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Abstract

Introduction

This study investigated the longitudinal relationship between self-reported physical activity and national examination results among adolescents in an upper-middle-income country.

Methods

This study engaged in a secondary data analysis derived from a closed prospective cohort consisting of 579 students, who were recruited at the age of 13 in 2012 and followed up at ages 15 (2014) and 17 (2016) as part of the Malaysian Health and Adolescents Longitudinal Research Team (MyHeART) study, which was conducted across three states in Peninsula Malaysia. Physical activity levels were evaluated using the Physical Activity Questionnaire, and outcomes were assessed based on the National-Based Examinations at ages 15 (Form 3, Year 9) and 17 (Form 5, Year 11) in Malaysia. A multivariate ordinal regression employing complex sample analysis was applied to ascertain the relationship between physical activity and national examination results.

Results

In Form 3 (Year 9), those physically active performed better in Malay Language, English Language, Mathematics and Science. Those physically active in Form 5 (Year 11), performed better in Modern Mathematics, Chemistry and Principles of Accounting. Longitudinally, there was an increase in the overall percentage of those who were overweight and obese and an increase in those with suboptimal dietary and iron intake.

Conclusions

This study has shown that those physically active students fared better in several subjects in the national-based examinations. Suitable physical activity intervention should be tailored accordingly to support adolescents' optimum achievement in academia.

Keywords adolescents, physical activity, academic achievement, national-based examinations

Introduction

Adolescents are defined as individuals aged between 10 and 19 years, comprising approximately 1.2 billion people within the global population. This demographic is anticipated to grow, particularly in low- and middle-income countries, where approximately 90% of adolescents reside (WHO, 2024). Adolescence serves as a critical transition phase between childhood and adulthood. Engaging with adolescents presents a threefold advantage. The World Health Organisation (WHO) asserts that promoting the health of adolescents today will lead to the emergence of healthier adults in the future, thereby contributing to the well-being of subsequent generations (WHO, 2023). Lifetime habits are normally created and inculcated at this time (Bélanger et al., 2011; Shao & Zhou, 2023; van Sluijs et al., 2021).

Physical activity is defined as any bodily movement that requires energy expenditure and is performed by skeletal muscles. WHO recommends 60 minutes of moderate-to-vigorous-intensity physical activity daily for children and adolescents aged 5-17 years (WHO, 2020). Physical activity has health and well-being benefits. In growing children and adolescents, regular physical activity is needed for growth and development (Alves & Alves, 2019; Brown et al., 2017), enhancing bone health (Gunter et al., 2012; Proia et al., 2021), reducing obesity (Kumar et al., 2015; Pate et al., 2016; Wyszynska et al., 2020), helps in regulating metabolism (Oliveira & Guedes, 2016; Silva et al., 2023; Whooten et al., 2019) and reducing incidences of non-communicable diseases (Landry & Driscoll, 2012; McTiernan et al., 2019; Ozemek et al., 2018). Studies have also linked physical activity with better mental health and psychological well-being by reducing stress, anxiety, depression and regulating sleep (Abou Elmagd, 2016; Belcher et al., 2021; Posadzki et al., 2020; Shao & Zhou, 2023). Physical activity also helps to improve self-esteem and self-confidence (Fernández-Bustos et al., 2019; Zamani Sani et al., 2016).

In addition to health and well-being, physical activity is associated with improved cognition and academic achievement in adolescents. More studies are available to establish the association between improved cognition and academic achievement (Asigbee et al., 2018; Kari et al., 2017; McPherson et al., 2018; Pellicer-Chenoll et al., 2015; Ruiz-Ariza et al., 2017; Singh et al., 2012; Singh et al., 2019; Sullivan et al., 2017; Syvaioja et al., 2019; Watson et al., 2017) while others mention a lack of or no relationship between the two (Barth Vedoy et al., 2021; Donnelly et al., 2016; Elish et al., 2022; Faught et al., 2019; Kalantari & Esmaeilzadeh, 2016; Papasideris et al., 2021; So, 2012; Taras, 2005; Yu et al., 2006). Studies in the local setting are mostly cross-sectional and unable to prove causality (Hashim et al., 2011; Kamal & Yusari, 2014). National-based examinations in Malaysia are carried out at the end of each level of schooling. The lower-secondary examination (Penilaian Tahap 3) is carried out in Form 3 (Year 9), and the upper-secondary examination (Sijil Pelajaran Malaysia) is conducted in Form 5 (Year 11) (Ministry of Education Malaysia, 2016).

Globally, the low levels of physical activity are alarming. About 81% of adolescents are physically inactive (WHO, 2018). Similar findings are observed even in the local setting in Malaysia. According to the Malaysian 2022 report card for physical activity in children and adolescents, only 20% of adolescents were physically active for 60 minutes or more, five or more days a week (Appukutty, 2014; Chung et al., 2018; Shahril et al., 2022; Shamsudin et al., 2014).

The current study contributes to the literature by examining the association of self-reported physical activity with national-based secondary examinations. It also explores the progression of other factors, such as anthropometric indices, dietary intake, and blood parameters over time.

Methods

Study Design and Area

The principal Malaysian Health and Adolescents Longitudinal Research Team (MyHeART) study represents an open and dynamic prospective cohort study conducted from 2012 to 2016. The current investigation is a closed prospective cohort utilising secondary data from participants who were followed up at all specified time points of data collection. This research was conducted across three Malaysian states: Kuala Lumpur, Selangor, and Perak, encompassing a total of seven rural and eight urban secondary schools. A two-stage clustered sampling methodology was employed in this study. The first stage entailed sampling within the selected schools located in the three designated states, while the second stage focused on the sampling of students within those chosen schools, as delineated in the published protocol (Hazreen et al., 2014). The national-based examination results were collected from all 15 schools by the researcher.

Study Population

Adolescents, with parental consent, from 15 rural and urban public schools who possessed the ability to read and communicate in either the Malay or English language were included in this study. Prior to the initiation of the research, consent forms and an informational sheet regarding the study were disseminated. Data were analysed from participants who were present at all three time points. Only sociodemographic data were collected at the baseline (T_0) of the study in 2012. The present study examined data from two subsequent collection points: the first (T_1) in 2014 when the participants were aged 15 years, and the second point (T_2) in 2016 when they were 17 years old. The same cohort of students was tracked over time, utilising identification numbers, and consistent measurements and parameters were employed at each time point (see Figure 1).

