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RESEARCH ARTICLE

Associations of Physical Inactivity with Health-Related Markers in Adults: A Discriminant Analysis from a Fitness Promotion Campaign

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ABSTRACT - The World Health Organization has initiated a strategic plan to curve the prevalence of physical inactivity across the globe by 10% and 30% by the years 2025 and 2030, respectively. However, a recent survey by the Ministry of Health Malaysia demonstrated that one in three Malaysian adults were physically inactive. Although survey data could provide useful information, it is prone to subjectivity. The current study is aimed at objectively evaluating the physical activity levels of Malaysian adults with respect to health-related markers, i.e., height, weight, body fat percentage (BFP), muscle mass, body mass index (BMI), basal metabolic rate (BMR), resting heart rate (RHR), blood pressure (BP), muscle endurance, and maximum oxygen consumption (VO_{2max}). A total of 232 adults were recruited for this study. The physical activity levels of the participants was categorized into high, moderate and low by using the International Physical Activity Questionnaire and the above-mentioned health-related markers were measured via standard health-related marker measurements. A discriminant analysis was used as a statistical technique to distinguish the physical activity levels and the corresponding health-related markers of the participants. The results showed that there were no differences between the physical activity levels in terms of BMI, muscle mass, visceral fat, BMR, and BP (p>0.05). However, there were significant differences in percentile of BFP, RHR, muscle endurance, and VO_{2max} (p<0.05). A high level of physical activity is attributed to lower RHR and BFP, muscular as well as cardiovascular endurance, which are non-trivial in helping individuals meet the demands of daily tasks.

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1. INTRODUCTION

Physical activity (PA) has been defined as "implying people who move, act, and perform in specific spaces and contexts in a unique array of desires, emotions, ideas, instruction, and relationships" (1). Regular participation in physical activity increases the health status and physical fitness of an individual. Physical activity is also associated with a lower risk of chronic disease, such as heart disease, hypertension, and diabetes mellitus (2). Recent PA guidelines for adults between the age of 18 to 64 years old state that adults should undergo at least 150–300 minutes of moderate-intensity aerobic PA per week; or at least 75–150 minutes of vigorous-intensity aerobic PA per week; or an equivalent combination of moderate- and vigorous-intensity activity throughout the week, for significant health benefits (3).

Despite abundant evidence that shows the benefits of physical activity, adults continue to have a high prevalence of insufficient physical activity, and it has been increasing in recent years. For instance, in 2017, the Global Health Observatory data from the World Health Organization (WHO) showed that globally, 28% of adults aged 18 years above and, specifically, 34.6% of male Malaysians were insufficiently physically active (4). A recent survey funded by WHO showed that more than 80% of adolescent did not comply with the latest daily physical activity guidelines (5). In Malaysia, the National Health and Morbidity Survey 2023 (6) showed 1 in 3 adults in Malaysia are physically not active. The survey also reported that 50% of adults in Malaysia lead sedentary lifestyles, such as spend over 2 hours a day either setting, lying down, or reclining while awake. These statistics highlight the troubling fact that physical inactivity is a public health problem in Malaysia.

Physical inactivity increases the risk of mortality, and it negatively leads to non-communicable diseases, such as type 2 diabetes, obesity, hypertension, and cardiovascular disease (7,8). According to the WHO, 38 million people died each year from non-communicable diseases, with physical inactivity being one of the major risk factors (9). In 2010, Maggio et al. found that children with chronic diseases have lower PA levels and cardiorespiratory fitness. In another study, Cannioto et al. (2018) found that physical inactivity is associated with lung cancer and mortality. Moreover, physical inactivity also contributes to the obesity epidemic, which is aggravated by poor cumulative environment quality (12). The

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evidence from previous studies clearly shows that physical inactivity results in many adverse health effects, and a decrease in physical inactivity levels among populations could hamper the improvement in the health of the population (13).

