



Research article

University students' overall and domain-specific physical activity during COVID-19: A cross-sectional study in seven ASEAN countries

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ABSTRACT

This research investigated the overall and domain-specific physical activity (PA) of university students in the coronavirus disease 2019 (COVID-19) pandemic. A cross-sectional study was applied to socioeconomic (SE) and PA online data collected from 15,366 students across 17 universities in seven Association of Southeast Asian Nations (ASEAN) countries. Statistical analyses using logistic regressions established SE-PA relationships. Over half (60.3%) of ASEAN university students met age-span specific PA guidelines. Students participated in recreational PA the most, followed by study-related activities and 44.1% of students engaged in >8 hrs/day of sedentary time (ST). Compared to students with a normal body mass index (BMI), students who were underweight (UW), overweight (OW), and obese (OB) respectively, had a 14% (UW odds ratio (OR) = 1.14, $p = 0.005$), 25% (OW OR = 1.25, $p < 0.001$), and 24% (OB OR = 1.24, $p = 0.005$) greater probability of meeting PA guidelines. Those who engaged in active transport and belonged to a sports club (SC) had 42% (SC OR = 0.58, $p < 0.001$, for both) less probability of meeting the PA guidelines, compared with those who travelled inactively and did not belong to a sports club, respectively. Students who participated in 4–6 sport or exercise activities had ten times more likelihood of meeting PA guidelines (OR = 10.15, $p < 0.001$), compared with those who did not play any sport or do any exercise. Students who spent >8 hrs/day of ST had 32% (ST OR = 0.68, $p < 0.001$) less probability of meeting PA guidelines, compared with those who spent <3 hrs of ST. These data showed that over half of ASEAN university students achieved PA guidelines and were highly sedentary during the COVID-19 pandemic. Recreational and study-related activities were important for students to maintain sufficient PA and should be actively promoted within the restrictions imposed during periods of the COVID-19 pandemic lockdowns.

1. Introduction

In 2019, the World Health Organization (WHO) reported that 40.8 million out of 55.4 million (73.6%) deaths worldwide were due to non-communicable diseases (NCDs) [1]. Physical inactivity (i.e. not meeting age-span specific PA guidelines) is a modifiable risk factor for NCDs besides tobacco smoking, alcohol consumption, unhealthy diet, and air pollution. Globally, the economic costs of physical inactivity

contributed to INT\$ (international dollars) 54 billion/year for direct health care and INT\$ 14 billion attributable for productivity loss [2]. In Southeast Asia, NCDs caused an estimated 9 million (68.6%) of the 13.2 million regional deaths in 2016 [1]. Insufficient physical activity (PA) caused almost 300,000 deaths in the Southeast Asia region annually [2]. The direct and indirect economic burden of physical inactivity in the region was estimated at INT\$ 1,500 million in 2013 [2]. The WHO adopted the NCD Global Monitoring Framework with an aim to achieve a

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15% relative reduction in physical inactivity levels by 2030 [3]. Nevertheless, based on worldwide trends of increasing levels of insufficient PA over time, it was forecasted that the global physical inactivity target would be difficult to achieve unless effective policies are seriously implemented, and multisectoral collaborations take place [4].

The ten member countries of the Association of Southeast Asian Nations (ASEAN) have been collaborating in many aspects, including on education and health. The ASEAN University Network – Health Promotion Network (AUN–HPN) has promoted healthy behaviors including PA among students based on its Healthy University Policy or Framework [5]. In ASEAN, there are more than 100 million people aged 15–24 years, and approximately 20 million of this population are university students [6]. Health behaviors that students establish during their university life can have a long-term impact on their PA habits and incidence of NCDs in their adulthood [7]. Thus, university is an important setting to promote a healthy active lifestyle. However, since the establishment of the AUN–HPN in 2014, the baseline information about PA levels among ASEAN university students has been unknown. A study conducted in 2015 in low- and middle-income countries included five ASEAN countries (Indonesia, Laos, the Philippines, Singapore, and Thailand), showed that 46% of young adults aged 18–25 years met the WHO PA guidelines of at least 150 min/week of moderate-intensity or 75 min/week of vigorous-intensity PA (or any equivalent combination of the two) [8]. Other studies conducted in Malaysia and Thailand showed the prevalence of meeting the PA guidelines among university students at 58.6% and 49.5% respectively [9, 10]. Typically, the prevalence of university students' overall PA levels is presented with limited information about participation in domain-specific PA (e.g., transportation and recreation) [11, 12, 13].

