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Research Article

Canonical Correlation Analysis of Lead Concentration in Hair Impacted With IQ, Antisocial Behavior, and Hand Strength at High School Students Community

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Abstract
Lead is widely found in the environment and it is a heavy metal element that has a neurotoxic effect. Unlike other elements, lead does not provide its benefits in the human body. Neurotoxicity describes the neurophysiological changes caused by exposure to toxic agents, which can be manifested by changes in various functions of the nervous system. The aim of this research was to examine the associations between high school students' lead hair levels, intelligence quotient (IQ) scores, propensities for antisocial behavior, and hand grip strength. This research used canonical correlation analysis. Lead levels were detection by flame atomic absorption spectrometry (AAS). Antisocial behavior tendency data was measured using a 21-item antisocial tendency scale using the aspects listed in diagnostic statistical mental disorder (DSM) V which had previously been tested for validity and the reliability. The IQ level was measured using the Wechsler adult intelligence scale (WAIS) test, while the hand muscle strength test was measured using a hand grip dynamometer. Based on the results of the canonical correlation analysis, the research results showed that there was no correlation between lead levels in hair and antisocial behavior tendencies, but there was a relationship between lead levels in hair and IQ levels and hand muscle strength.

Keywords: antisocial, IQ, hair, hand strength, hand grip, lead

1. INTRODUCTION

Lead is a heavy metal element that has a neurotoxic effect. In contrast to other elements such as iron and zinc, lead does not provide its benefits in the human body [1]. Neurotoxicity describes neurophysiological changes caused by exposure to toxic agents, which can be manifested by changes in various functions of the nervous system, such as cognitive disorders, mental health, mood disorders, and neuromotor disorders [2][3]. The impact of exposure to toxic agents is unique, depending on the neurophysiological changes that occur after exposure. In addition, toxic exposure can be distinguished between acute and chronic levels which can be indicated by the resulting symptoms.

This lead exposure can be through wall paint, plumbing, and gasoline residue [4]. The slow nature of elimination in the body causes lead to accumulate in the long term and has an impact on children, one of which is a decrease in intelligence quotient (IQ). Research conducted by Confield [5] showed that every 10 µg/dL lead increase in blood was associated with a decrease of 4.6 IQ points (p=0.004). The results of previous research also showed that children with low intelligence had higher blood lead levels than children with high intelligence [6].

Meta-analysis of 33 previous research showed that there was a relationship between ADHD symptoms (inattention and hyperactivity/ impulsivity), with significance values of 0.16 and 0.13 [7]. Reviewed the literature on lead, the results of the meta-analysis showed that there was a significant correlation of 0.19 between lead levels and behavioral disorders, developmental disorders, fighting, and committing delinquency [8]. In addition, several research have also found that lead levels are higher in hyperactive children or those with behavior problems compared to those without behavior problems. This continuously has an impact on the emergence of delinquency or criminal acts when these children grow up.

Lead exposure has an impact on neuromotor disorders which can be seen from the strength of the hand muscles. Grip strength is often used in the assessment of neurotoxicity in humans. Research

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Table 1. Description of the research population grouped by gender.

Characteristics	Female (n = 10)	Male (n = 14)
Age (years), mean (SD)	16.20 (0.789)	16.14 (0.663)
Lead levels (µg/g), mean (SD)	0.1285 (0.0942)	0.2042 (0.1618)
IQ, mean (SD)	88.80 (17.074)	75.07 (26.546)
Antisocial, mean (SD)	28.00 (4.619)	28.86 (4.928)
Hand muscle strength (kg), mean (SD)*	31.72 (4.3852)	27.3464 (9.5292)

* Hand strength standard (Ismaryanti, 2008) [20]

conducted by Wahil and Jaafar [9] shows that the higher levels of lead will weaken hand grip strength, manifestations of peripheral muscle weakness are still present even in low levels of lead. Metals that are physiologically integrated into the metalloproteins required for regular neuronal functions and the preservation of energy homeostasis are readily accumulated in the brain. An overabundance of essential metals or exposure to heavy metals unrelated to nervous system functioning can have serious repercussions [10] [11]. Lead exposure can cause disturbances in central nervous function related to cognitive development, behavior and motor function. The disorder is thought to be caused by the effects of lead on the neurotransmitter system, myelin formation, and synaptic function which play an important role in learning, memory formation, and motor control. Exposure to lead can be an important risk factor for cognitive development/IQ in adolescents, antisocial behavior (for example: adolescents have a negative perception of themselves), and motor skills (hand muscle strength) are not optimal.

