Nutritional Status And Working Memory In Children: Physical Activity As A Mediator

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ABSTRACT

Working memory is a component of executive function that plays an important role in processing, using, and remembering information on a daily basis also known as an important predictor of future cognitive functions and school achievement. Previous research found that nutritional status could not be the only factor that significantly correlated to working memory. Therefore, research that describes the role of physical activity as a mediator in both variables is needed. This research aims to investigate how physical activity becomes a mediator between nutritional status and working memory. This research was conducted on 79 children aged 10 – 12 years old. The instruments used were Digit Span Test, Physical Activity Questionnaire for Children and Body Mass Index Measurement. The Hayes' PROCCESS mediation test was used to analyze the data. The result shows that physical activity mediates the relationship between nutritional status and working memory by 15% (0.1576; $p < 0.05$; 95% CI [0.0394, 0.3365]). According to the findings of the research, physical activity was proven to play the role of a mediator in relation to nutritional status and working memory.

Keywords: Nutritional Status; Physical Activity; Working Memory

INTRODUCTION

The issue of memory such as the limited retention of sensory input and incomplete absorption of information acquired through the learning process, is a commonly encountered challenge that disrupts children' learning process. Some student are quick to remember lessons they get. However, a significant number of school-age children face challenges in absorbing learning materials and having to repeat learning materials several times to remember. The prevalence of children with low working memory is estimated at 15%, and 80% of these children experience difficulties in academic areas (Wiguna et al., 2012). The survey conducted by Purnamasari, et al (2023) also found that student in grade 5 have difficulties in retaining academic lessons, including to memorizing mathematic formulas.

Children's ability to retaining academic lessons, count and complete cognitive tasks are strongly associated with working memory capacity. Working memory is a component of children's neurodevelopment and important predictor of future cognitive functions and school achievement (Fitamen et al., 2019). Working memory is type of memory defined as the capability to keep small amount of information in limited short time, that is important to children in order to develop executive function that contribute to school achievement, such as solve problem effectively, remember number in mathematics, combine words in reading (Nugroho et al., 2023). Various factors cause working memory' problem such as genetic, nutritional status, physical activity, biochemical damage in brain,

environmental pollution, social-psychological disorder. However, most common lifestyle problems among children and adolescent include inappropriate nutrition and insufficient physical activity (Slowik et al., 2019).

Indonesia as a developing country is experiencing multiple nutritional problems. Riskesdas (2013) data shows that the nutritional status of children in Indonesia aged 5-12 years (according to BMI/A) is at an underweight prevalence of 11.2%, consisting of 4% extremely underweight and 7.2% underweight. The national prevalence of overweight among children is also high at 18.8%, consisting 10.8% overweight and 8.8% obesity. Optimal nutrition during childhood is necessary for normal brain development of children since it is an important period for the formation of the brain, laying the foundation for the development of cognitive, motor, and socio-emotional skill throughout their life (Kabero et al., 2021).

Poor nutrition and overnutrition during early period can result in a long lasting physical and mental impairment by affecting the structural and functional development of the brain. Consequently the performance of the children who had earlier suffered from malnutrition was clearly inferior to that of children who had not gone through malnutrition, which results in inferior school performance and low level of working memory (Hunt, 2005). Malnourished children with poor physical growth perform poorly in intelligence test and emphized that malnutrition during childhood can lead to irreversible impairment of mental and cognitive function in later life (Fernstrom et al, 2001; Kamath, 2017). Not only malnutrition, numereous studies also linked obesity to poorer academic performance, memory performance, and impairment in decision making.

Obesity occurs as a result of extreme escalation in body's fatty mass percentage the muscle mass when the proportion of height to weight surpasses the optimum level, that can be caused by lack of physical activity (Alhazmi et al., 2021). Recent studies have sugessted that physical activity is associated with not only chronic diseases prevention, but also cognitive and brain health (Kamijo et al., 2011). According to data from the WHO (2017) it was found that 81% of children are physically inactive. These children tend to prefer sedentary activities such as spending hours on the internet accessing social media, watching videos, playing games, and engaging in social media activities. The low level of physical acivity has an impacy on cognitive function, such as working memory, learning motivation, and concentration that can lead to difficulties in processing new information, and if this persist, it can result in academic achievement (Nadira & Daulay, 2021).