Realizing the trend of increasing physical inactivity in recent years, in 2018, the WHO published their 'Global Action Plan on Physical Activity 2018–2020: More Active People for a Healthier World'. The initiative aims to minimize physical inactivity by 10% by 2025 and 30% by 2030 worldwide. According to the action plan, it is critical to assess a population's current level of physical activity. Assessment of PA level can be a marker to determine the health status of an individual, such as cardiovascular risk (14). To date, information regarding PA level among adults, especially in those in Terengganu. is limited. Therefore, the aims of this study were to determine and correlate the physical inactivity of adults with their health-related markers. The results from this study can be used as guidelines for stakeholders or authorized organizations to plan more effective health improvement strategies and activities for the adult population.

2. METHODS AND MATERIAL

2.1 Participants

A cross-sectional design was adopted in this study. In total, 232 adults from the Universiti Malaysia Terengganu were recruited for this purpose. Individuals with acute heart disease or chronic diseases such as diabetes, hypertension (>140/90 mmHg), renal failure, or any other medical problems were barred from participating in the study. The aims of the study and the procedures of testing measurements were explained to all participants. Each participant was asked to sign an informed consent form before participating in the study.

2.2 Study Procedures

Eligible participants were asked to fill out the demographic form and International Physical Activity Questionnaire (IPAQ). The anthropometric measurements, including height, weight, body fat percentage, visceral fat percentage, muscle mass, body mass index (BMI), resting heart rate (RHR), basal metabolic rate (BMR), and systolic and diastolic blood pressure of the participants, were taken immediately after they completed the forms. Participants then performed a 1-min push-up test and 1-min sit-up test to determine their muscular endurance and a 20-meter multistage shuttle-run test to measure their estimated maximum oxygen consumption (VO_{2max}). The study procedures were approved by the research ethics committee (Human) of Universiti Sains Malaysia (USMKK/PPP/JEPeM (217.3.(16.6)).

2.3 Determination of PA Level

The PA level of the participants was assessed using a shortened version of the International Physical Activity Questionnaire (IPAQ). The questionnaire was recommended and validated by WHO to assess the PA level for individuals 15 to 69 years of age. This tool involves three unique styles of activities, namely walking and moderate and vigorous intensity activity. Based on this questionnaire, the subjects were divided into three categories of PA, which were at a low, moderate, and high level. All questionnaires were self-reported and completed by the participants themselves.

2.4 Anthropometric Measurement

The heights of the participants were measured by using a Body meter 406 (SECA), and the weight, body fat percentage, visceral fat percentage, muscle mass, BMI, and BMR of the participants were measured by using Bioelectrical Impedance Analysis (Omron). The resting heart rate and blood pressure of the participants were measured by using an Omron Automatic Pressure Monitor (SEM1-Model).

2.5 Muscle Endurance

The subjects' muscle endurance was measured using a 1-minute push-up and a 1-minute sit-up test. The validity and reliability of the push-up and sit-up tests have been well established (15).

2.6 1-Min Push-up Test

This test assesses upper-body muscular endurance (anterior deltoid, pectoralis major, and triceps). The subjects' hands were slightly broader than shoulder width apart, with fingers facing forward. One fist was placed on the floor below the subject's chest by the administrator. Starting in the upright position (elbow extended), the subjects dropped their bodies to the floor until their chests touched the administrator's fist. Subjects were then returned to the up posture for one repeat. Resting was only possible in the up posture. The score was determined by the total number of accurate push-ups completed in one minute (16).

2.7 1-Min Sit-up Test

This test assesses the endurance of the abdominal muscles. The subjects began by resting on their backs, legs bent and heels flat on the floor. Arms were crossed across the chest, with hands on opposite shoulders. The buttocks remained on the floor with no tip thrusting. A partner firmly holds the feet down. The subjects next executed as many accurate sit-ups as they could in one minute. In the up position, the subjects brought their elbows to their knees and then lowered their shoulders to the floor. Any rest was taken in the upright position. The subjects' necks remained in a neutral position. The score was determined by the total number of accurate sit-ups completed in one minute (16).

2.8 Cardiorespiratory Fitness

The subjects' cardiorespiratory fitness was evaluated using the 20-meter Multistage Shuttle Run test. The test was carried out in accordance with earlier research (Zaqout et al. 2016). This test's reliability and validity in estimating VO_{2max} in children and adolescents has been thoroughly demonstrated(17). The validity of a 20-meter multistage shuttle run for predicting VO_{2max} in adult Singaporean athletes has been widely acknowledged throughout Asia (18). The multistage shuttle run test was carried out in a vast space at the Sports Complex, Universiti Malaysia Terengganu. The test consisted of progressive increases in running speed over a 20-meter distance, with the running velocity determined by an audible 'beep' for each 20-meter distance.