Lead that enters the human body will generally accumulate in the kidneys, liver, nails, and hair. Hair can be used as a sample for checking the levels of lead accumulation in the body. Since hair is not impacted by internal metabolic processes once it grows beyond the skin, levels of elements in hair indicate long-term exposure dependent on hair length, whereas levels in blood and urine are only transitory exposure measures [12][13], Additionally, hair is easily kept and can be sampled noninvasively. In recent years, a growing number of studies have measured various elements in hair in both polluted and non-contaminated areas [14][15]. Lead levels in hair correlate with the number of heavy metals absorbed by the body [16]. According to the Decree of the Minister of Health of the Republic of Indonesia Number 1406/MENKES/SK/IX/2002 concerning the standard for examination of lead levels in human biomarker specimens, namely hair, shall be less than 10 µg/g. Compared with using urine or blood, analysis of lead levels in hair has advantages, because the accumulation of lead in hair is longer than in urine and blood which undergoes metabolism, so lead levels in urine and blood are easily reduced along with body metabolism. Although measurements of lead in tissues are useful for calculating exposure dosages, they do not show any negative effects from the body's absorption of lead. Based on its harmful effects, the researcher intends to find out whether there is a relationship between exposure of lead in hair on IQ levels, tendencies towards antisocial behavior and hand muscle strength as a neurotoxic effect on high school students in Wonogiri using canonical correlation analysis. The findings of this research are anticipated to lead to early education about the risks of lead exposure to IQ loss, behavioral changes, and decreased hand muscle strength.

2. MATERIALS AND METHODS

This research uses a quantitative research approach. The analysis used is canonical correlation analysis. Canonical correlation analysis is a multivariate analysis used to identify and measure the relationship between two sets of variables. The first set is the response variables (Y1, Y2, etc.), while the second set is the predictor variables (X1, X2, etc.). The linear combination of these two sets of variables can be written as follows Härdle et al. [17] as Equations (1) and (2):

$$\mathbf{U} = a_1X_1 + a_2X_2 + \cdots + a_qX_q = \underline{a}'\mathbf{X} \quad (1)$$

$$\mathbf{V} = b_1Y_1 + b_2Y_2 + \cdots + b_pY_p = \underline{b}'\mathbf{Y} \quad (2)$$

The canonical correlation is obtained by the following the Equation (3):

$$\rho = Corr(U,V) = \frac{Corr(\mathbf{U},\mathbf{V})}{\sqrt{Var(\mathbf{U})}\sqrt{Var(\mathbf{V})}} = \frac{\underline{a}'\mathbf{\Sigma}_{XY}\underline{b}}{\sqrt{\underline{a}'\mathbf{\Sigma}_{XY}\underline{a}}\sqrt{\underline{a}'\mathbf{\Sigma}_{XY}\underline{b}}} \quad (3)$$

The research was conducted at SMA Wonogiri, Nguntoronadi area by taking a sample of 24 students of class XII by purposive non-random sampling with sample criteria including: aged 15–18 years old, had been called by a counseling teacher because of problems. This research has obtained an ethical clearance certificate with the number KEPK/UMP/83/III/2022 issued by the Health Research Ethics Commission of the University of Muhamadiyah Purwokerto.

Secondary data, in this case the records from the counseling guidance teacher's notes and filling out questionnaires are also needed as research controls to find out personal data related to research, activities and illness history of students who are the research sample. Checking the lead levels in hair is conducted by taking a hair sample (100–200 hairs), tying it with cotton thread at the root end, cutting the sample as close as possible to the scalp (2 mm) and placing it in a tamper-proof envelope, tightly closed, and brought to the Center for Environmental Health Engineering and Disease Control (BBTKLPP) Yogyakarta then the hair samples were subjected to wet digestion and read the lead levels using the AAS instrument.