Physical inactivity is a significant risk factor for cardiovascular disorders and a broad spectrum of chronic diseases comprising obesity, diabetes mellitus, hypertension, osteoarthritis, osteoporosis, and depression (Warburton et al., 2006). Both lack of physical activity and its excess have a negative effect on the nutritional status, which most common nutritional abnormalities include malnutrition and overweight or obesity. The benefits of healthy eating are for increasing children' cognition, such as executive function, attention, working memory, concentration, and academic proficiency maybe moderated by physical activity.

The previous research conducted by Mamrot & Hanc (2019) it was found that there is an inverse relationship between nutritional status and executive function (EF) performance, higher BMI or nutritional status (obesity) is associated with poorer EF performance including working memory. BMI in obesity was found to be associated with decreased frontal and limbic gray matter volume (Alosco, 2014). Ruiz et al. (2010) reported that physical activity during leisure time positively influenced EF performance. Therefore, physical activity plays a crucial role in preventing excessive weight gain and optimizing working memory.

Most study examining relationship between nutritional status and physical activity on working memory in children and adolescents that described information on the strength of the association between variables separately yielded inconsistent findings. The discrepancies indicate that testing the relationship of variables separately between nutritional status and working memory, as well as physical activity and working memory may not be able to reveal the complex association between nutritional status and physical activity on working memory due to the interdependencies among these variables. Notably, the correlation between nutritional status and physical activity underscores the need to view them as holistic concept that influences working memory in children. Therefore, research that describes the role of physical activity as a mediator in both variables is needed

METHODS

Research Design

A quantitative correlational method was used in this research to investigate the relation between the three examined variables: Nutritional Status, Working Memory, and Physical Activity. The data were taken direct to participant who fit with the criteria for this research using several instrument: Digit Span Test, Physical Activity Questionnaire for Children and Body Mass Index Measurement. Prior to the research, all participants were given a chance to give their consent in an Informed Consent form.

Participants

The populations in this research were all 134 students in grade 4, 5, and 6 at SD N X Lampung Timur. The participants in this research were selected by non-probability sampling method, the sampling technique used by the researcher was purposive sampling because there were certain considerations for sampling. These criteria are children in grades 4, 5, and 6 aged 10-12 years. Sudarmawan (2013) argued that children aged 10-12 years have a fairly high level of understanding, so the child can take the test properly.

The participants used in this research is 79 students consisting 50,6% (40) female participants and 49,4% (39) male participants aged 10-12 years.

Instruments

Three research instruments were used in this research:

Digit Span Test: The instrument was to measure working memory in children. This test is one of the subtests in the WISC test created by David Wechsler. There are two parts of the digit span test; digit span forward and digit span backward. Each parts of the test consist seven numeric items starting at three to nine (forward) or two to eight (backward). In the digit span forward test, the participants is instructed to repeat a series of number mentioned by examiner sequentially from front to back, whereas in the digit span backward test participants repeats from last number to the first number mentioned by examiner (from back to front). The scoring system is by adding up the last series that were successfully repeated by the participants in both tests (forward and backward). This test has high reliability across all age ranges with a coefficient of 0.77-0.86 (Dison, 1893) and construct validity for this test has stabilized (Kush and Watkins, 1997).

Physical Activity Questionnaire for Children: Physical activity as the mediator variable in this measured using the physical activity questionnaire, which was developed by Kowalski et al (2004) is a seven-day recall self-administered questionnaire to assess general levels of physical activity throughout

the elementary school year for student in grades 4 to 8 and approximately 8-14 years of age. The PAQ-C can be administered in classroom settings and provides summary physical activity score delivered nine items, each scored on a 5-point scale starting from 1 "very low activity" to 5 "high activity". After having scores from 1 to 5 for each items (items 1 to 9) used in the physical activity composite score, take the mean of these 9 items to get the PAQ-C result. The item scale correlations on this instrument were all above 0.30, and the scale reliability was acceptable for both females (0.83) and males (0.80) (Kowalski et al, 2004).

Body Mass Index Measurement: BMI is the most popular and common method for nutritional status assessment. BMI is calculated of body weight in kilograms divided by height in meters squared. In the case of children, the interpretation of nutritional status should compare BMI values with norms, it is recommended that BMI standard deviation z-score, age, and gender are considered to determine the classification of nutritional status.