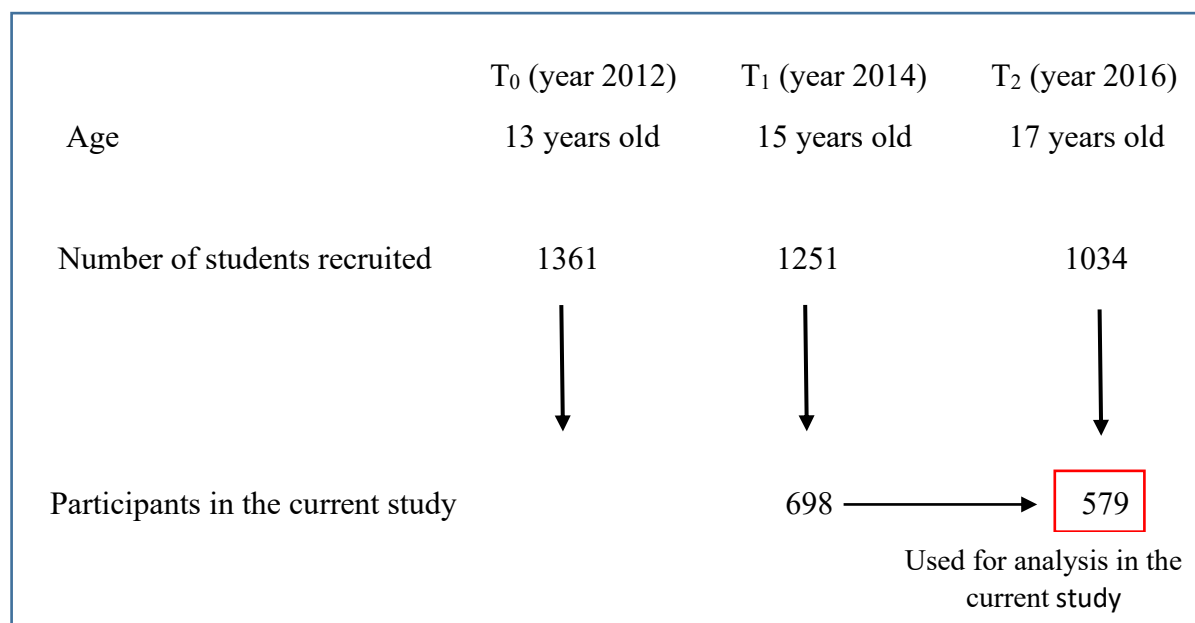


Fig. 1 Sampling flow of the main MyHeART study and the current study

Physical Activity Levels

The Physical Activity Questionnaire is a self-reported questionnaire based on the validated PAQ-C questionnaire (Kowalski et al., 2004). Although recommended to be used for children from the age of 8-14 years, it has been used for children and adolescents up to the age of 18 years old (Brady et al., 2024; Mohd Zaki et al., 2016; Ong et al., 2018). The primary distinction between the PAQ-C and PAQ-A is that the PAQ-C incorporates recess periods, a feature that is particularly relevant in the local context and contributes to a more accurate estimation of overall physical activity levels. The baseline study (MyHeART) began when the participants were 13 years old. The PAQ-C was used to ensure consistency and standardization across all data collection points throughout the study. This questionnaire includes an assessment of physical activity during recess. It assessed the type and frequency of physical activities performed during the last seven days, the physical activity during the different times of the day, and the previous week's physical activity (Kowalski et al., 2004). The first question focused on the types of sports and/or dance activities the adolescents participated in over the past week and how often they engaged in them. The following questions (2 to 8) explored the adolescents' physical activity during various times, including physical education (PE) classes, recess, lunch breaks, after school, during weekends, and other leisure periods. The ninth item enquired about the frequency of physical activity in the previous week. The mean of the nine questions was used to obtain the composite score that determined the physical activity level. A score of 5 indicates high physical activity, whereas a score of 1 indicates low physical activity. The physical activity scores were categorised into good (≥ 3.66), moderate (≥ 2.33 and < 3.66), and poor levels (< 2.33).

National-based Examination Results

The Form 3 (Year 9) examination comprises eight core subjects. All subjects were analysed in relation to physical activity, with the exception of Islamic Studies and Moral Studies as not all students were enrolled in these subjects. Conversely, the Form 5 (Year 11) examination is categorised into core subjects, the STEM (Science, Technology, Engineering, Mathematics) stream, which includes 38 subjects, and the Arts & Humanities stream, which encompasses 53 subjects. This organisation of subjects is aligned with the Malaysian Education Blueprint for pre-school to post-secondary education, covering the period from 2013 to 2025.

In Year 11, all core subjects—namely Malay Language, English Language, Mathematics, Science, and History—were analysed with respect to physical activity and additional factors, again excluding Islamic and Moral Studies. The selection of subjects from both the STEM and Arts & Humanities streams was predicated on higher student enrolment figures from the years 2014 and 2016, facilitating a more efficient analysis. Within the STEM stream, the pure science subjects analysed included Physics, Chemistry, Additional Mathematics, and Biology. From the Arts & Humanities stream, the subjects of Principles of Accounting, Commerce, and Economics were included in the analysis.

The results were classified into three categories: good, moderate, and poor, based on the marking criteria established by the Malaysian Education Council (Ministry of Education Malaysia, 2016). In the PT3 (Year 9 National-Based Examination), grades A and B were recorded as 1 (indicating good results), grades C and D were recorded as 2 (indicating moderate results), and grades E and

F were classified as 3 (indicating poor results). In the SPM (Year 11 National-Based Examinations), the grades A+, A, and A- were recorded as 1 (good results), grades B+, B, C+, and C were recorded as 2 (moderate results), while grades D, E, and G were recorded as 3 (poor results).

Sociodemographic Factors

The variables from the parental and student questionnaire (adapted from the Northern Ireland Young Hearts project) in this study were gender, ethnicity, gross monthly family income, the highest level of education of the parents/guardian, and place of residency (Gallagher et al., 2002; Hazreen et al., 2019).

Anthropometric Measurements

The anthropometric measurements were taken by trained personnel. Measurements taken were the weight, height, waist circumference, hip circumference, and body fat percentage. The body fat percentage was measured using the Tanita portable Body Composition Analyser SC-240 MA. The SC-240 Tanita measurement uses footpad electrodes and a single frequency of 50–60 kHz. Prior to an assessment, the participant's height, gender, and age were entered into the bioelectrical impedance analyser (BIA). Then, the participants stepped onto the platform barefoot, and the percentage of body fat was recorded to the nearest decimal fraction. BMI, waist-to-hip ratio, and waist-to-height ratio were then calculated as all three indices provide different information related to obesity. All anthropometric measurements were then categorised. The body fat reference was categorized based on age and gender, utilizing cut-off points at the 85th and 95th percentiles to define overweight and obesity, respectively (McCarthy et al., 2006). The International Obesity Task Force was used to categorise overweight and obesity with adjustments made to align with adult BMI thresholds: 25 kg/m² for overweight (21.91 kg/m² for males and 22.58 kg/m² for females) and 30 kg/m² for obesity (26.84 kg/m² for males and 27.76 kg/m² for females) (Cole et al., 2000). Abdominal obesity was characterised by a waist-to-hip ratio greater than 0.90 for males and greater than 0.85 for females (WHO, 2008). The cut-off value for the waist-to-height ratio was based on the National Institute for Health and Care Excellence (NICE) guideline of <0.5, indicating no increased health risk (Eslami et al., 2022; National Institute for Health and Care Excellence, 2023). Among the anthropometric measurements, waist-to-height ratio was used in further analysis as it is a better predictor of health risk related to obesity.

