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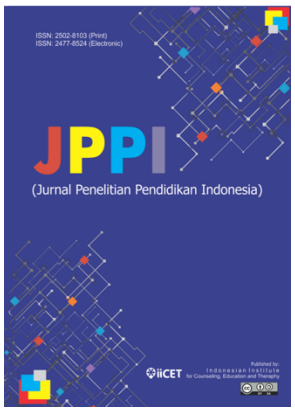

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The effect of breakfast energy, physical endurance, and speed on physical education learning achievement

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ABSTRACT

This study aims to reveal the direct and indirect effects, as well as the simultaneous effects between variables.This is a quantitative associative study using a path analysis approach. The population in this study was all 612 Physical Education (PJOK) students at SMAN 5 Batam. A sample of 123 students was taken using purposive sampling. Data were collected using a questionnaire for breakfast energy, a bleep test for physical endurance, a 30-meter run test for speed, and report card scores for learning achievement. The data were analyzed using path analysis through a structural model test at $\alpha = 0.05$. The results of the hypothesis testing show: (1) there is a direct effect of breakfast energy on PJOK learning achievement (py1 = 0.435 or 18.92%), (2) there is a direct effect of physical endurance on PJOK learning achievement (py2 = 0.564 or 31.08%), (3) there is a direct effect of speed on PJOK learning achievement (py3 = 0.057 or 0.27%), (4) there is an indirect effect of breakfast energy on PJOK learning achievement (p31.py3 = 0.886 or 78.49%), (5) there is an indirect effect of physical endurance on PJOK learning achievement (p32.py3 = 0.0345 total effect 3.49%), and (6) there is a simultaneous effect of breakfast energy, physical endurance and speed on PJOK learning achievement (Rsquare = 0.886 or 88.6%).

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Introduction

Physical Education (PJOK) is an integral component of the school curriculum that aims to develop students' physical fitness, motor skills, and understanding of healthy lifestyles in a balanced manner (Huang et al., 2023; Siedentop & Van der Mars, 2022). In the Indonesian school context, PJOK learning achievement is commonly reflected in students' report card scores, which are derived primarily from assessments of physical performance and skill mastery. However, several schools, including SMAN 5 Batam, continue to report relatively low PJOK achievement, indicating potential limitations in students' physiological readiness and physical capacity to engage optimally in learning activities. This condition

suggests the need to examine internal factors that directly support students' participation and performance in PJOK lessons (Clemente et al., 2022).

One important factor influencing students' readiness for physical activity is nutrition, particularly breakfast consumption. Breakfast plays a crucial role in supplying energy required for both cognitive processes and physical performance, including glucose regulation, muscular work, and sustained attention during school hours (A et al., 2024; Lundstrom et al., 2024; Mhamed et al., 2024). Students who consume insufficient breakfast have been shown to experience reduced endurance, slower motor responses, and decreased concentration during learning activities. Despite this evidence, most studies emphasize breakfast habits or frequency, while research that specifically examines breakfast energy, defined as the caloric intake obtained during breakfast, remains limited in the context of school-based physical education. Given the physically demanding nature of PJOK, investigating breakfast energy as a determinant of learning achievement is therefore highly relevant (Dring et al., 2022; Ługowska et al., 2023).

Physical endurance represents another essential component of success in PJOK learning. Adequate endurance enables students to participate actively throughout lessons, delay the onset of fatigue, and maintain movement quality during skill execution (García-Hermoso et al., 2022). Previous studies have consistently demonstrated a strong association between endurance and physical performance outcomes. However, endurance is often examined as an isolated predictor, with limited attention given to its indirect influence through other motor components. Considering that physical fitness components interact dynamically, examining endurance within a structural framework allows for a more comprehensive understanding of its contribution to PJOK learning achievement (Bilondi et al., 2024; Huangsaksri et al., 2024; Inkpen et al., 2024).

Speed, defined as the ability to perform movements rapidly, is also an important motor attribute in physical education learning. Speed influences students' ability to execute tasks efficiently, respond quickly during drills, and perform well in movement-based assessments. Although speed has been widely studied in competitive sports contexts, its role in school-based PJOK learning achievement remains relatively underexplored (Gilbert et al., 2023). Existing literature suggests that speed may function more as a supporting component rather than a dominant predictor of learning outcomes, indicating the possibility that its contribution may occur through mediating pathways rather than direct effects.

Despite the recognized importance of breakfast energy, physical endurance, and speed, previous research has rarely examined these variables simultaneously within a single analytical model. Most studies investigate nutritional or fitness factors independently, without considering how these variables may interact to influence learning outcomes. A path analysis approach is therefore appropriate to identify both direct and indirect relationships among these factors, providing a more nuanced explanation of PJOK learning achievement, which is shaped by physiological readiness, physical fitness, and motor performance (Baumann et al., 2022; Becerra Patiño et al., 2023).

