Full length article

Cannabis use and physical activity among 89,777 adolescents aged 12-15 years from 21 low- and middle-income countries

Garcia Ashdown-Franks[a,b,*], Catherine M. Sabiston[a], Davy Vancampfort[c,d], Lee Smith[e], Joseph Firth[f,g], Marco Solmi[h], Nicola Veronese[i], Brendon Stubbs[a,b,j], Ai Koyanagi[k,l]

[a] Department of Exercise Sciences, University of Toronto, 55 Harbord Street, Toronto, Ontario, M5S 2W6, Canada
[b] Department of Psychological Medicine, Institute of Psychiatry, Psychology and Neuroscience, King's College London, London, SE5 8AB, United Kingdom
[c] KU Leuven, Department of Rehabilitation Sciences, Leuven, 3000, Belgium
[d] KU Leuven, University Psychiatric Center KU Leuven, Kortenberg, 3000, Belgium
[e] The Cambridge Centre for Sport and Exercise Sciences, Anglia Ruskin University, Cambridge, CB1 1PT, United Kingdom
[f] NICM Health Research Institute, Western Sydney University, Sydney, NSW, 2751, Australia
[g] Division of Psychology and Mental Health, Faculty of Biology, Medicine and Health, University of Manchester, M13 9PL, United Kingdom
[h] Department of Neurosciences, University of Padova, 35122, Italy
[i] National Research Council, Neuroscience Institute, Aging Branch, Padua, 35122, Italy
[j] Physiotherapy Department, South London and Maudsley National Health Services Foundation Trust, SE5 8AB, United Kingdom
[k] Research and Development Unit, Parc Sanitari Sant Joan de Déu, Universitat de Barcelona, Fundació Sant Joan de Déu, CIBERSAM, Dr. Antoni Pujadas, Barcelona, 08830, Spain
[l] ICREA, Pg. Lluis Companys 23, Barcelona, 08010, Spain

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ABSTRACT

Background: Cannabis legalization and use are increasing globally, however, little is known about associations between cannabis use and other health behaviors, such as physical activity (PA). Importantly, the extent to which cannabis use is associated with PA in adolescents is yet to be explored in low- and middle-income countries (LMICs), where there may be unique sociodemographic and environmental characteristics compared with high-income countries. Therefore, this study examined the association between PA and cannabis use among adolescents in 21 LMICs using data from the 2010–2016 Global School-based Student Health Survey.
Methods: A multivariable logistic regression analysis was performed among a final sample of 89,777 adolescents (49.2% females) aged 12–15 years with a mean (SD) age of 13.7 (0.9) years.
Results: The overall prevalence of past (i.e., in lifetime but not in past 30 days) and current (in past 30 days) cannabis use were 1.0% and 2.9% respectively, while the prevalence of adequate PA in the past week (7 days/week of 60 min of PA) was 16.6%. The prevalence of adequate levels of PA in past and current cannabis use was 7.3% and 6.9%, respectively. Current and past cannabis use (vs. never) were associated with a significant 0.62 (95% CI = 0.41-0.94) and 0.43 (95%CI = 0.30-0.63) times lower odds for achieving adequate levels of PA, respectively.
Conclusion: The results underscore the high prevalence of low PA among adolescents in LMICs, and emphasize the need to understand behavioral factors that may affect PA levels, such as cannabis use, when designing interventions to improve health.

1. Introduction

Physical inactivity [defined in children and youth as not meeting the World Health Organization physical activity (PA) recommendation of 60 min of moderate-to-vigorous activity each day (World Health Organization, 2015)] increases risks for type-2 diabetes, cardiovascular disease, obesity, depression, suicidal ideation and mortality (Kumar et al., 2015; Schuch et al., 2018; Vancampfort et al., 2018), but rates of physical inactivity continue to rise worldwide, posing a tremendous health risk at the population level (Guthold et al., 2018). Thus, the

World Health Organization member states have set a goal to reduce the prevalence of insufficient PA by 10% in 2025 in an effort to address the burden of non-communicable diseases (Guthold et al., 2018). Adolescence is an important stage to intervene, as it is a time when lifelong PA habits are often formed (Kumar et al., 2015). Despite this, a worldwide study showed that more than 80% of adolescents do not meet the recommended amount of 60 min per day of moderate-to-vigorous PA (WHO, 2015). This highlights the need to explore factors that may be related to PA, and ways in which these activity levels can be improved, particularly among adolescents.