Research Procedure

The research was a cross-sectional study. Prior to the tests, preliminary studies were conducted to collect profiles of children to exclude ineligible participants (under 10 years and over 12 years). Data were collected at school on the same day. The first measurement is BMI, participants' weight and height were collected barefoot and lightly clothed. The digit span test is carried out afterward, the children are tested one by one. The last measurement is the PAQ-C questionnaire which is filled in directly by the participants.

Data Analysis

The acquired data in this research were processed using an IBM SPSS for Statistics 22 and The Hayes' PROCCESS. Three main variables will be analyzed in this research, Nutritional Status as the independent variable, Working Memory as the dependent variable, and Physical Activity which is expected to play the mediating role in the relationship between independent and dependent variables. To test the hypotheses, the researchers use The Hayes' PROCCESS with the help of IMB SPSS for Statistics 22. It was expected that physical activity takes the mediating role in the relationship between nutritional status and working memory; whether the mediating effect was partial or complete mediation also be investigated statistically. Before conducting the analysis, the normality of the items and the scale were checked and the data is normally distributed

RESULT

Participant's Characteristic

In this research, 79 students were selected as participants consisting 50,6% (40) female participants and 49,4% (39). This research characteristic participants are children in grades 4, 5, and 6 aged 10-12 years.

Data Analysis

Researcher used PROCESS to test the hypotheses, the role of physical activity towards the correlations between nutritional status and working memory in children. Detailed explanations regarding the path of the role of each variable can be seen in Fig.1 and Fig.2 :

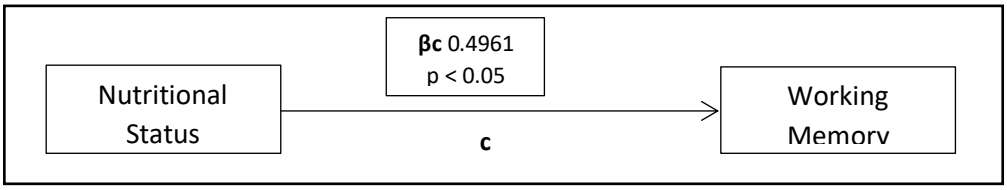

Figure 1.
The Relationship between Nutritional Status, Physical Activity, and Working Memory
Note: βc = βcoefficient between dependent and independent variables (total effect)

As depicted in Figure 1, the total effect of collectivism was significant with βc= 0.4961, SE= 0.136, p= 0.0005, 95% CI (0.2244, 0.7678). This indicates a significant and positive relationship between nutritional status and working memory. These result demonstrate that a child's nutritional status plays a crucial role in determining their working memory abilities. Therefore, an enhanced nutritional status is associated with improved working memory in children.

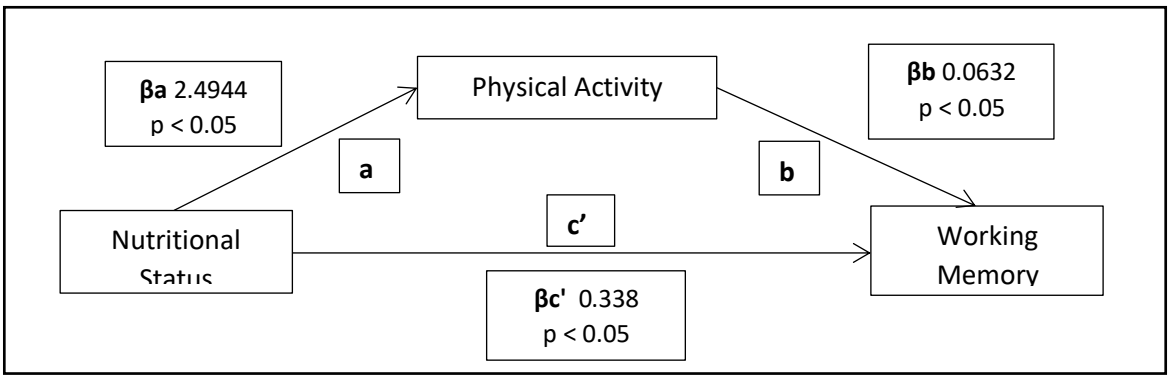

Figure 2.
Path Analysis Diagram between Nutritional Status, Physical Activity, and Working Memory
Note: βc' = β coefficient between dependent and independent variables (direct effect); βa = β coefficient between dependent variable and mediator; βb = β coefficient between mediator and independent variable.