Understanding domain-specific PA among university students is helpful for developing interventions to promote PA. Furthermore, the information about sociodemographic factors associated with PA in ASEAN university students is also scarce with only a few factors confirmed as correlates of PA, such as gender and age [8, 14, 15, 16]. Body mass index (BMI), year of study, grade point average (GPA), and living arrangements have been examined, but their associations with meeting the PA guidelines were mixed and inconclusive [9, 11, 16]. The evidence drawn from Western or developed countries might be different evidence from less developed or Asian countries due to cultural and social contexts. Although there is growing evidence from these countries, the evidence from the ASEAN countries is still limited. With this limited information, the development of well-informed PA promotion policies and strategies for the AUN–HPN is challenging. In an effort to address this gap, the present research investigated the overall and domain-specific PA participation, and sedentary time (ST) among university students in seven ASEAN countries. Results of this research provide important evidence on the current state of PA and ST to promoters of PA among university students, particularly to AUN–HPN and its member universities.

2. Methods

2.1. Study design and participants

This study is part of a larger multinational cross-sectional research project, called “AUN–HPN health behavioral survey”. All AUN–HPN member universities were invited to participate in the research project, and their participation was based on a voluntary basis. Eventually, 17 member universities from seven ASEAN countries, namely Brunei Darussalam, Indonesia, Malaysia, Philippines, Singapore, Thailand, and Vietnam accepted the invitation (Table 1). Participants were undergraduate students aged 18–22 years. All eligible undergraduate students in participating universities were invited to complete the online survey. Student recruitment and the online survey distribution were coordinated by representatives of each university and was tailored to the culture and practices of each university. Students were invited to participate through

Table 1. ASEAN University Network – Health Promotion Network (AUN–HPN) member universities participating in the study.

Countries (Number of participating universities)	Name of participating universities
Brunei Darussalam (1)	1. Universiti Brunei Darussalam
Indonesia (3)	2. Universitas Airlangga 3. Universitas Gadjah Mada 4. Universitas Indonesia
Malaysia (2)	5. University of Malaya 6. Universiti Putra Malaysia
The Philippines (1)	7. Ateneo de Manila University
Singapore (1)	8. Nanyang Technological University
Thailand (8)	9. Burapha University 10. Chiang Mai University 11. King Mongkut's University of Technology North Bangkok 12. Naresuan University 13. Mahasarakham University 14. Mahidol University 15. Thammasat University 16. Walailak University
Vietnam (1)	17. Vietnam National University Ho Chi Minh City

several media, including public relations posters, university-wide email circulation, official university social media channels such as group LINE (Line Corporation, Tokyo, Japan), Instagram, Facebook, and WhatsApp (WhatsApp LLC, CA, USA). Participants accessed the survey through a link or a QR code provided in the media. Students were encouraged to participate in the study by being eligible for a prize draw for fifty smart watches. All participating universities collected data during March to June 2021, when movement and social gathering restrictions were imposed in different forms in all participating universities due to the coronavirus disease 2019 (COVID-19) pandemic.

2.2. Instruments and measurement

The AUN–HPN health behavioral survey comprised seven sections: 1) Physical activity (PA), 2) Social support for PA, 3) University's environment, 4) Health-related behaviors, 5) Mental wellbeing, 6) Opinion regarding university support, and 7) Sociodemographic information. PA and sociodemographic data of students reported in this present study were retrieved from this online survey. The survey was developed based on previously tested instruments [17]. The online survey and all recruitment materials, originally developed in English, were translated into four languages that included Bahasa Indonesia, Malay, Thai, and Vietnamese. The translations were back translated into English according to the World Health Organization (WHO) guidelines [18] to ensure comprehension and understanding of the questionnaire items, and to check for any inaccuracies in the translated versions. The online survey was pilot-tested with university students for comprehension of the survey and functionality of the online Qualtrics survey platform (Qualtrics International Inc., WA, USA). The online survey was revised based on student feedback from the pilot test.

Participation in PA was measured using the 16-item Global Physical Activity Questionnaire (GPAQ) version 2.0 developed by WHO [19]. The GPAQ had an acceptable concurrent validity ($r = 0.54$) and high level of repeatability (0.67–0.81) [19,20]. In essence, university students' PA participation in three contexts were collected: in study, transportation, and recreation. According to the WHO PA guidelines [21] and GPAQ analysis guides [22], students were categorized as “meeting the PA guidelines” when they achieved ≥ 150 min/week of moderate-intensity PA or ≥ 75 min/week of vigorous-intensity PA or an equivalent combination of moderate- and vigorous-intensity PA achieving ≥ 600 metabolic equivalent (MET)-mins/week (a measure of energy expenditure of 1 MET equals 1 kcal/kg/h) [23]. Students were categorized into “not meeting the PA guidelines” when they failed to comply with these conditions.