2.1. Sample Preparation

Hair samples that have been collected according to collection requirements are washed. The sample was put into a 100 mL beaker, soaked with 10 mL of technical acetone for 15 min while stirring with a glass stirrer, rinsed 3 times with distilled water, washed again with 10 mL of acetone for 15 min while stirring, and then drained. Next, the samples are dried at room temperature for 3 or 4 days in a vacuum desiccator so that the hair is completely dry and ready to be analyzed [18]. Each hair sample was weighed 5 g in a clean porcelain cup, added by 5 mL concentrated HNO_3 and left for 1 h. The sample was digested, cooled, added by 0.4 mL of concentrated H_2SO_4, and heated. A mixture of concentrated HNO_3 and $HClO_4$ (5:1 v/v) was then added and heated until complete evaporation until a clear solution is obtained. Each digested sample was transferred into a 50 mL measuring flask, and then diluted by deionized water until the test mark was homogeneous.

2.2. Preparation of Standard Lead Solution

$Pb(NO_3)_2$ powder was weighed 0,16 g and put into a 1 L measuring flask. A 10 mL of concentrated HNO_3 and mineral-free water were added until it reaches the specified mark and then homogenized. Next, 10 mL of 100 mg/L Pb stock solution was added into a 100 mL measuring flask,

Table 2. Distribution of antisocial data, IQ, and hand muscle strength.

Variable		N	%
Antisocial	Low (< 26.23)	9	37.50
	High (≥ 26.23)	15	62.50
IQ	Low (< 80)	10	41.67
	Below mean (80–89)	6	25.00
	Mean (90–110)	7	29.17
	Above mean (111–120)	0	00.00
	Superior (> 120)	1	04.17
Hand muscle strength*	Less (male : < 36.0, female : < 24.0)	12	50.00
	Moderate (male : 36.5–46.0, female : 24.5–32.0)	7	29.17
	Good (male : > 46.5, female : > 32.5)	5	20.83

* Hand strength standard (Ismaryanti, 2008) [20]

Table 3. Multivariate tests of significance.

Test Name	Value	Exact F	Hypoth. DF	Error DF	Sig. of F
Pillars	0.76805	22.07518	3	20	0*
Hotellings	3.31128	22.07518	3	20	0*
Wilks	0.23195	22.07518	3	20	0*
Roys	0.67805				

*Significant with alpha 5%

diluted with distilled water, and homogenized. Then a series of standard solutions was made with a concentration of 1.000, 0.800, 0.600, 0.400, 0.200 ppm. The lead standard solutions were prepared with a concentration of 0.0, 0.2, 0.4, 0.8, 1.0, 1.2, and 1.4 ppm in a 100 mL measuring flask.

2.3. IQ Level and Antisocial Behavior Tendencies

IQ data were taken using the WAIS test, while the antisocial tendency scale was measured using the aspects listed in the DSM V published by the American Psychiatric Association (APA).

2.4. The Hand Muscle Strength

The hand muscle strength test uses a hand grip dynamometer which is expressed in kg. This test has been standardized with a test validity of 0.880 and a test reliability of 0.938 [19]. Before measuring the handgrip strength, the dynamometer was adjusted to the size of the participant's hand. Participants were instructed to press the dynamometer as hard as possible using one hand. The test is repeated three times for each hand, alternating hands with a 1 min rest between measurements on the same hand. These steps were considered when the participant was able to perform the test while standing and managed to form an angle of 90 with the index on the dynamometer handle.

2.5. Data Analysis

Data analysis technique of lead levels in hair, IQ level, antisocial behavior tendencies, and hand muscle strength were analyzed using correlation test using SPSS 26.

