47)	0.02	0.94	0.37-2.36	-0.12(0.50)	0.06	0.89	0.34-2.35
> 1 hr/day	-0.04(0.51)	0.01	0.96	0.35-2.62	-0.04(0.51)	0.01	0.96	0.35-2.63	-0.25(0.55)	0.21	0.78	0.27-2.29
Smoking restriction	0.21(0.35)	0.37	1.24	0.62-2.46	0.21(0.35)	0.36	1.24	0.62-2.46	0.17(0.37)	0.22	1.19	0.58-2.46
Block 2												
Gender					-0.02 (0.34)	0.003	0.98	0.50-1.93	-0.45(0.40)	1.29	0.64	0.29-1.39
Block 3												
Household income									0.26(0.47)	0.31	1.30	0.52-3.22
Parent education									-0.53(0.41)	1.68	0.59	0.27-1.31
Tuition classes									0.76(0.58)	1.73	2.14	0.69-6.61
Absence (day)									0.11(0.04)	8.09	**1.11***	**1.02-1.20**
Classification rate (Yes/No)	76.3(0/100)				76.3(0/100)				78.3(12.8/99.7)			
Cox&Snell -Nagelkerke R^2	0.03-0.05				0.03-0.05				0.09-0.14			

Note: * *P<0.05 OR: odds ratio SE: Standard error B: Beta*
Model was adjusted for individual, classrooms, schools and states differences
[a]indication of direction of the relationship
[b]indication of how much the value of the test statistics varies from samples
[c]statistic for testing significance of parameter estimates
[d]indication of how well the model is able to predict the correct category for each case
[e]indication of amount of variation in the independent variable explained by the model

There is a strong probability for this study that the main source of SHS exposure during toddlerhood was mainly from parental smoking at home. Previous studies in the US and Canada have stated that younger children spend more than 70% of their time indoors at home (25). There is no reported literature providing time distribution in microenvironments for the Malaysian population. However, while there might be differences in the time expenditure distribution among children between different regions, these differences might not be too broad within a similar age range. A study covering 10 regions revealed that the most time spent and exposed to SHS was reported to be in residential locations (60-70%) (26). Home is the place where children under 11 years old spent their time the most (25). This further supports the fact that SHS sources were from parental smoking. However, SHS exposure occurring outdoors should not be overlooked. Since there were no regulations that prohibited smoking in public places until 2004, outdoor SHS could also be a source of exposure during the toddlerhood years of 2001 to 2003 (≤2years old) (27). The Smoke-Free Legislation covering extended public spaces formally came into force in 2008 when the adolescents were 7-8 years old.

Environmental factor inclusive of exposure to SHS has an important impact on determining how the brain grows and develops for the first three years of a child's life. Evidence has shown during the age of less than 3 years old, a child's brain doubles in size in the first year, and by age of three, it has reached 80% of its adult volume (28). It is the phase where the brain maturation and important neural connections are developing progressively (9). Synapses are formed at a fastest rate during these years than at any other times (29). Exposure to SHS during these important development stages has been shown to affect children's cognitive ability (30).

In considering the SHS pathway in its association with the reduction of cognitive ability, lead (Pb) content in cigarette smoke has been reported to affect the neurodevelopment of toddlers. Lead together with polonium (Po) from the decaying process of radon (Rn) is taken up by the tobacco plant from the soil. Polonium and lead are deposited in soil by rain as well as from phosphate fertilizers used in tobacco farming (31, 32). Deposition of both polonium and lead on the leaf surfaces of tobacco plant occurs by the root system uptake of the plant.

Tobacco cigarettes subsequently release polonium and lead in its particulate phase when smoked and may be inhaled by non-smokers and children who are susceptible to lead exposure (33, 34). Higher blood lead level has been shown to interfere with the synthesis process of haemoglobin that suppresses the synthesis of δ-aminolevulinic acid dehydratase (δ-ALAD) enzyme (35). The enzyme is responsible for the production of heme where decrease in δ-ALAD enzyme will result in a decrease in haemoglobin production and ultimately decreases the supply of O_2 to the brain; thus, interrupting the neurodevelopment process.

The findings of this study was in agreement with other previous studies that support postnatal SHS exposure especially during the early childhood to significantly linked to deficit in neurodevelopment scores which the effects can be carried over into adolescents life (31, 36, 37). Postnatal SHS exposure was also a risk factor contributing to delayed neurodevelopment and cognitive impairment later in adolescent hood (5).

In this study, school absence days were linked to lower cognitive ability among adolescents. Upon further analysis, it was found that mean of school absence days between adolescents with smoking history (5.56±7.49 days) were significantly higher when compared to adolescents without smoking history (2.39±3.81 days) (t=18.6, P=0.039). Absences of the adolescents were associated to a history of smoking where about 7.3% of the adolescents in this study have previously smoked. Studies have shown the link between smoking history with delinquent behaviour such as school truancy among adolescents (38, 39). Adolescents with behavioural problem linked with the use of cigarettes and drugs have been shown to have lower academic performance (40). Thus, the low cognitive ability shown by adolescents in this study could possibly be due to their delinquent behaviours rather than school absenteeism.

Conclusion

The reported exposure of SHS during toddlerhood was associated with detrimental cognitive performance among adolescents. Lower cognitive ability was also associated with school absenteeism of the adolescents that had a history of smoking. The findings of this study showed the need for health officials to focus on preventing involuntary SHS exposure during toddlerhood in order to protect children from the detrimental effect of SHS exposure. Apart from that, findings of this study will also help in an expansion of the existing smoke-free legislation to the home environment by starting to practice home smoking restriction.

Ethical considerations

Ethical issues (Including plagiarism, Informed Consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

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