Hours of sedentary behavior were also collected by the GPAQ and categorized into low (≤ 3 hrs), moderate (4–8 hrs), and high (> 8 hrs). Data on amount of sleep hours were collected and grouped into < 7 hrs and ≥ 7 hrs.

Sociodemographic and other associated student data included age, gender, year of study, country of residence, GPA, living arrangement, type of commute to/from university, type of housing, sports club membership, and number of sport/exercise activities engaged. Height and weight were used to calculate BMI and results were classified into 4 groups: underweight (< 18.5 kg/m²), normal (18.5–22.9 kg/m²), overweight (23.0–24.9 kg/m²), and obese (≥ 25 kg/m²), according to the WHO Asian cut-off for BMI [24]. GPA was standardized into a scale of 1–5, and categorized into low (≤ 3.2), moderate (3.3–3.9), and high (> 3.9). Type of commute to/from university was assessed by asking how students usually commuted to/from university. A list of possible means of transportation were provided, and responses were categorized into “inactive” when students traveled by motorized vehicles, and “active” when they walked/biked. For the number of sport/exercise activities students engaged in, they were asked if they did any sport/exercise activities over the past seven days. A list of the activities was provided. Responses were computed and classified into four categories (0, 1–3, 4–6, and > 6 activities).

2.3. Statistical analysis

Data cleaning procedures such as removal of ineligible cases, duplicate responses, invalid questionnaire responses, and responses with more than 50% missing values (listwise deletion), were employed to minimize errors before conducting statistical analysis. Missing data in valid cases were handled using multiple imputation techniques set at 10 multiple imputations to replace missing with predicted values [25], using R package MICE (Multivariate Imputation by Chained Equations). All statistical analyses were computed using RStudio v.1.4.1717 (RStudio, MA, USA).

Descriptive statistics were used to describe the participant characteristics, PA, ST, and sleep time stratified by gender as well as prevalence of those who met the PA guidelines stratified by gender and age. Chi-square tests for independence were performed to investigate associations of gender with explanatory and outcome variables. The independent t-test was used to compare ST and gender where normal distribution of data is assumed according to the central limit theorem. However, for variables with large standard deviation, the alternative independent t-test without accounting for equal variance was used. Binary multiple logistic regressions were computed to investigate salient factors associated with PA levels. The binary multiple logistic regressions were adopted as they were helpful in differentiating and interpreting the results. Firstly, simple logistic regression was calculated to explore bivariate association between explanatory variables and meeting PA guidelines. Automatic stepwise variable selection was used to determine factors for the preliminary model, where lower Akaike information criterion (AIC) indicated better model selection. Variable selection was also checked manually to confirm the significance of selected variables. The variance inflation factor (VIF) was used to ensure multicollinearity was not present. All possible two-way interaction effects were also checked to ensure the main effects model was true. A Cook's distance graph was used to determine any outliers where distance of more than 1 indicated the presence of an outlier. Finally, the Hosmer-Lemeshow goodness of fit test was conducted to ensure that the data fitted well with the final model. Two-sided p-values of less than 0.05 were considered statistically significant.

2.4. Ethical approval and consent to participate

The study protocols were undertaken in accordance to relevant international (i.e. Declaration of Helsinki) and local ethical guidelines and regulations. The ethical approval for the whole study protocol was obtained from Mahidol University Central Institutional Review Board (MU-

CIRB 2020/089.0704). Ethical approval for the research were also obtained from all participating universities prior to conducting the research. All participants in the research provided informed consent online by clicking “I agree to participate” before participating in the survey.

3. Results

The final sample comprised 15,366 university students. One third of the respondents (33.2%) were from Vietnam, followed by Indonesia (28.8%) and Thailand (25.6%). The distribution by gender was almost equal (female at 52.6% vs. male at 47.4%), and 58.9% of the respondents belonged to a sports club. About two-thirds of respondents were 19–21 years old (66.3%), in year 1 of university studies (64.7%), achieved a GPA of 3.3–3.9 (69.2%), and lived off-campus (65.2%). Nearly half were underweight (48.2%). The majority of respondents lived in a single house (73.7%) and commuted to/from university inactively (82.9%) (Table 4).