2.9 Statistical Analysis

Data in this study were statistically analyzed by using discriminant analysis (DA). Generally, DA is a statistical analysis method that can differentiate or separate variables of two or more joined group or classes (19). In this study, DA was used to ascertain the differences between the PA level (low, moderate, and high) based on the health-related indicators. The statistical analysis was conducted using XLSTAT2014 add-in software for Windows. Differences were considered significant at $p<0.05$.

3. RESULTS AND DISCUSSION

The results of the present study were tabulated in depth. The mean (standard deviation) BMI and body fat percentage of the participants were 23.34 (4.9) kg/m^2 and 25.67 (8.05)%, respectively. The other health-related markers of the participants are shown in Table 1.

Table 1. Health-related markers of the participants

Variables	Mean	Standard Deviation
BMI (kg/m^2)	23.342	4.917
Body Fat Percentage (%)	25.667	8.049
Muscle Mass (kg)	28.875	5.752
Visceral Fat (%)	5.878	5.184
BMR (Kcal)	1358.733	261.669
M STBP (mmHg)	114.252	12.281
M-DDSBP (mmHg)	75.474	8.700
M-RHR (b/min)	82.030	12.238
VO_{2max} (mL/kg/min)	27.91	8.14
Pa (Met)	4852.355	5468.353

Body mass index (*BMI*), basal metabolic rate (*BMR*), systolic blood pressure (*STBP*), diastolic blood pressure (*DSBP*), resting heart rate (*RHR*), maximum oxygen consumption (VO_{2max})

No significant differences occurred between low-, moderate and high-PA groups in body mass index, muscle mass, visceral fat, basal metabolic rate, systolic blood pressure and diastolic blood pressure. However, the body fat, resting heart rate, push-up, sit-up and $VO_{2max.}$ were significantly different ($p<0.05$) (Table 2).

Table 2. Relationship between physical activity level and health-related markers of the participants (Mean (SD))

Health-related markers	Physical activity level			p-value
	High	Moderate	Low	
BMI (kg/m^2)	22.97 (4.91)	23.96 (4.96)	23.19 (4.82)	0.371
Body fat percentage (%)	24.16 (8.18)	27.67(7.69)	26.40 (7.43)	0.008*
Muscle mass (kg)	28.58 (6.18)	29.11 (5.60)	29.44 (4.29)	0.687
Visceral fat (%)	5.64 (5.50)	6.56(5.11)	5.06 (3.86)	0.303
BMR (Kcal)	1365.31 (284.27)	1368.79 (231.83)	1307.10 (243.43)	0.498
STBP (mmHg)	114.40 (12.12)	114.64 (12.86)	112.68 (11.63)	0.740
DSBP (mmHg)	74.66 (9.12)	76.89 (8.45)	75.00 (7.34)	0.196
RHR (b/min)	79.89 (11.43)	84.11 (12.29)	85.02 (13.90)	0.019*
1-min push-up (rep/min)	26.95 (14.03)	23.30 (10.13)	21.48 (8.94)	0.029*
1-min sit-up (rep/min)	25.65 (11.56)	22.39 (10.47)	21.03 (9.53)	0.036*
$V0_{2max}$ (mL/kg/min)	29.30 (8.23)	26.12 (6.89)	27.07 (9.87)	0.021*

*****p<0.05, significant different between PA level, body mass index (*BMI*), basal metabolic rate (*BMR*), systolic blood pressure (*STBP*), diastolic blood pressure (*DSBP*), resting heart rate (*RHR*), maximum oxygen consumption (VO_{2max})