Dietary Measurements

The seven-day recall diet history is the most feasible method to obtain dietary information from school students (Burrows et al., 2010; Gallagher et al., 2002; Mehranfar et al., 2024). A 7-day diet history provides a more comprehensive understanding of emerging dietary patterns, particularly variations in macronutrient intake (van Staveren et al., 1985) and provides a more comprehensive representation of adolescents' habitual intake compared to other methods (Livingstone et al., 1992). The seven-day diet history method is cost-effective, easy to implement in a population-based study and culturally relevant, making it accessible and easy for participants to recall local food practices (Hazreen et al., 2016). The dietary intake and portion sizes of food consumed at various mealtimes over a period of seven days were meticulously documented through face-to-

face interviews conducted by qualified dietitians. The collection tools utilised for the seven-day dietary history included household measurement instruments, food flipcharts, and a structured diet history collection tool. Participants provided a detailed account of their food intake, covering meals from breakfast until bedtime, with specific inquiries regarding portion sizes and meal compositions. To capture weekend variations in dietary habits, participants were probed about their social activities, alterations in meal timing, the consumption of indulgent foods, and differences in portion sizes. Household measurement tools, such as cups, bowls, plates, spoons, and ladles, were employed during the interview sessions to assist in accurately estimating portion sizes. Food flip charts suggested by Atlas of Food Exchange and Portion Size (Abdul Manaf et al., 2015) that outlined common Malay, Chinese and Indian foods were used to help with the seven-day diet history recall. Each diet history was translated into coding sheets. The code for the food/drink was extracted mainly from the Nutrient Composition of Malaysian Food, and new codes were given for recipes that were not available in the Nutrient Composition of Malaysian Foods (Ministry of Health Malaysia, 2011; Tee et al., 1997). The nutrient intake (energy, carbohydrate, protein, fat) was calculated by the Nutritionist Pro Diet Analysis software, Axxya Systems, United States of America (Axxya Systems, 2015). Participants with implausible energy intake (<500 kcal/day or >5000 kcal/day) were excluded from dietary data analysis (Ng et al., 2019).

Haemoglobin, Blood Pressure and Heart Rate Recovery

The blood parameter examined in this study was the levels of haemoglobin (g/dL). The normal haemoglobin levels for males were defined as ≥ 13 g/dL, while for females, the threshold was established at ≥ 12 g/dL (WHO, 2011). Additionally, blood pressure was evaluated, with a reading of $\leq 120/80$ mmHg considered to be within the normal range. Heart rate recovery was assessed using the Modified Harvard Test, which serves as an indicator of physical fitness. This assessment was conducted under the close supervision of a Sports Medicine Physician. Maximum heart rate was recorded at the conclusion of each minute during the initial five minutes of exercise, while recovery heart rate measurements were taken three times (at 0, 1, and 2 minutes) within the first two minutes following the cessation of exercise (Hazreen et al., 2019).

Statistical Analysis

Data analysis was conducted utilising the Statistical Package for Social Sciences software for Windows (version 25.0). An analysis of missing values was performed, revealing that the data was not missing completely at random. Subsequently, multiple imputations were implemented to address the missing data. For numerical variables, assumptions of normality were assessed using the continuous dataset. Most variables were recoded, and some were categorised according to syntax pertinent to demographic characteristics and the associated options for all variables, with the exception of the dependent variable and the physical activity level.

Multicollinearity was examined, and variables exhibiting a correlation greater than 0.8 or a variance inflation factor (VIF) exceeding 10, which indicates high multicollinearity, were not included in the modelling process. The significance level was established at 0.05, and a 95% confidence interval was reported for all descriptive and inferential statistics. Weighting was

applied to each respondent due to the complex multi-stage sampling design employed in this study. This approach effectively addresses issues arising from varying selection probabilities and nonresponse.

The statistical tests conducted involved complex analysis, ensuring that the data obtained is representative of the studied population. The student weightage was calculated based on the total number of students from each school participating in the current study, while the school weightage was derived from the total number of schools involved within each stratum. The combined school and student weightage yielded the final weights used in the analysis.

Descriptive statistics, Chi-square tests, univariate ordinal regression, and multivariate ordinal regression analyses were conducted. A descriptive analysis was performed to elucidate the fundamental findings regarding sociodemographic information, anthropometric measurements, dietary intake (including total energy, protein, and iron), as well as anaemia outcomes. Continuous data were presented as means with standard deviations, while categorical data were conveyed in terms of frequencies and percentages, as the majority of the data comprised categorical variables. Pearson's Chi-square test was utilised to assess the relationships between categorical variables. The investigation explored physical activity, anthropometric measurements, haematological parameters, dietary factors, and vital signs in relation to national examination results. Additionally, the relationship between physical activity and national examination outcomes was analysed while controlling for sociodemographic characteristics, anthropometric measurements, and energy intake.

Ethical Approval

Ethical approval was obtained from the Medical Ethics Committee, University Malaya Medical Centre (MEC Ref. No: 896.34) in 2012 and from the National Medical Research Register (14-376-20486) in 2014. Written informed consent was obtained from the parents or guardians and even from the participants. Participation in this study is voluntary. Parents and participants gave consent to participate in future research related to the MyHeART study.

Results

Sociodemographic Characteristics of Participants

The majority of the participants in this study, as shown in Table 1, were female (72.3%). Malays made up a large number of participants at 76.5%, followed by Indians at 9.9%, Chinese at 8.6%, and Others (Indigenous groups in the peninsula, Indigenous groups in Sabah and Sarawak, Eurasians and minority ethnic communities such as the Sikhs) at 5%. There were nearly equal percentages of participants from the urban and rural areas, with the rural participants being at 53.4%. A significant majority of the participants (82.6%) came from households with income less than RM3000 (USD 600) per month. As for parents' highest education, most of the parents at least had secondary school education.