Overall, 60.3% (95% confidence interval (CI): 52.9, 67.0) of the respondents met the PA guidelines in the COVID-19 pandemic (Table 2). The lowest proportion of students who met the PA guidelines were from Indonesia (45%) with the highest proportion coming from Thailand (71.7%). A significantly higher proportion of female university students (54.3%, 95% CI: 53.3, 55.4) met the PA guidelines than males (45.7%, 95% CI: 44.6, 46.6). These results were also similar for students from Brunei, Indonesia, Thailand, and Vietnam. A significantly higher proportion of students between 19–21 years old achieved the PA guidelines than students from other age categories for all of the countries.

The prevalence of university students' participation in domain-specific physical activities stratified by gender is presented in Table 3. Female students had a significantly higher average energy expenditure in study-related PA ($p < 0.001$) but also had significantly higher amounts of time spent on sedentary activities ($p = 0.002$) than male students. Male students spent a significantly higher average time in recreational PA ($p < 0.001$). A majority of students slept ≤ 7 hrs with a significantly higher proportion of females (71.4%) compared with males (65.8%) ($p < 0.001$). There was no significant difference in ST spent between males and females (Male: 7.84 hrs/day vs. Female: 8.05 hrs/day).

The associations between sociodemographic factors and meeting the PA guidelines are presented in Table 4. The results from multiple logistic regression revealed that BMI, country of residence, type of commute to/from university, belonging to any sports club, number of sport/exercise activities, and ST were significantly associated with meeting the PA guidelines. After adjusting for confounders, students who were underweight, overweight and obese were 14%–25% more likely to achieve the PA guidelines in the COVID-19 pandemic, compared to those classified with having a normal BMI. Students from the Philippines and Vietnam were 32%–70% more likely to achieve the PA guidelines than students from Brunei, whereas students from Indonesia and Singapore were less likely to achieve them. Students who travelled actively to/from the university, alongside students who travelled inactively and belonged to sports clubs, and students who did not belong to any sports clubs, were 42% less likely to meet the PA guidelines.

Students, who participated in 1–3 sport/exercise activities/week, had more than four times the odds of meeting the PA guidelines, compared to those who did not participate in any sport/exercise activities. The odds rose to 10 times when students participated in 4–6 sport or exercise activities per week. However, the odds dropped to approximately 3 times when students participated in more than 6 sport/exercise activities/week, compared with those who did not participate in any sport/exercise activities. University students who spent > 8 hrs/day of ST had 32% lower odds of achieving the PA guideline than those who spent ≤ 3 hrs/day of ST.

4. Discussion

The present research investigated participation in overall and domain-specific physical activity (PA) among university students across seven

Table 2. Prevalence of ASEAN university students who met physical activity guidelines (≥ 600 MET-min/week) by country, gender, and age (n = 15,366).

Country	Total		Gender ^a				Age ^a					
	n (%)	(95% CI)	Male n (%)	(95% CI)	Female n (%)	(95% CI)	18 years		19–21 years		>21 years	
Brunei (n = 1020)	583 (57.2)	(54.0, 60.2)	231 (39.6)	(35.6, 43.7)	352 (60.4)	(56.3, 64.4)*	54 (9.3)	(9.1, 13.0)	312 (55.5)	(47.9, 63.1)	199 (34.1)	(32.4, 38.3)
Indonesia (n = 4430)	1993 (45.0)	(43.5, 46.5)	1205 (60.5)	(58.3, 62.6)	788 (39.5)	(37.4, 41.7)**	509 (25.5)	(24.2, 26.3)	1238 (62.1)	(60.2, 63.1)	110 (6.8)	(3.3, 10.3)**
Malaysia (n = 289)	174 (60.2)	(54.3, 65.8)	114 (65.5)	(57.9, 72.4)	60 (34.5)	(27.6, 42.1)	154 (88.5)	(83.8, 91.6)	4 (2.3)	(0.8, 4.7)	0 (0.0)	(0.0, 0.0) [#]
Philippines (n = 322)	204 (63.4)	(57.8, 68.6)	64 (31.3)	(25.2, 38.3)	140 (68.6)	(61.7, 74.8)	19 (9.3)	(6.5, 13.2)	152 (74.5)	(69.3, 79.1)	30 (14.7)	(10.7, 18.7)
Singapore (n = 259)	131 (50.6)	(44.3, 56.8)	88 (67.2)	(58.4, 75.0)	43 (32.8)	(25.0, 41.6)	1 (0.8)	(0.3, 3.6)	18 (13.7)	(12.7, 22.2)	66 (50.4)	(47.8, 60.2)
Thailand (n = 3940)	2825 (71.7)	(70.3, 73.1)	846 (29.9)	(28.3, 31.7)	1979 (70.1)	(68.3, 71.7)**	158 (5.6)	(4.4, 5.8)	1647 (58.3)	(57.9, 61.0)	485 (18.9)	(16.0, 20.4)*
Vietnam (n = 5106)	3359 (65.8)	(64.4, 67.1)	1684 (50.1)	(48.4, 51.8)	1675 (49.9)	(48.2, 51.6)**	477 (14.2)	(12.3, 16.2)	2043 (60.8)	(59.9, 62.6)	441 (13.1)	(12.6, 14.5)*
Overall (n = 15,366)	9269 (60.3)	(52.9, 67.0)	4232 (45.7)	(44.6, 46.6)	5037 (54.3)	(53.3, 55.4)**	1372 (14.8)	(14.1, 15.5)	5414 (58.4)	(57.4, 59.4)	1331 (14.4)	(13.6, 15.1)**