Based on these considerations, this study aims to analyze the direct, indirect, and simultaneous effects of breakfast energy, physical endurance, and speed on PJOK learning achievement among students at SMAN 5 Batam. By employing a structural model, this research seeks to clarify the relative contribution and interaction of nutritional and physical factors in PJOK learning, thereby offering empirical evidence to support school-based nutrition programs, fitness development strategies, and the improvement of physical education instruction (Hammoudi Halat et al., 2023; Seger et al., 2022).

Method

This study employed a quantitative associative approach using path analysis to examine the direct, indirect, and simultaneous effects of breakfast energy, physical endurance, and speed on PJOK learning achievement. The population consisted of all 612 students enrolled in Physical Education classes at SMAN 5 Batam. A total sample of 123 students was selected using purposive sampling based on predetermined inclusion criteria. Breakfast energy was measured using a structured questionnaire assessing caloric intake during breakfast, while physical endurance was assessed through the standardized bleep test. Speed was measured using a 30-meter sprint test, and PJOK learning

achievement was obtained from students' official report card scores. All instruments used in this study were validated prior to data collection to ensure reliability and accuracy.

Data analysis was conducted using path analysis through a structural equation model to determine the magnitude of direct, indirect, and total effects among variables. Before hypothesis testing, data were verified, coded, and checked for normality, linearity, and multicollinearity to ensure compliance with the assumptions of path analysis. The structural model was tested at a significance level of $\alpha = 0.05$. Effect coefficients were interpreted to explain the relative contribution of each predictor variable to PJOK learning achievement. The combination of validated instruments and robust statistical procedures ensured that the findings accurately represented the relationships among nutritional, physiological, and performance-related factors affecting students' outcomes in physical education.

Results and Discussions

The results of this study present the direct, indirect, and simultaneous effects of breakfast energy, physical endurance, and speed on students' PJOK learning achievement at SMAN 5 Batam. Data analysis using path analysis revealed varying magnitudes of influence across the predictor variables, with physical endurance and breakfast energy emerging as the most dominant contributors to learning outcomes. In addition to examining direct relationships, the study also assessed speed as a mediating variable to determine whether its role strengthened or modified the impact of breakfast energy and physical endurance on achievement. Furthermore, simultaneous testing of all variables provided a comprehensive picture of how nutritional and physical factors collectively shape students' performance in physical education. The key findings are summarized in the tables below.

Table 1. Direct Effects of Breakfast Energy, Physical Endurance, and Speed on PJOK Learning Achievement

Predictor Variable	Path Coefficient (β)	Contribution (%)	Significance
Breakfast Energy, Achievement	0.435	18.92%	Significant
Physical Endurance, Achievement	0.564	31.08%	Significant
Speed, Achievement	0.057	0.27%	Significant

Table 1 shows the direct effects of breakfast energy, physical endurance, and speed on PJOK learning achievement. Physical endurance produced the strongest direct contribution (31.08%), indicating that students with higher endurance levels tend to achieve better PJOK performance. Breakfast energy also had a substantial direct influence (18.92%), suggesting that adequate morning caloric intake supports cognitive and physical readiness during PE classes. Speed, while statistically significant, contributed minimally (0.27%), showing that sprint ability alone does not substantially impact overall learning achievement compared to the other variables.

Table 2. Indirect Effects of Breakfast Energy and Physical Endurance Through Speed

Indirect Pathway	Indirect Effect (β)	Total Effect (%)	Interpretation
Breakfast Energy, Speed, Achievement	0.886	78.49%	Strong indirect effect
Physical Endurance, Speed, Achievement	0.0345	3.49%	Weak indirect effect

Table 2 presents the indirect contributions mediated through speed. Breakfast energy shows a remarkably strong indirect effect (78.49%), implying that students who consume more breakfast energy tend to exhibit better speed performance, which subsequently supports PJOK learning outcomes. Conversely, physical endurance demonstrates only a modest indirect contribution through speed (3.49%), indicating that the influence of endurance on learning achievement is primarily direct rather than mediated by speed. These findings highlight speed as a meaningful but selective mediator in the model.

Table 3. Simultaneous Effects of All Predictor Variables on PJOK Learning Achievement

Model Component	R^2 Value	Total Contribution (%)	Description
Breakfast Energy + Physical Endurance + Speed	0.886	88.6%	Strong simultaneous effect

Table 3 indicates that breakfast energy, physical endurance, and speed collectively explain 88.6% of the variance in PJOK learning achievement. This high R^2 value demonstrates that the model is robust and the combination of physiological and behavioral factors strongly predicts student performance in physical education. The findings suggest that optimizing nutritional intake, improving endurance, and developing speed can jointly enhance students' learning outcomes in PJOK.