Table 1 Sociodemographic characteristics of participants

Variable		Unweighted (n=579) n (%)
Gender	Boy	161(27.8)
	Girl	418(72.2)
Race	Malay	442 (76.3)
	Chinese	50 (8.6)
	Indian	58 (10.0)
	Others	29 (5.0)
School by locality	Urban	269(46.5)
	Rural	310(53.5)
Monthly income	< RM 1500	328(56.6)
	RM1500-RM3000	159 (27.5)
	RM3001-RM5000	55 (9.5)
	>RM5000	37 (6.4)
Mother's highest education	Non-schooling/Never schooled	14 (2.4)
	Primary school	62 (10.7)
	Secondary school (Form 1-3)	170 (29.4)
	Secondary school (Form 4-5)	246 (42.5)
	STPM/Matriculation/A-Level	32 (5.5)
	College/University/Diploma/Degree/Masters/PhD	52 (9.0)
	Others	3 (0.5)
Father's highest education	Non-schooling/Never schooled	8 (1.4)
	Primary school	58 (10.0)
	Secondary school (Form 1-3)	165 (28.5)
	Secondary school (Form 4-5)	264(45.6)
	STPM/Matriculation/A-Level (Foundation Studies?)	28 (4.8)
	Tertiary education/College/University/Diploma/Degree/Masters/PhD	53 (9.2)
	Others	3 (0.5)

Physical Activity Levels Among Adolescents Over the Years

Only 2.2% of the adolescents in 2014 had good levels of physical activity, and this further declined to 1.2% in 2016. The percentage of those with moderate physical activity levels in 2014 (45.4%) reduced to 39.5% in 2016. As for those with poor levels of physical activity, it increased from 52.4% in 2014 to 59.5% in 2016, as shown in Table 2.

Table 2 Physical activity levels among participants over the years

Variable	2014 (% / 95%CI)	2016 (% / 95%CI)
PA		
Good	2.2% (1.1,4.8)	1.2% (1.1,2.2)
Moderate	45.4% (39.7,51.3)	39.5% (33.9,45.5)
Poor	52.4% (46.6,58.2)	59.5% (53.3,65.2)

Progression of Characteristics of Participants from T1(2014) to T2 (2016)

Overall, when we look at the progression of participants' characteristics in Table 3, there was an increase in the percentage of those who were overweight and obese, an increase in those with anaemia and inadequate iron, and an increase in students with inadequate dietary intake. There were significant changes over the years in the trend of all characteristics except in energy, carbohydrate, and fat intake. Although there was an increase in the number of those with inadequate energy, carbohydrate, and fat intake in 2016 (Table 3), the changes were not statistically significant.

Table 3 Trend of characteristics in participants over the years

2014		2016			Adjusted F	p-value
	PHYSICAL ACTIVITY					
	Good (% /95%CI)	Moderate(% /95%CI)	Poor (%/95%CI)			
Good	4.6 (0.6,28.8)	83.1 (49.4,96.1)	12.3 (2.1,48.0)		21.71	<0.001
Moderate	1.1 (0.4,3.2)	60.6 (51.0,69.5)	38.3 (29.5,47.9)			
Poor	0.7 (0.2,2.9)	19.5 (13.8,26.8)	79.8 (72.5,85.6)			
	BMI (kg/m²)					
	Thinness(% /95% CI)	Normal Weight (% /95% CI)	Overweight(% /95% CI)	Obesity(% /95% CI)		
Thinness	87.3 (77.6,93.2)	12.7 (6.9,22.4)	-	-	55.34	<0.001
Normal	15.3 (10.0,22.6)	77.6 (70.0,83.8)	7.1 (4.0,12.3)	-		
Weight						
Overweight	-	23.6 (12.0,41.1)	61.3 (44.5,75.8)	15.1 (6.8,30.4)		
Obesity	-	1.8 (0.4,7.1)	8.4 (2.9,22.1)	89.8 (76.7,95.9)		
	SYSTOLIC BP (mmHg)					
	Normal(% /95% CI)	Abnormal (% /95% CI)				
Normal (<120 mmHg)	91.5 (89.1,93.5)	8.5 (6.5,10.9)			51.03	<0.001
Abnormal	61.4 (48.7,72.7)	38.6 (27.3,51.3)				
	DIASTOLIC BP (mmHg)					
	Normal(% /95% CI)	Abnormal(% /95%CI)				
Normal (<80mmHg)	95.2 (93.2,96.6)	4.8 (3.4,6.8)			31.18	<0.001
Abnormal	72.8 (56.9,84.4)	27.2 (15.6,43.1)				

Table 3 continued

2014		2016			Adjusted F	p-Value
WAIST CIRCUMFERENCE (cm)						
	Normal (% /95% CI)	Abdominal Obesity (%/95% CI)			215.59	<0.001
Normal	97.5 (95.6,98.6)	2.5 (1.4,4.4)				
Abdominal Obesity	27.0 (15.7,42.4)	73.0 (57.6,84.3)				
BODY FAT PERCENTAGE						
	Underfat (% /95% CI)	Normal(% /95% CI)	Overfat(% /95% CI)	Obese(% /95% CI)	53.00	<0.001
Underfat	79.7 (63.2,90.0)	19.7 (9.6,36.3)	-	0.6 (0.1,4.0)		
Normal	6.1 (3.0,12.1)	90.0 (84.1,93.8)	3.5 (1.9,6.3)	0.5 (0.1,1.4)		
Overfat	-	54.2 (38.2,69.3)	41.0 (26.5,57.3)	4.8 (2.0,11.3)		
Obese	-	8.6 (3.7,18.8)	23.4 (13.7,37.0)	68 (54.8,78.8)		
WAIST-TO-HEIGHT RATIO						
	Normal (% /95% CI)	Abnormal(% /95% CI)			120.10	<0.001
Normal	93.6 (88.8,96.4)	6.4 (3.6,11.2)				
Abnormal	28.4 (19.5,39.4)	71.6 (60.6,80.5)				
WAIST-TO-HIP RATIO						
	Normal (% /95% CI)	Obesity(% /95% CI)			103.93	<0.001
Normal	92.3 (88.9,94.7)	7.7 (5.3,11.1)				
Obesity	36.4 (23.6,51.4)	63.6 (48.6,76.4)				
DIETARY IRON (mg)						
	Adequate(% /95% CI)	Inadequate(% /95% CI)			34.00	<0.001
Adequate	41.8 (31.3,51.3)	58.2 (46.7,68.9)				
Inadequate	10.7 (7.1,15.8)	89.3 (84.2,92.9)				

Body fat percentage - Underfat: Suboptimal fat; Overfat: pre-obese.