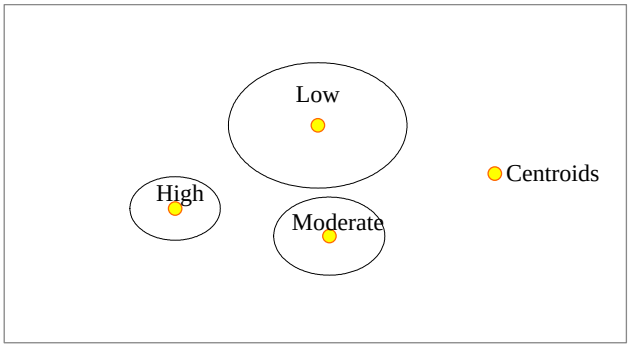

Figure 1. Separation of the PA levels of the participants

The discriminant analysis was effective in discriminating the students regarding the PA level. As shown in the figure, a clear separation was established between the 3 levels of PA, i.e., high, moderate and low PA (Figure 1). The result indicates that there was a significant difference between PA level in terms of body fat percentage (p = 0.008). The moderate PA level group showed the highest body fat percentage, and the high PA level group had the lowest body fat percentage, whereas the means of both groups were 27.67 (7.69)% and 24.16 (8.18)%, respectively (Figure 2).

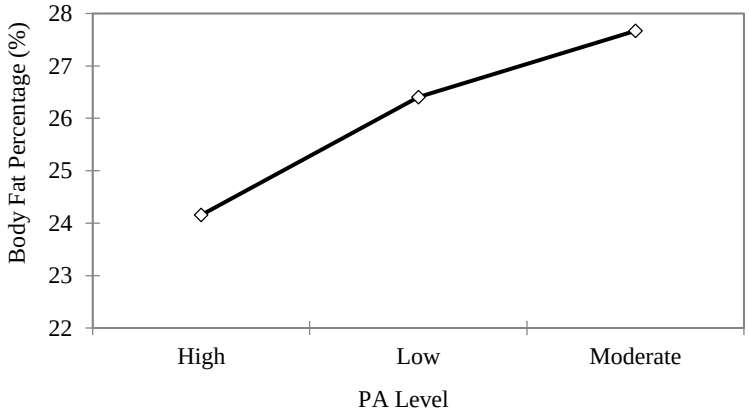

Figure 2. Relationship between body fat percentage and PA level of the participants

The results show that the difference between groups on resting heart rate was significant (p = 0.019). The low PA level group showed the highest resting heart rate, and the high PA level group had the lowest resting heart rate; the means of both groups were 85.02 (13.90) and 79.89 (11.43) $b.min^{-1}$, respectively (Figure 3).

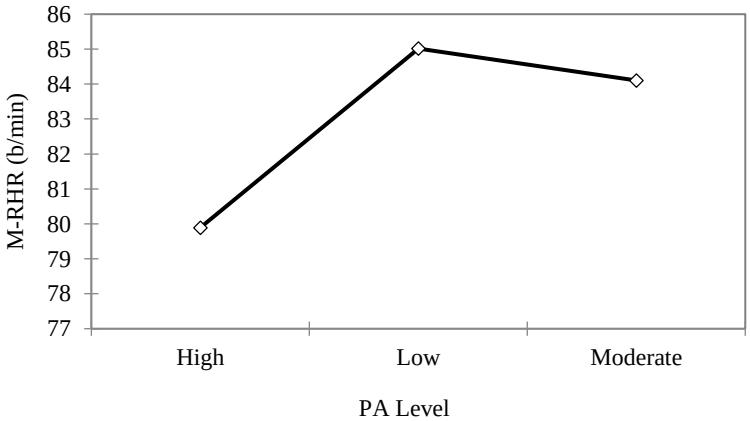

Figure 3. Relationship between resting heart rate and PA level of the participants

The results show that there was a significant difference between groups on 1-min push-up (p = 0.029). The high PA level group had the highest 1-min push-up score, and the low PA level group had the lowest 1-min push-up score; the means of both groups were 26.95 (14.03) and 21.48 (8.94) $repetition.min^{-1}$, respectively (Figure 4).