As depicted in Figure 2, path **a** represents the relationship between nutritional status and physical activity. There is a significant and positive relationship between nutritional status and physical activity with βa= 2.4944, p= 0.0019 (p<0.05). This indicates that a higher nutritional status is associated with increased levels of physical activity in children.

Path **b** represents the relationship between physical activity and working memory. There is a significant and positive association between physical activity and working memory with βb= 0.0632, p= 0.0013 (p<0.05). This indicates that an improve level of physical activity are associated with enhanced working memory in children.

Path **c'** represents the direct effect, which is the relationship between nutritional status and working memory mediated by physical activity. The analysis shows a significant result with βc' =

0.3385, SE= 0.1365, p= 0.0154 (p<0.05), 95% CI (0.0666, 0.6104). The effects of physical activity are summarized in Table 1 below.

Tabel 1. Direct, indirect, and total effect between Nutritional Status and Working Memory on Physical Activity

Relationship	Total Effect	Direct Effect	Indirect Effect	Confidence Interval		Conclusion
				Lower Bound	Upper Bound	
Nutritional Status → Physical Activity → Working Memory	0.4961	0.338	0.1576	0.0394	0.3365	Partial Mediation

The subsequent findings is the indirect effect pathway, revealing the magnitude of the mediator' role, as depicted in table 1. The result shows that physical activity mediates the relationship between nutritional status and working memory by 15% (0.1576; p <0.05; 95% CI [0.0394, 0.3365]). According to the findings of the research, physical activity was proven to play the role of a mediator in relation to nutritional status and working memory. Hence, physical activity partially mediated the relationship between nutritional status and working memory.

DISCUSSION

The research examines three variables; nutritional status, working memory, and physical activity as mediator. The main hypothesis of this study is to investigate the role of physical activity as a mediator towards the relationship between nutritional status and working memory. The higher levels of physical activity in children will lead to an optimization of nutritional status, which in turn plays a role in enhancing working memory. The result shows that physical activity mediates the relationship between nutritional status and working memory by 15% (0.1576; p<0.05; 95% CI [0.0394, 0.3365]). That means that 85% of the variance in working memory can be attributed to other factors related to working memory such as genetic, lack of oxygen due to brain injury, biochemical damage in brain, environmental pollution, social-psychological disorder (Slowik et al., 2019).

These findings are supported by previous research conducted by Alhazmi et al. (2021) which state that regular physical activity is associated with weight loss and overall health that affect in cognitive capabilities. Participants with normal weight did a higher level of physical activity than overweight student, which in turn enhances their academic performance. A positive relationship between physical activity (PA) and memory in elementary school student was suggested in previous research conducted by Sibley & Etnier (2003), the psychological mechanisms suggested to elucidate the association between physical activity and memory include the following: (1) exercise may increase cerebral blood flow to increase the supply of glucose and oxygen to the brain; (2) both acute and chronic exercise may influence neurotransmitter levels with potential effects on memory and psychological state, and (3) exercise may increase the vasculature in the cerebral cortex and reduce vascular diffusion distance (Etnier et al., 1997). Therefore, physical activity is beneficial in optimizing the influence of nutritional status on working memory.

Another finding from this research is there was a positive correlation between nutritional status and working memory both directly and after being mediated by physical activity. Hence, physical activity partially mediated the relationship between nutritional status and working memory. The study conducted by Purnamasari et al. (2023) also found that there was a positive correlation between nutritional status and short term memory which includes working memory. The better nutritional status of student, the higher their memory. Children with malnutrition experience limited memory, productivity, and learning achievement. Malnutrition will affect the formation of neuropsychology and neurochemistry of the formation of the hippocampus (Rachmawati et al., 2021). Hippocampus is thought to have a crucial role in determining brainpower in capturing and storing memories.

The research conducted by Alhazmi et al. (2021) found different result that nutritional status (BMI) was significantly negatively correlated with BMI among student. Mamrot & Hanc (2019) also found that there is an inverse relationship between nutritional status and executive function (EF) performance, higher BMI or nutritional status (obesity) is associated with poorer EF performance including working memory. Laurent et al. (2020) states that from neurophysiological perspective, high BMI (overweight or obesity) is significantly related to low cortical thickness of eighteen cortical regions and decreased frontal and limbic gray matter volume. These suggest the possibility of poorer executive function performance including working memory. Hence, an optimal working memory can be achieved by maintaining a balanced nutritional status (neither deficient nor excessive also known as underweight or overweight). This necessitates the involvement of physical activity as a mediating factor in the process.

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