Table 3 continued

2014		2016		Adjusted F	p-Value
HAEMOGLOBIN (g/dL)					
	Normal (% /95% CI)	Abnormal(% /95%CI)		112.09	<0.001
Normal	92.8 (88.4,95.6)	7.2 (4.4,11.6)			
Abnormal	29.0 (18.3,42.7)	71.0 (57.3,81.7)			
ENERGY INTAKE (kcal/day)					
	Adequate(% /95% CI)	Inadequate(% /95% CI)		0.112	0.737
Adequate	25.9 (20.3,32.5)	74.1 (67.5,79.7)			
Inadequate	27.5 (21.0,35.1)	72.5 (64.9,79.0)			
PROTEIN INTAKE (g/day)					
	Adequate(% /95% CI)	Inadequate(% /95% CI)		6.65	0.010
Adequate	83.0 (77.4,87.5)	17.0 (12.5,22.6)			
Inadequate	66.4 (51.6,78.5)	33.6 (21.5,48.4)			
CARBOHYDRATE INTAKE (g/day)					
	Below Normal (% /95% CI)	Normal(% /95% CI)	Above Normal(%/95% CI)	2.03	0.089
Below Normal	63.3 (54.9,70.9)	29.0(21.8,37.3)	7.8 (4.7,12.7)		
Normal	52.5 (41.8,62.9)	34.4 (24.8,45.4)	13.2 (7.9,21.2)		
Above Normal	43.0 (30.7,56.2)	43.3 (31.0,56.5)	13.7 (7.7,23.1)		
FAT INTAKE (g/day)					
	Below Normal (% /95% CI)	Normal(% /95% CI)	Above Normal(%/95% CI)	0.629	0.632
Below Normal	61.2 (52.0,69.7)	30.8 (22.9,40.2)	7.9 (4.8,12.8)		
Normal	56.7 (47.5,65.5)	33.2 (25.6,41.8)	10.1 (5.7,17.3)		
Above Normal	50.1 (38.1,62.1)	37.8 (26.9,50.2)	12.1 (7.6,18.8)		

Association of Physical Activity and National-based Year 9 Examinations

In Year 9, as indicated in Table 4, a positive correlation was identified between physical activity and enhanced performance in the Malay Language (Oral), English Language (Oral), Mathematics, and Science. Participants exhibiting high levels of physical activity demonstrated 19.7 times greater odds of excelling in the Malay Language (Oral) compared to their counterparts with low physical activity levels. In the context of the English Language (Oral) subject, those who engaged in regular physical activity experienced 11.2 times higher odds of performing better, while individuals categorised as moderately active had 3.1 times higher odds compared to those with poor physical activity. Furthermore, participants with good physical activity levels performed 3.9 times better in Mathematics, and those with moderate physical activity showed 1.8 times improvement over those with poor levels. Lastly, there was a 3.9 times higher likelihood of achieving better results in Science among those demonstrating high levels of physical activity.

Table 4 Association of Physical Activity and National-based Secondary School Examinations (Year 9).

No	Subjects	Physical activity levels	Crude	p-value	Physical activity levels	Adjusted *	p-value
1.	Malay Language (Written)	Good PA	1.44 (0.78, 2.66)	0.087	Good PA	2.65 (0.71, 9.95)	0.007
		Moderate PA	1.61 (1.04, 2.50)		Moderate PA	2.27 (1.35, 3.82)	
2.	Malay Language (Oral)	Good PA	8.79 (1.75, 44.16)	0.017	Good PA	19.69 (2.10, 184.73)	0.016
		Moderate PA	1.40 (0.86, 2.27)		Moderate PA	1.57 (0.92, 2.69)	
3.	English Language (Written)	Good PA	4.59 (0.72, 29.31)	0.153	Good PA	4.91 (0.43, 55.95)	0.206
		Moderate PA	1.34 (0.85, 2.14)		Moderate PA	1.39 (0.84, 2.31)	
4.	English Language (Oral)	Good PA	9.78 (2.17, 44.16)	<0.001	Good PA	11.17 (1.76, 71.01)	<0.001
		Moderate PA	3.16 (2.03, 4.92)		Moderate PA	3.09 (1.89, 5.06)	
5.	Mathematics	Good PA	4.66 (1.78, 27.94)	0.019	Good PA	3.93 (1.40, 39.23)	0.045
		Moderate PA	1.84 (1.13, 3.01)		Moderate PA	1.84 (1.08, 3.11)	
6.	Science	Good PA	3.36 (1.93, 12.16)	0.032	Good PA	3.98 (1.68, 23.32)	0.043
		Moderate PA	1.41 (0.82, 2.43)		Moderate PA	1.46 (0.83, 2.56)	
7.	History	Good PA	3.94 (0.54, 28.92)	0.252	Good PA	7.24 (0.61, 86.00)	0.146
		Moderate PA	1.33 (0.80, 2.21))		Moderate PA	1.67 (0.86, 3.25)	
8.	Geography	Good PA	4.73 (0.87, 25.69)	0.170	Good PA	9.35 (1.37, 63.95)	0.039
		Moderate PA	1.21 (0.73, 2.00)		Moderate PA	1.59 (0.90, 2.84)	

corrected for all sociodemographic characteristics (gender, household monthly income, locality, mother and father's highest education, waist-height ratio and energy intake)
PA: physical activity (Low PA was used as the reference group)

Association of Physical Activity and National-based Year 11 Examinations

In Year 11 (Table 5), an association was observed between physical activity and academic performance in Mathematics, Chemistry, and Principles of Accounting. Participants exhibiting high levels of physical activity demonstrated 6.5 times greater odds of achieving superior performance in Mathematics when compared to those with low levels of physical activity. Furthermore, individuals with moderate levels of physical activity outperformed their less active peers in Chemistry by a factor of 7.2. In the Principles of Accounting subject, participants who engaged in regular physical activity exhibited 3.5 times greater odds of achieving better results than those with poor physical activity levels.

Table 5 Association of Physical Activity and National-based Secondary School Examinations (Year 11)