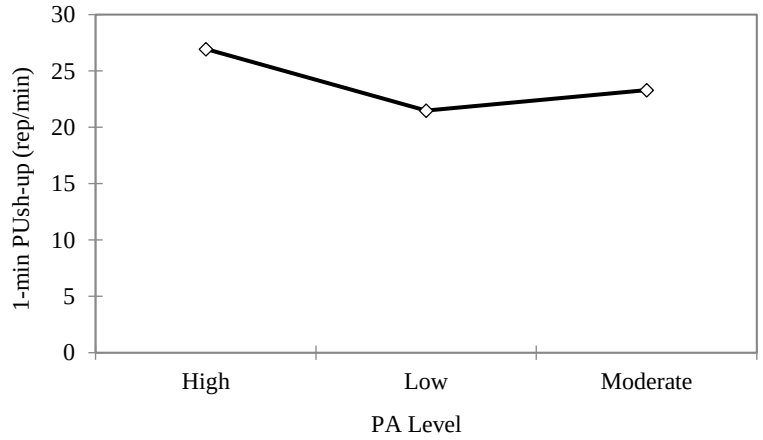

Figure 4. Relationship between 1-min push-up score and PA level of the participants

The results show that the difference between groups on 1-min sit-up was significant ($p = 0.036$). The high PA level group showed the highest 1-min sit-up score, and the low PA level group had the lowest 1-min sit-up score; the means of both groups were 25.65 (11.56) and 21.03 (9.53) repetition.min^{-1}, respectively (Figure 5).

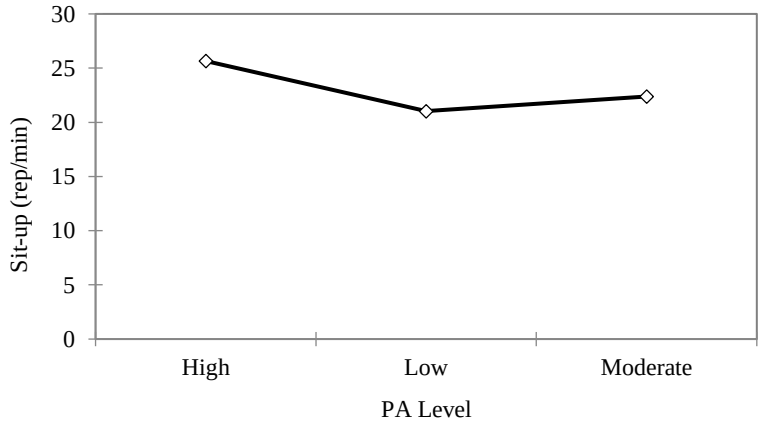

Figure 5. Relationship between 1-min sit-up score and PA level of the participants

The results indicate that there was a significant difference between the groups on VO_{2max} ($p = 0.021$). The high PA level group showed the highest VO_{2max}, and the moderate PA level group had the lowest VO_{2max}; the means of both groups were 29.30 (8.23) and 26.12 (6.89) ml.kg^{-1}.min^{-1}, respectively (Figure 6).

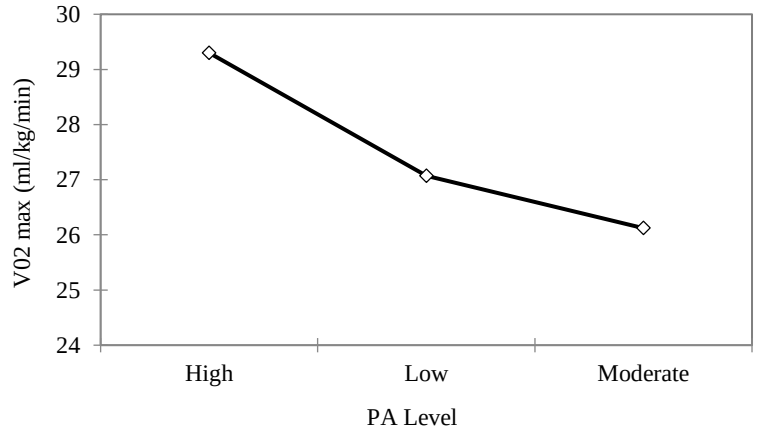

Figure 6. Relationship between VO_{2max} and PA level of the participants

In this study, we attempted to determine the PA level of adults and discriminated the PA level based on their health-related markers. The main finding of this study was that the PA level of participants was differentiated by the following health-related markers: body fat percentage, RHR, 1-min push-up, 1-min sit-up. and VO_{2max}. In contrast, no significant

relationship was observed between PA levels and other health indicators, including BMI, muscle mass, visceral fat, BMR, and systolic and diastolic blood pressure.