3. RESULTS AND DISCUSSIONS

This research involved 24 high school students in Wonogiri aged 15–18 years old, consisting of 10 (41.67%) female students and 14 (58.33%) male students. Table 1 shows that exposure to lead levels in hair for male is higher than that for female while IQ scores and hand muscle strength data show that male are lower than female. This result is in line with previous research explains that male are more susceptible than female to lead exposure [21]. The 24 respondents who scored the most from each observation of antisocial, IQ, and hand strength showed that 15 (62.50%) had low antisocial scores, 10 (41.67%) had low IQ scores and 12 (50.00%) had less hand muscle strength (Table 2).

The next step is multivariate testing using Pillai's, Hotelling's, and Wilks' tests (Table 3). It appears that all tests show significant results, indicating that canonical correlation analysis can be used (Table 4).

Based on these results, it can be seen that the first canonical function has a magnitude of 87.638%, indicating that we only need to use the first canonical function (Table 5). The results in Table 5 show that there is a very strong relationship between lead levels and IQ with a correlation value of 98.871%, a negative relationship where an increase in lead levels in hair will reduce IQ scores. There is a relationship between lead levels and hand muscle strength, namely with a correlation value of 82.636% with a negative value meaning that an increase in lead will decrease hand muscle strength, but there is no relationship between ;ead levels and antisocial with a low correlation value of 2.650%.

Metals including lead are unbreakable and indestructible. Organisms can detoxify lead ions by hiding the active constituents in proteins or storing them in intracellular granules in an insoluble form and subsequently excreted in the feces or stored in the long term. When lead is ingested or inhaled into our bodies, they bioaccumulate in our systems. This bioaccumulation will cause negative biological and physiological complications [22]. Lead exposure to the environment causes neurotoxic effects that can manifest in changes in nervous system function, such as cognitive impairment, mental health or mood disorders, and impaired neuromotor function [3]. The impact of lead exposure on the peripheral nervous system has also been observed in forms of peripheral neuropathy, involving reduced motor activity due to loss of the myelin sheath that insulates the nerves, thereby severely impairing the transduction of nerve impulses, causing muscle weakness, especially of the external muscles, fatigue, and lack of muscle coordination. It also interferes with calcium regulation resulting in a lack of muscle coordination, i.e., muscle fatigue [23].

Based on the results of the analysis using the correlation test, it was found that there was no relationship between lead levels and antisocial tendencies with a low correlation value of 2.65%. The results of the low correlation between lead levels and antisocial tendencies can be explained as follows. The technique of filling in the instrument is carried out online so that there may be errors in perceiving sentences, lack of focus in filling out, human errors and so on for an age under 18 years old. The diagnostic characteristics of the tendency of antisocial behavior according to Nevid et al. [24] are aged more than or equal to 18 years. There is evidence of behavior disorder before the age of 15, demonstrated by behaviors such as truancy, running away, starting physical fights, using weapons, forcing someone to engage in sexual activity, physical cruelty to people or animals, intentionally destroying or burning buildings, lying, stealing, or robbing. Since the age of 15 years, it shows a personality that is less concerned and violates the rights of others.

In the sample aged less than 18 years (high school students) then there are not so many violation behaviors that have appeared. The nervous system is the main target and is more sensitive to lead toxicology. Lead exposure will affect the nervous system and peripheral nervous system. Peripheral effects are more pronounced in adults while the central nervous system is more clearly affected in children [25][26]. Based on the explanation above, in high school students, the manifestation of antisocial behavior tendencies has not appeared because they are still more affected by intelligence.

Children may appear inattentive, hyperactive, and irritable even at low lead exposure. Children with higher levels of lead may be affected by delayed growth, decreased intelligence, short-term memory, and hearing loss, at higher levels, lead can cause permanent brain damage and even death [27]. Adolescence cognitive development has reached the peak stage, namely the formal operational stage, namely a capacity for abstract thinking, where adolescent reasoning is more similar to the way scientists look for problem solving in the laboratory [28].

The following are some of the characteristics of cognitive development in adolescence being able to reason abstractly in situations that offer several opportunities to perform hypothetical deductive reasoning (hypothetical-deductive reasoning) and propositional thought (propositional thought). Hypothetical deductive reasoning is a cognitive process, where when a person is faced with a problem, he starts with a "general theory" of all the factors that might affect the outcome and concludes it in a hypothesis (or prediction) about what might happen (the result).