No	Subjects	Physical activity levels	Crude	p-value	Physical activity levels	Adjusted *	p-value
1.	Malay Language	Good PA	3.96 (0.99, 15.78)	0.043	Good PA	2.77 (0.39, 19.93)	0.108
		Moderate PA	0.70 (0.42, 1.17)		Moderate PA	0.60 (0.34, 1.06)	
2.	English Language	Good PA	1.13 (0.15, 8.76)	0.56	Good PA	1.60 (0.18, 14.36)	0.786
		Moderate PA	0.78 (0.49, 1.24)		Moderate PA	1.16 (0.71, 1.91)	
3.	Mathematics	Good PA	5.22 (1.68, 40.20)	0.030	Good PA	6.52 (1.45, 93.74)	0.048
		Moderate PA	0.63 (0.40, 0.99)		Moderate PA	0.78 (0.45, 1.35)	
4.	Science	Good PA	1.65 (0.49, 5.58)	0.522	Good PA	1.79 (0.17, 18.30)	0.883
		Moderate PA	0.79 (0.41, 1.51)		Moderate PA	1.06 (0.52, 2.17)	
5.	History	Good PA	1.28 (0.25, 6.45)	0.698	Good PA	1.19 (0.11, 13.22)	0.638
		Moderate PA	0.83 (0.52, 1.33)		Moderate PA	0.79 (0.47, 1.31)	
6.	Physics	Good PA	1.70 (0.30, 9.55)	0.744	Good PA	15.54 (1.74, 138.66)	0.020
		Moderate PA	1.28 (0.57, 2.87)		Moderate PA	2.93 (1.12, 7.65)	
7.	Chemistry	Good PA	5.37 (0.91, 63.9)	<0.001	Good PA	9.24 (0.92, 100.30)	<0.001
		Moderate PA	1.88 (1.29, 4.51)		Moderate PA	7.29 (2.43, 21.87)	
8.	Biology	Good PA	14.20 (1.24, 162.95)	0.104	Good PA	16.52 (0.90, 178.2)	0.010
		Moderate PA	1.14 (0.40, 3.26)		Moderate PA	4.32 (1.28, 14.60)	
9.	Additional Mathematics	Good PA	1.57 (0.17, 14.67)	0.90	Good PA	2.09 (0.11, 40.83)	0.771
		Moderate PA	0.94 (0.46, 1.93)		Moderate PA	1.28 (0.59, 2.74)	
10.	Principles of Accounting	Good PA	2.76 (1.23, 92.8)	<0.001	Good PA	3.58 (1.12, 85.3)	<0.001
		Moderate PA	1.61 (0.64, 4.02)		Moderate PA	2.32 (0.77, 7.05)	
11.	Economics	Good PA	1.95 (0.03, 1184.7)	0.375	Good PA	4.79 (0.03, 683.25)	0.381
		Moderate PA	0.57 (0.25, 1.28)		Moderate PA	0.49 (0.14, 1.71)	
12.	Commerce	Good PA	1.95 (0.19, 20.26)	0.346	Good PA	2.62 (0.25, 28.06)	0.179
		Moderate PA	1.79 (0.79, 4.05)		Moderate PA	2.69 (0.94, 7.72)	

corrected for all sociodemographic characteristics (gender, household monthly income, locality, mother and father's highest education, waist-height ratio and energy intake)

PA: Physical activity (Low PA was used as the reference group)

Longitudinal Relationship of Physical Activity with Selected Subjects

The analysis conducted longitudinally evaluated four core subjects, each with an equal number of students. As illustrated in Figure 2, there were significant positive correlations among the performances in Malay Language, English Language, Mathematics, and History during Years 9 and 11 (p-value <0.001). This finding suggests that students who excelled in Year 9 also tended to achieve high performance in Year 11. Furthermore, physical activity during Year 9 was positively associated with Malay Language (p=0.020), English Language (p=0.003), and Mathematics (p=0.001). Conversely, physical activity in Year 11 did not demonstrate significant associations with any of the subjects examined. Additionally, a significant positive correlation between physical activity in Years 9 and 11 was observed (p<0.001).

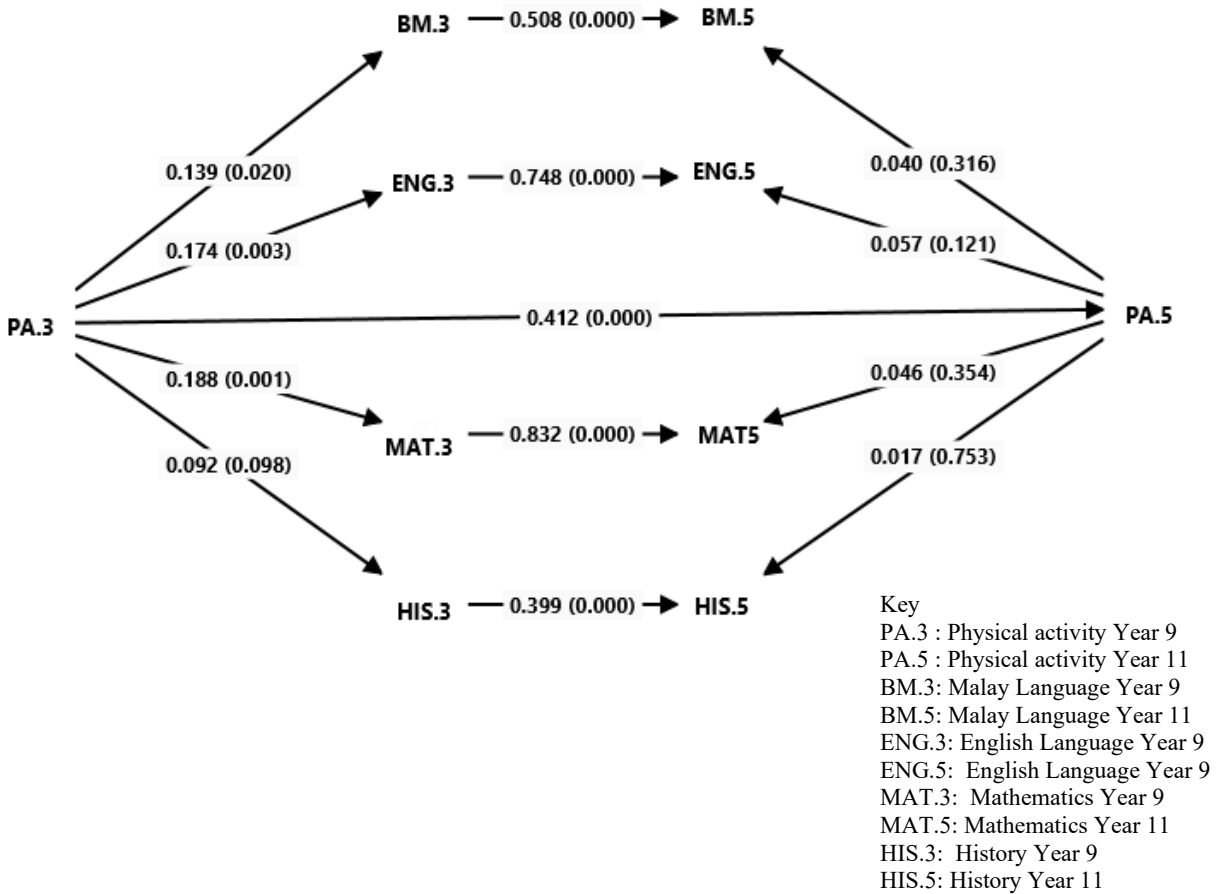


Fig. 2 Longitudinal relationship of physical activity with selected subjects

Figure 3 shows the longitudinal relationship between physical activity and selected subjects after being controlled for sociodemographic factors, energy intake, and waist-height ratio. Longitudinally, there were significant positive associations between the performances in the Malay Language, English Language, Mathematics, and History in both Year 9 and Year 11 (p -value <0.001). Physical activity in Year 9 was significantly associated with the Malay Language ($p<0.001$), English Language ($p<0.001$), and Mathematics ($p<0.001$). A significant association was also seen between physical activity in Year 9 and History ($p=0.002$), which was not observed prior to the control of other variables. In this analysis, physical activity in Year 11 was not associated with the four subjects. A significant positive relationship between physical activity in Year 9 and Year 11 was also observed ($p<0.001$).