A key finding of this study was that VO_{2max}, an indicator of cardiorespiratory fitness, significantly differentiated PA levels among participants. This result aligns with previous research demonstrating a positive association between PA levels and cardiorespiratory fitness in children and adolescents (20–22). These studies suggest that individuals who regularly engage in physical activity tend to have better cardiorespiratory fitness. Regular physical activity induces several physiological adaptations in the cardiovascular and respiratory systems. For instance, Wilson et al. (2015) reported that prolonged cardiovascular training leads to increased size and strength of the heart muscle. A larger, stronger heart allows greater blood volume to fill the left ventricle and enhances its ability to pump oxygenated blood efficiently throughout the body. This adaptation also contributes to a lower resting heart rate (RHR), as the heart can meet the body's demands with fewer beats per minute. Such changes are especially evident following consistent endurance training or activities like yoga (24). Consistent with these physiological effects, our study found a significant relationship between RHR and PA level.

Additionally, endurance training has been shown to increase blood capillary density, which enhances the delivery of oxygen and nutrients to body tissues (25). Furthermore, the number of mitochondria within muscle cells also rises with sustained endurance training, allowing for greater energy production and improved exercise performance (26,27). This condition allows more energy production and consequently improves exercise performance. Muscular endurance, as assessed by 1-min sit-up and 1-min push-up tests, also significantly differentiated participants' PA levels in our study. These results are supported by findings from Bogdanis, (2012), who observed an inverse relationship between PA levels and muscle fatigue. Regular physical activity enhances muscular endurance by inducing specific adaptations in the muscular system. For example, improved blood circulation within muscle contributes to a more efficient buffering system, facilitating the clearance of lactic acid and reducing the risk of muscle cramps. These adaptations enhance overall muscular endurance, as documented in various studies (29,30). Our study supports the evidence that higher physical activity levels are associated with favorable physiological adaptations in both the cardiovascular and muscular systems. These findings underscore the importance of regular physical activity for improving overall fitness and health among adults. Moreover, body fat percentage was one of the health-related markers that significantly differentiated participants' PA levels in this study. Participants in the moderate PA group exhibited the highest body fat percentage, while those in the high PA group possessed the lowest body fat percentage. The findings are consistent with prior research showing that those with a low PA had the lowest. These findings are consistent with previous studies, which reported that individuals with lower PA levels tend to have higher body fat percentages (31,32).

In general, body fat increases when caloric intake exceeds energy expenditure. Regular engagement in physical activity facilitates the burning of stored fat, thereby reducing overall body fat percentage. Furthermore, consistent participation in PA enhances lipid metabolism and stimulated lipolysis, the breakdown of triglycerides into free fatty acids and glycerol (33,34). PA also promotes the production of lipase enzyme, which accelerate the lipolysis process, contributing to reductions in body fat over time. In contrast, no significant differences in BMI were observed across different PA levels in the current study. This finding differs from previous research, which found a significant relationship between PA levels and BMI, particularly between sedentary individuals and those engaged in vigorous-intensity PA. For example, Morelli et al. (2020) reported that individuals in the vigorous PA group had significantly lower BMIs than those in the physically inactive group. Similarly, De Meester et al. (2016) found that children with higher PA levels had lower BMIs than those with low PA levels.

4. CONCLUSION

In conclusion, this study demonstrated that physical inactivity of adults was differentiated by health-related markers, including VO_{2max}, muscular endurance, resting heart rate, and body fat percentage. However, no significant associations were found with BMI, muscle mass, visceral fat, BMR, or systolic and diastolic blood pressure. As the study was limited to a single state in Malaysia, further research across multiple regions is recommended to obtain more representative and generalized data on the PA level of Malaysian adults. Additionally, future studies could replicate this research in diverse groups and populations within the country to strengthen the findings.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interests.

AUTHORS CONTRIBUTION

Suhaimi, M.Z. (Conceptualisation; data collection, writing manuscript)

Musa, R.M (Data analysis; supervision, revising the manuscript, final approval)

Suhaimi, M.Z. (Conceptualisation; data collection; writing manuscript)

Ooi, F.K (Supervision, revise the manuscript, final approval)

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