95% CI: 95% Confidence interval; MET: metabolic equivalent; n: number.

*p < 0.05, **p < 0.001.

^a Chi-square test for independence.

[#] Insufficient power to detect significant difference between groups, due to a small sample size.

Table 3. Participation in overall and domain-specific physical activity, sedentary and sleep time among ASEAN university students (n = 15,366).

	Total n (%)	Male n (%)	Female n (%)	P-value ^a
Meeting PA guidelines				<0.001
Yes	9269 (60.3)	4232 (58.1)	5037 (62.4)	
No	6097 (39.7)	3057 (41.9)	3040 (37.6)	
Sleep time (hrs/day)				<0.001
≤7	10566 (68.8)	4798 (65.8)	5768 (71.4)	
>7	4800 (31.2)	2491 (34.2)	2309 (28.6)	
	Mean (SD)	Mean (SD)	Mean (SD)	
Overall METs-min/week	5290.5 (3572.0)	5325.1 (3635.4)	5260.2 (3515.4)	0.286 ^b
PA by domain (MET-min/week)				
Study-related	860.3 (2152.5)	762.0 (2041.3)	949.0 (2244.5)	<0.001
Recreation	2212.9 (2609.4)	2305.5 (2685.1)	2129.3 (2536.4)	<0.001
Transportation	1553.1 (1778.6)	1578.8 (1776.3)	1530.0 (1780.4)	0.089
Sedentary time (hrs/day)	8.0 (4.1)	7.84 (4.0)	8.05 (4.1)	0.002 ^b

hrs: hours; MET: metabolic equivalent; n: number; PA: physical activity; SD: standard deviation.

^a Chi-square test for independence.

^b Independent t test (equal variance not assumed).

ASEAN countries in the COVID-19 pandemic where various combinations of movement restrictions, mask-wearing, and social gathering size restrictions were operational. On average, 60.3% of university students across the seven ASEAN countries met the global PA guidelines. This is consistent with the 59.6% estimated prevalence identified in a previous study that featured university students from 23 low- and middle-income countries in 2015 before the COVID-19 pandemic [8].

The relatively high proportion of ASEAN university students achieving the PA guidelines in the COVID-19 pandemic is somewhat unexpected but plausible. Students might engage in recreational exercise

at home and outdoors to keep themselves healthy, albeit with considerable government restrictions on their social interactions and travel movements [26]. A recent systematic review showed that university students who met PA guidelines before the pandemic generally met the guidelines during the pandemic lockdown [13]. Similarly, a multicenter study among adults aged 18–74 years from six European countries showed that exercise practice during the COVID-19 pandemic remained over 65% in all participating countries [27]. In several cases, there is evidence that people participated more in PA during the COVID-19 pandemic. For instance, in a Brazilian study, the proportion of Brazilian adults who engaged in exercise once a week or every day before the COVID-19 pandemic increased significantly during the pandemic [27]. In the US, one-third of adults reported decreased PA, while 20% of them reported increased PA [28]. Furthermore, Belgian research showed that 58% of people who had low PA levels reported higher exercise levels, while 36% of people who had high PA levels exercised even more in the COVID-19 lockdown [26]. The absence of PA data prior to the COVID-19 pandemic among the participants in the present research precluded before, and in COVID-19, pandemic comparison of PA levels. It is recommended that a regular collection of PA data of university students from ASEAN countries should be made so that changes in PA behaviors over time can be reviewed, and for evidence-based PA to better inform health promotion policies in the future.