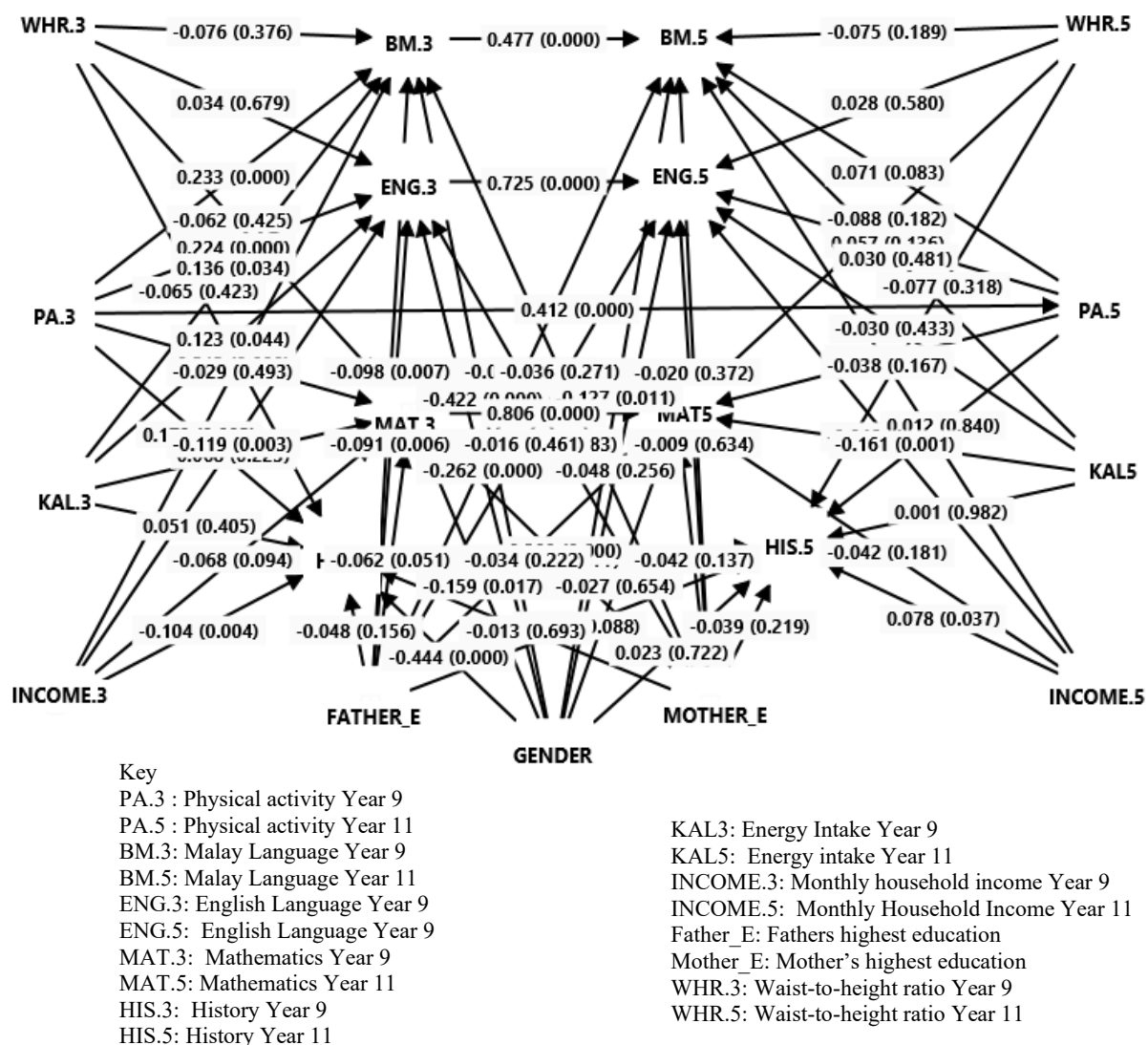


Fig. 3 Longitudinal relationship of physical activity with selected subjects after being controlled for sociodemographic characteristics, waist-to-height ratio and energy intake

Discussion

Physical Activity Levels and Other Measurements with the Trend Over Three Years

The majority of the students in both years had poor levels of physical activity. In 2014, only a small percentage of participants had good physical activity levels, and this percentage further decreased in 2016. The majority of those with good physical activity in 2014 shifted to the moderate physical activity category in 2016, while a smaller group moved to the poor physical activity category. There was a noticeable increase in the number of participants with poor physical activity levels from 2014 to 2016. Most of those with poor physical activity in 2014 continued to remain in that category in 2016. A significant portion of those with moderate physical activity in 2014 declined to the poor physical activity category in 2016.

This decline in physical activity levels is in line with the global picture. Around 81% of adolescents are physically inactive, and only 20% of Malaysian adolescents are physically active, as recommended by WHO (Shahril et al., 2022; WHO, 2018). This decline in levels of physical activity could be due to many factors, such as a lack of awareness of the importance of physical activity (Ahmad et al., 2021) and biological changes that occur during adolescence (Caldwell et al., 2023). During puberty, there is higher resting and total energy expenditure; this is due to an increase in body size, fat-free mass, skeletal growth, pubertal hormones, and neurocognitive changes. Throughout this phase, physical activity is reduced, and sedentary time is increased to conserve energy to meet these demands (Caldwell et al., 2023). Increased screen time and dependence on gadgets/ technology contribute to this decline (Almaqawi & Albarqi, 2022). Parents who are not involved in sports or who do not give emphasis to physical activity could also contribute to this decline (Charlton et al., 2014). In schools, teachers and administrators place emphasis on academic achievement. Slots for physical activity and education are at times taken over by other subjects deemed more important (Veloo et al., 2016). Environmental factors such as an unconducive neighbourhood, inadequate facilities, and equipment could also be contributing factors to the decline of physical activity (Ahmad et al., 2021).