The findings of this study indicate that breakfast energy has a meaningful direct effect on PJOK learning achievement, suggesting that adequate morning nutritional intake supports students' readiness to participate in physical education activities. This result is consistent with physiological evidence showing that sufficient carbohydrate intake contributes to glucose availability for both neural processing and muscular work, thereby supporting attention, endurance, and task execution during school hours (Ahmad et al., 2025; Gallotta et al., 2024). Nevertheless, it is important to interpret this effect cautiously, as breakfast energy was assessed through self-reported intake and the study design does not allow for causal inference. Thus, while breakfast energy appears to be an important supporting factor, its role should be understood within the broader context of students' daily nutritional patterns.

Physical endurance emerged as the strongest direct predictor of PJOK learning achievement, reinforcing the central role of cardiorespiratory fitness in school-based physical education. Students with higher endurance levels are better able to sustain participation throughout lessons, experience less fatigue, and maintain performance quality across learning tasks. From a theoretical standpoint, endurance enhances physiological resilience and supports repeated engagement in skill-based activities, which are commonly emphasized in PJOK assessments. These findings align with previous studies that have linked endurance to both physical performance and learning engagement, although the present results should be viewed as associative rather than strictly causal (Gajardo-Araya et al., 2022; Welis et al., 2024).

Although speed showed a statistically significant direct effect on PJOK learning achievement, its magnitude was relatively small, indicating that sprint performance alone contributes only marginally to broader learning outcomes in physical education (Ferreira et al., 2024; Li et al., 2024). This finding suggests that speed is highly task-specific and may not directly correspond to the composite assessment criteria used in PJOK, which often integrate multiple skill and fitness components. In this context, speed appears to function as a complementary rather than a dominant predictor, supporting certain movement-based tasks without substantially determining overall achievement (Cristi-Montero et al., 2024; Huang et al., 2025).

The indirect analysis highlights a notable pathway in which breakfast energy influences PJOK learning achievement through speed. While this indirect effect was statistically strong, it should be interpreted carefully, as the relatively small direct contribution of speed raises questions regarding the proportionality of this mediation pathway. One possible explanation is that adequate nutritional intake enhances neuromuscular efficiency and short-term energy availability, which may improve sprint-related performance under test conditions (Brobakken et al., 2024; Sindwani & Kaur, 2024a, 2024b). However, this finding may also reflect model sensitivity or overlapping variance among predictors, indicating the need for further studies to validate the mediating role of speed. In contrast, the indirect effect of physical endurance through speed was minimal, suggesting that endurance primarily influences PJOK learning achievement through sustained physiological capacity rather than through improvements in sprint performance (Hsieh et al., 2025).

The simultaneous analysis showed that breakfast energy, physical endurance, and speed collectively accounted for 88.6% of the variance in PJOK learning achievement. While this high explanatory value indicates that the model captures key physiological and motor-related factors, it may also suggest potential overestimation due to shared variance or unmeasured contextual influences, such as teaching methods, student motivation, and assessment practices. Therefore, the robustness of the model should

be interpreted with caution and not as evidence that these variables fully explain PJOK learning outcomes. Nonetheless, the findings emphasize that students' performance in physical education is shaped by a combination of nutritional readiness, fitness capacity, and motor proficiency (Issa, 2022).

From a practical perspective, the results support the importance of holistic school-based interventions that address nutrition and physical fitness simultaneously. Rather than focusing solely on speed development, PJOK programs should prioritize endurance enhancement and nutritional awareness as foundational elements of student readiness and participation. Integrating structured fitness activities with school nutrition initiatives may provide more sustainable benefits for improving PJOK learning achievement and students' overall physical literacy.

Conclusions

This study concludes that breakfast energy, physical endurance, and speed significantly contribute to students' PJOK learning achievement at SMAN 5 Batam through both direct and indirect pathways. Breakfast energy and physical endurance demonstrate strong direct influences, indicating that adequate morning nutrition and high endurance levels are essential determinants of students' physical education performance. Although speed shows a relatively small direct impact, it serves as an important mediating factor, particularly in amplifying the effect of breakfast energy on achievement. Furthermore, the simultaneous analysis reveals that all three variables collectively explain a substantial proportion of the variance in PJOK learning outcomes, confirming that nutritional readiness, fitness capacity, and motor performance interact synergistically to shape students' success in physical education learning.

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