This present research is apparently the first to explore ASEAN university students' participation in specific PA domains. These results showed that recreational and study-related activities were dominant lifestyle habits among university students. Activities of recreation were the most common PA domain among male students, but they were less active than female students in the study-related domain. The present results are similar to other studies conducted in Croatia [29] and India [30] where recreational PA was a major contributor to the total PA levels among university students, and where males had greater recreational PA than female students. Students' participation in active transportation in the present research however contrasted with findings of the studies cited [28, 29] where active transport contributed more to overall PA. The difference in findings could be explained by the variety of travel and movement restrictions, online learning and work from home arrangements across the seven ASEAN countries imposed during the early period of the COVID-19 pandemic. Many might also have chosen not to use

Table 4. Logistic regression results of sociodemographic variables associated with meeting physical activity guidelines (≥ 600 MET-min/week) (n = 15,366).

	Total	Meeting PA Guidelines	Crude OR ^a	95% CI		P-value	Adj. OR ^b	95% CI		P-value
	n (%)	n (%)		Lower	Upper			Lower	Upper	
Age (Years)										
18	2496 (18.4)	1372 (16.9)	1.00	-	-	-				
19-21	9016 (66.3)	5414 (66.7)	1.23	1.13	1.35	<0.001**				
>21	2085 (15.3)	1331 (16.4)	1.45	1.28	1.62	<0.001**				
Gender										
Male	7289 (47.4)	4232 (45.7)	1.00	-	-	-				
Female	8077 (52.6)	5037 (54.3)	1.19	1.12	1.27	<0.001**				
Year of study										
1 st year	9940 (64.7)	5859 (63.2)	1.00	-	-	-				
2 nd year	2895 (18.8)	1780 (19.2)	1.11	1.02	1.21	0.014*				
3 rd year	1800 (11.7)	1176 (12.7)	1.31	1.18	1.46	<0.001**				
4 th year	731 (4.8)	454 (4.9)	1.18	0.99	1.41	0.055				
BMI										
Normal	2917 (21.3)	1631 (19.9)	1.00	-	-	-	1.00	-	-	-
Underweight	6619 (48.2)	3987 (48.6)	1.19	1.09	1.30	<0.001**	1.14	1.04	1.26	0.005*
Overweight	2983 (21.7)	1866 (22.7)	1.32	1.19	1.46	<0.001**	1.25	1.11	1.40	<0.001**
Obese	1202 (8.8)	721 (8.8)	1.18	1.03	1.36	0.017*	1.24	1.06	1.44	0.005*
Country										
Brunei	1020 (6.6)	583 (6.3)	1.00	-	-	-	1.00	-	-	-
Indonesia	4430 (28.8)	1993 (21.5)	0.61	0.53	0.70	<0.001**	0.68	0.59	0.80	<0.001**
Malaysia	289 (1.9)	174 (1.9)	1.13	0.87	1.48	0.354	0.94	0.69	1.28	0.715
Philippines	322 (2.1)	204 (2.2)	1.29	1.00	1.68	0.049*	1.70	1.26	2.30	<0.001**
Singapore	259 (1.7)	131 (1.4)	0.77	0.58	1.01	0.057	0.70	0.50	0.99	0.043*
Thailand	3940 (25.6)	2825 (30.5)	1.90	1.64	2.19	<0.001**	0.96	0.79	1.18	0.755
Vietnam	5106 (33.2)	3359 (36.2)	1.44	1.26	1.65	<0.001**	1.32	1.13	1.54	<0.001**
GPA										
≤ 3.2	2443 (20.1)	1541 (21.3)	1.00	-	-	-				
3.3-3.9	8406 (69.2)	4837 (66.9)	0.79	0.72	0.87	<0.001**				
>3.9	1302 (10.7)	857 (11.8)	1.13	0.98	1.30	0.096				
Living arrangement										
On campus	5345 (34.8)	3698 (39.9)	1.00	-	-	-				
Off campus	10021 (65.2)	5571 (60.1)	0.56	0.52	0.60	<0.001**				
Type of commute to/from university										
Inactive (by vehicles)	12727 (82.9)	1774 (19.1)	1.00	-	-	-	1.00	-	-	-
Active (Walk/bike)	2639 (17.1)	7495 (80.9)	0.70	0.64	0.76	<0.001**	0.58	0.52	0.64	<0.001**
Type of housing										
Single house	11319 (73.7)	6553 (70.7)	1.00	-	-	-				
Town house	2773 (18.1)	1899 (20.5)	1.58	1.45	1.73	<0.001**				
Flat/Apartments/Hostel	1201 (7.8)	771 (8.3)	1.30	1.15	1.48	<0.001**				
High rise condo	73 (0.5)	46 (0.5)	1.24	0.78	2.02	0.378				
Belong to any sports clubs										
No	9054 (58.9)	4455 (48.1)	1.00	-	-	-	1.00	-	-	-
Yes	6312 (41.1)	4814 (51.9)	0.47	0.44	0.51	<0.001**	0.58	0.51	0.65	<0.001**
No. of sport/exercise activities/week										
0	2131 (13.9)	554 (6)	1.00	-	-	-	1.00	-	-	-
1-3	8081 (52.6)	4922 (53.1)	4.44	4.00	4.94	<0.001**	4.26	3.47	4.38	<0.001**
4-6	2937 (19.1)	2443 (26.4)	14.08	12.29	16.16	<0.001**	10.15	8.22	11.44	<0.001**
>6	2217 (14.4)	1350 (14.6)	4.43	3.90	5.04	<0.001**	2.86	2.21	3.17	<0.001**
Sedentary time (hours/day)										
≤ 3	2376 (15.5)	1577 (17)	1.00	-	-	-	1.00	-	-	-
4-8	6213 (40.4)	3934 (42.4)	0.87	0.79	0.97	0.008*	0.90	0.82	1.02	0.115
>8	6777 (44.1)	3758 (40.5)	0.63	0.57	0.70	<0.001**	0.68	0.58	0.72	<0.001**
Sleep time (hours/day)										
≤ 7	10566 (68.8)	6453 (69.6)	1.00	-	-	-				
>7	4800 (31.2)	2816 (30.4)	0.90	0.84	0.97	0.005*				