The findings in this study are in line with many longitudinal studies. There was overall increase in the percentage of those who were overweight and obese (Gordon-Larsen et al., 2010; Molina et al.), an increase in those with inadequate iron and anaemia (Alshwaiyat et al., 2021; Saad & Qutob, 2022; Wang et al., 2023), as well as an increase in students with inadequate dietary intake (Kesztyüs et al., 2016; Mohd Sallehuddin et al., 2021). This study is also in line with the obesity epidemic and the effects associated with it (Sanyaolu et al., 2019).

Association of Physical Activity with National-based Examinations in 2014 (Year 9 Examinations) and 2016 (Year 11 Examinations)

Physical activity is associated with better results in the Year 9 Malay Language, English Language, Mathematics, and Science. In Year 11, three subjects, namely, Modern Mathematics, Chemistry, and Principles of Accounting, were associated with physical activity. Physical activity causes certain brain changes that would cause improved attention, memory, and cognition (Getu, 2020; Mandolesi et al., 2018). Many studies, whether locally or globally, reported similar findings

regarding the association noted in this study (Chung et al., 2018; Dzoolkarnain et al., 2021; McPherson et al., 2018; So, 2012).

Studies have reported positive associations between Mathematics and physical activity (Have et al., 2018; Hraste et al., 2018; Sember et al., 2022; Sneek et al., 2019; Syväoja et al., 2021; Zhou et al., 2022). Mathematics is associated with physical activity, as reported in this study, due to its role in executive functioning. Physical activity promotes nerve growth and induces vascularisation in the brain, which improves behaviour, thinking, and decision-making (Alvarez-Bueno et al., 2017).

This study also reported the association of languages with physical activity. Students with good physical activity had better performance in the Malay and English languages. This was also observed in a few other studies, especially in classroom-based physical activities (Lukančič, 2021; Mavilidi et al., 2019). Lukančič (2021) conducted a study with university students, which found that physical activity enhanced their understanding, memory, and learning of the Italian language. Similarly, a study by Mavilidi (2019) conducted with primary school children demonstrated that the Thinking While Moving in English (TWM-E) programme had positive effects on the children's English language skills. Language proficiency improves as physical activity strengthens the neural connections in the brain and improves blood perfusion to the brain, causing one to grasp language better. Sports and physical activity also helps develop good communication skills, which will improve the grasp in language (Martin-Martinez et al., 2023; Rudzinska & Jakovljeva, 2015). Studies reporting the association of physical activity with other subjects are scarce; however, a study carried out in the Middle East which used mean grades of Chemistry, Physics, Biology, Mathematics, Science, History, Geography, and Religious Study also reported better performance with physical activity (Alghadir et al., 2020).

Several variables were controlled for, namely, sociodemographic characteristics such as gender, locality, parent's highest education, and household monthly income. Energy intake and waist-to-height ratio were also controlled for in order to demonstrate the association of physical activity with national-based examination.

Some studies reported that the waist-to-height ratio is inversely associated with moderate-to-vigorous physical activity and negatively associated with the academic performance of students (Lee et al., 2016; Pathrudu, 2015). Increased adiposity is associated with lower hippocampal volume that may interfere with attention and verbal memory (Isaac et al., 2011). The waist-to-height ratio was chosen from all other anthropometric measurements to be controlled for, as it is a better predictor of screening obesity in a population and outperforms other measurements in predicting cardiometabolic risk (Ashtary-Larky et al., 2018; Bacopoulou et al., 2015; Pasdar et al., 2020; Shao et al., 2010; Sweatt et al., 2024; Tewari et al., 2023; Vikram et al., 2016).

Energy is crucial for the functioning of all cells in the body, especially neurons and the glial cells in the brain. Adequate energy intake was observed to help complement daily physical and mental activities, which will enable a person to perform better academically; thus, it was controlled for (Alqahtani et al., 2020; MacLellan et al., 2008; Woodhouse et al., 2012).

Longitudinally, it was noted that if a student performs better academically or in physical activity in Year 9, they will do well in Year 11, as well. Good habits that are inculcated during childhood, be it excelling in studies or having an active lifestyle, will follow through into adolescence and adulthood (Acosta et al., 2015; Ha et al., 2019). Being physically active can improve a child's academic achievement and overall well-being.

Strengths and Limitations

This study is a novel longitudinal study on physical activity and national-based examinations. It is the first longitudinal study among Malaysian adolescents that provides details of physical activity levels, body composition, dietary intake, and blood parameters. Measurements were carried out using trained personnel. There were comprehensive anthropometric measurements using calibrated tools/equipment and dietary and physical activity assessments using validated methods/questionnaires.

This study used national-based examinations, which were examinations that were standardised nationwide and not self-reported grades. National-based examinations are designed and graded according to uniform standards by the Malaysian Examination Council, ensuring consistency across all test-takers. Standardised exams allow for a level of comparison across different schools, providing a more consistent benchmark for assessing student performance. Although, at present, the Year 9 national-based examination has been replaced with a School Based Assessment, the subject matter is similar; only the mode of assessment has changed over time. The foundational principle within each subject remains relevant despite changes in the system. The primary goals of education, such as critical thinking, literacy, and numeracy, have not fundamentally changed. The findings of this study will encourage both adolescents and parents to engage more actively in physical activity, with the aim of improving academic performance. This study yields promising results and warrants the need for further research on a larger scale. Being a longitudinal study, it has also enabled us to make associations between variables of interest. The variables in the study were weighted, which provided a better depiction of the population estimates at large. Not many studies have explored the association of physical activity with other subjects. Most studies focused on Mathematic and Language Skills; however, this study was able to provide insights into the association between physical activity and better performance in Languages (Malay and English), Mathematics, Science, Chemistry, and Principles of Accounting.

This is a cohort study, and the non-return of respondents and missing data are some of the issues that occur in this study design. Since the data was noted to be missing at random, multiple imputation was carried out to overcome this issue. As with all studies on self-reported physical activity or dietary research, recall bias could be a limitation. However, this method is suitable in the current setting and among adolescents, especially since they have better overall memory quality, better recollective memory, and an increase in the precision of details (Schlichting et al., 2022). Under-reporting or over-reporting may occur, but these issues were overcome when the data was analysed using multiple imputations to adjust for potential biases.

Conclusion

This study offers valuable insights into the trends of physical activity among adolescents in an upper-middle-income country, highlighting the significance of understanding how these trends relate to national examination outcomes. The findings suggest that promoting a healthy lifestyle, particularly through robust physical activity programmes in schools, plays a crucial role in the overall development and academic success of adolescents.

Furthermore, the study underscores the necessity of implementing targeted intervention programmes that focus on enhancing physical activity among young people. By addressing the gaps identified in this research, these interventions could lead to improved health behaviours and academic performance. Ultimately, the data gathered can inform the creation and refinement of public health policies aimed at fostering a more active and healthier generation of youth.

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