At this formal operational stage, adolescents can think systematically, by doing various combinations, understanding the various aspects of a problem that can be solved instantly and at once. Based on the explanation above, this allows research subjects with antisocial tendencies to manipulatively related to filling out the questionnaire. Manipulative is one manifestation of the tendency of antisocial behavior. This is in accordance with the symptoms of antisocial tendencies mentioned in DSM V including failure to comply with social norms, manipulative, impulsive, aggressive, reckless, irresponsible, and not feeling guilty. Some of the manifestations of

Table 4. Eigenvalues and canonical correlations.

Root No.	Eigenvalue	Pct.	Cum. Pct.	Canon Cor.	Sq. Cor
1	3.31128	100	100	0.87638	0.76805

Table 5. Correlations between dependent and canonical variables.

Variabel	Function No 1
Antisocial behavior	0.02650
IQ	-0.98871
Hand strength	-0.82636

these symptoms appeared during the data collection process, such as being irresponsible and not feeling guilty when they did not participate in the research data collection process even though the informed consent had been signed beforehand [29].

The observed gender differences in the effects of lead exposure on cognitive function, behavior, and motor function may be attributed to differences in metabolism and biological sensitivity between men and women. This study emphasizes the importance of considering gender factors in understanding the impact of environmental exposures on child and adolescent development. These results may help develop more specific and effective interventions to minimize the adverse effects of lead exposure based on gender differences.

The results of the correlation test for lead content in hair with IQ showed a correlation value of 98.871%, where the relationship was negative where an increase in lead levels in hair would decrease the value of IQ. This is in line with research conducted by Indah et al. [30], showing that there is a relationship between lead levels in the blood and IQ levels in students who also work as online motorcycle taxi. The Canfield study showed that every 10 µg/dL lead increase in blood was associated with 4.6 points decrease in IQ ($p=0.004$) [31]. The influence of lead on intelligence can be through the process of apoptosis, neurotransmitter disorders, impaired interneuron regulatory mechanisms, impaired glial cell differentiation, and inhibition of the delta aminolaevulinic acid enzyme which causes a decrease in heme synthesis and brain tissue hypoxia [32].

The relationship between lead levels and hand muscle strength shows a correlation value of 82.636% with a negative value meaning that an increase in lead will decrease hand muscle strength. Measurement of hand muscle strength, used as a marker of neuromotor function that provides a measure of hand grip strength. Motor weakness is one of the most common effects of neurotoxicity exposure and can predict disability [33].

The key aspect underlying lead-induced neurotoxicity is oxidative stress, which is caused by increased activity of oxidative parameters such as lipid peroxidation or by alteration of protein chains by reactive oxygen species (ROS) or reactive nitrogen species (RNS). The increase in reactive species is caused by an increase in pro-oxidation factors, which act as radicals' formation through the Fenton reaction as a form of metal redox activity, and a decrease in antioxidant ability. This process will cause changes in membrane biophysics, disruption of cell signaling and neurotransmitter disruption, as well as substitution for other polyvalent cations [34].

The results of this research can be used for schools and families must play a proactive role in identifying and addressing lead exposure through screening, source identification, and appropriate interventions. The results of this research can support stricter policies to reduce lead exposure in the environment, such as controlling emissions in school environments. Educational institutions can develop educational and public health programs that focus on increasing motivation and awareness of the dangers of lead exposure to human quality of life.

4. CONCLUSIONS

According to the study's findings, there is no connection between lead levels in hair and antisocial behavior. However, a correlation between lead levels in hair and IQ and a correlation between lead levels in hair and hand muscle strength were found. Due to the online nature of the survey forms and the fact that respondents modified their responses, there was no correlation between lead levels in hair and antisocial conduct. The respondent is under the age of 18, and manipulation conduct is one of the signs of antisocial behavior. The findings of this research are anticipated to lead to early education about the risks of lead exposure to IQ loss and behavioral changes. Research in the near will analyze how lead exposure affects harmful gene mutations.

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Conflicts of Interest

The authors declare no conflict of interest.

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