*p < 0.05 **p < 0.001.

95% CI: 95% confidence interval; Adj. OR: adjusted odds ratio; BMI: body mass index; GPA: grade point average; MET: metabolic equivalent; OR: odds ratio; PA: physical activity.

^a Simple logistic regression (bivariate).

^b Binomial logistic regression (multivariable).

public transport for fear of getting infected. There are few studies on the impact of COVID-19 prevention measures on university students' active commute such as walking and biking. Some evidence shows that the COVID-19 pandemic had a negative impact on travel behaviors of people, with decreased passenger volume, frequency of use and ridership of public transport as people viewed as unsafe [31, 32, 33]. The results of the present study suggest that engaging in recreational activities may be a helpful strategy for students to achieve the PA guidelines during the COVID-19 restrictions.

The present research showed interesting counterintuitive results for BMI, type of commute to/from university, and belonging to a sports club against achieving recommended levels of PA. Students who were under and overweight, and obese had greater odds of meeting the PA guidelines, than those who had a normal weight. These results contrasted with the findings of Pengpid et al. (2015) which highlighted that university students who had a BMI outside a normal range were more likely to have insufficient PA, at a time when COVID-19 did not exist [8]. Current literature suggests that the association between BMI and PA is inconclusive, and BMI and PA have the bidirectional impacts on each other [34]. However, the positive associations identified in the present research were also observed in Chinese (>50 years old) and Malaysian (≥ 18 years old) women who had an unhealthy body weight, but met the PA guidelines, more so compared to those who had normal weight [35, 36]. Some research showed that having a better physical appearance and health consciousness are primary reasons for increasing PA participation in students [35]. These similar reasons might apply to university students who had an unhealthy body weight. These students might have more worries and motives compared to classmates with a normal body weight, and might have taken the COVID-19 pandemic and associated disruptions to normal life as a good opportunity to improve and increase PA levels [37]. Nonetheless, the information to support our assumption is unavailable and we welcome further research to verify or dispute the assumption. Despite the contrary, our findings reinforce efforts to promote PA among ASEAN university students, regardless of their BMI.

The COVID-19 related restrictions were reflected in the results of the current study where students engaged in active transportation had lower odds of meeting the PA guidelines than those who travelled inactively. The contribution of active transportation to meeting the PA guidelines were well documented prior to COVID-19 restrictions [38, 39]. Monitoring university students' active transport behaviors under different restrictions would contribute to a better understanding of the overall impact of the movement and travel restrictions. Engagement in sports clubs can contribute significantly to obtaining higher exercise levels and achieving the PA guidelines among the population [40, 41, 42]. However, ASEAN university students who engaged in a sports club had lower odds of meeting the PA guidelines during the COVID-19 pandemic. Although counterintuitive, our results are in agreement with research on Belgian university students who belonged to a sports club who had relatively less opportunity to engage in higher intensity exercise during the COVID-19 lockdown, than students who were not engaged in a sports club [26]. ASEAN university students might have struggled to maintain their PA participation as they had limited access to the clubs during the restrictive COVID-19 measures. Our results plausibly indicated that participation in PA among ASEAN university students who belonged to a sports club might be extrinsically motivated (e.g., socialization and social support) rather than intrinsically motivated (e.g., health and fitness) [43]. Future research anchored on behavioral theory frameworks may provide greater clarity and enable a deeper understanding on how to better incentivize and encourage ASEAN university students to sustain sufficient PA levels during periods of movement and travel restrictions and beyond.

The present research revealed a strong and positive relationship between the number of sport/exercise activities students engaged in (albeit, up to a maximum of six) and meeting the PA guidelines, a finding that is supported by research evidence from a younger population [44]. A variety of sport/exercise activities, especially individual activities, might be considered when promoting PA when people are in isolation or under

confinement restrictions in the COVID-19 pandemic. The present research indicated that many ASEAN university students were highly sedentary during the COVID-19 pandemic. Their ST was negatively associated with meeting the PA guidelines. Although these results are consistent with existing research, the relationship between PA and ST is complicated and inconclusive [34, 45]. For instance, some evidence showed that people could be highly sedentary and physically active concurrently [26, 46]. Despite an absence of clear guidelines on ST, university students are encouraged to reduce ST as much as they can and replace it with PA at any intensity (light, moderate, and vigorous) [21].

Residential country also influenced the probability of meeting the PA guidelines among university students in ASEAN. There is a paucity of data on university students' PA participation in ASEAN countries, making it difficult to interpret the results, although we suspect that different economic, social, and environmental contexts might be behind the differences identified in the present results. The present research indicated that university students in Indonesia and Singapore were particularly physically inactive and further research as to why this is so is needed to better address the relatively lower levels of PA in the COVID-19 pandemic in these two countries.

Several strengths and limitations were apparent in the present research. A key strength was that the research was a large-scale multiple-site study that used a valid and reliable self-report questionnaire to collect PA and socioeconomic data from university students across seven ASEAN countries. This provided the AUN-HPN with important and useful data that could seed future research collaborations within and outside the network countries. Nonetheless, the large sample of university students might not be representatives of all students across the ASEAN countries, and caution was advised when interpreting the findings. The cross-sectional design of this research limited the conclusions of the causal relationships, and targeted longitudinal studies on the PA and ST of university students living in ASEAN countries in the future might help address this limitation. Recall ability was a potential weakness of the self-reported instruments used to collect data. Finally, the seven ASEAN countries involved in the research were in different situations regarding the COVID-19 pandemic and prevention measures varied during the data collection period. This could also account for some of the disparate results obtained in the present research.

5. Conclusions

The present research provided important information about overall and domain-specific PA participation among university students in seven ASEAN countries during the COVID-19 pandemic. The results indicated that almost two-thirds of the students achieved the PA guidelines. Participation in recreational and study-related PA played a vital role in keeping ASEAN university students sufficiently active, while participation in active transportation might not be high during periods of mobility restrictions. Several sociodemographic and associated factors, including BMI, residential country, type of commute to/from university, belonging to a sports club, the number of sport/exercise activities engaged, and ST had a significant impact on students' meeting the PA guidelines. Further investigation is recommended to unpack details of some of the counterintuitive results (i.e., type of commute, and belonging to a sports club) that differed from other research in the COVID-19 pandemic. Regular monitoring of PA in ASEAN university students is strongly encouraged to identify trends and better intervene where possible so that a greater proportion of ASEAN university students can reap the health benefits of meeting PA guidelines.

Declarations

Author contribution statement

Areekul Amornsriwatanakul, Hanif Abdul Rahman: Conceived and designed the experiments; Performed the experiments; Analyzed and

interpreted the data; Contributed reagents; materials, analysis tools or data; Wrote the paper.

Apichai Wattanapisit, Ira Nurmala, Ma. Henrietta Teresa O. de la Cruz, Josip Car, Michael Chia: Performed the experiments; Analyzed and interpreted the data; Contributed reagents; materials, analysis tools or data; Wrote the paper.

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Data availability statement

Data will be made available on request.

Declaration of interests statement

The authors declare no competing interests.

Additional information

No additional information is available for this paper.

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