One factor that may be associated with PA levels is cannabis use. Theoretically, while cannabis use might be associated with being less physically active due to decreased lung function associated with chronic cannabis use, or increased apathy and lack of motivation (Bloomfield et al., 2014; Lutchmansingh et al., 2014), it may also be positively related with increased PA levels. Indeed, the World Anti-Doping Agency has included cannabis as a prohibited substance, as it is believed to potentially enhance sports performance (Gillman et al., 2015) via decreased pain (Kozela et al., 2013; De Vita et al., 2018; Lisano et al., 2018), increased relaxation among high performance athletes (Pillard et al., 2001; Huestis et al., 2011) and improved oxygenation to tissues (Renaud and Cormier, 1986). It is clear, however, that this research may not be generalizable to adolescents who are not professional athletes.

The effect of cannabis use on exercise motivation, in particular, is largely unknown. Sensations experienced during and following PA such as pain reduction and euphoria (i.e., 'runner's high') are similar to effects from highs induced from cannabis, and as such it may be that these experiences are biologically comparable (Gillman et al., 2015). These positive responses to exercise are likely underpinned by neurobiological mechanisms in the endocannabinoid pathways (Gillman et al., 2015). Given this, it may be that exogenous cannabinoids (i.e., cannabis) could have a positive effect and reinforcing association with PA motivation. However, it is also possible that the use of cannabis could also interfere with the function of endocannabinoids, resulting in decreased exercise motivation (Gillman et al., 2015). Thus, there is an urgent need to understand how cannabis use and PA levels are associated but currently, this topic is understudied in the scientific literature. This is a major concern as there has been increasing legislation that supports the legalization and/or decriminalization of cannabis use globally (Gillman et al., 2015), but with great deal of uncertainty regarding the impacts of cannabis on health or health behaviors.

To our knowledge, there are very few studies on the association between cannabis use and PA to date. A small study from the USA found that adolescents who engaged in high levels of vigorous PA used cannabis less often than those with low levels of vigorous PA (Delisle et al., 2010). In addition, among a large sample of 4293 American adolescents, low PA was associated with cannabis use (Pate et al., 1996). Furthermore, a study of 12,618 American adults found that both current and past marijuana use were associated with lower odds of recreational moderate PA (Vidot et al., 2017).

Given that the only studies on this topic have been conducted in the USA, there is clearly a need to assess this association in diverse settings. To the best of our knowledge there are no studies from low- and middle-income countries (LMICs). Studying this association among adolescents in LMICs is important because the prevalence of low PA has been reported to be high in this setting, with a recent large-scale study finding that the prevalence of low PA (i.e., not achieving the WHO recommended guidelines of 150 min per week) was 29% among adults in 46 LMICs (Koyanagi et al., 2018). At the same time, cannabis use in LMIC youth is common, with the prevalence of lifetime cannabis use being 4% among adolescents in LMICs (Carvalho et al., 2019). Of concern, in LMICs such as Argentina, Uruguay and Chile, in the past 20 years, past-month adolescent cannabis use has increased, while it has remained relatively stable in the United States (Observatorio Uruguayo de Drogas, 2016; Observatorio Chileno de Drogas, 2016; Observatorio

Argentino de Drogas, 2016; Miech et al., 2018). Moreover, the association between cannabis use and PA may differ in magnitude in LMICs compared to high-income countries due to, at least in part, a complex interaction with relevant sociodemographic and environmental risk factors, such as poverty, political instability and food insecurity (Breet et al., 2018; Cluver et al., 2015; Swahn et al., 2012). For example, environmental stressors such as violence and unrest may result in the use of cannabis as a form of coping (Peltzer and Pengpid, 2017). Similarly, such violence may result in less opportunities for adolescents to pursue physical activity outside of their home due to security issues. Furthermore, in the United Nations Office on Drugs and Crime (UNODC) regions of Africa and Oceania, in which many of the current study's countries are located, cannabis is now the drug of primary concern based on numbers of treatment episodes (UNODC, 2015). Therefore, context-specific research is imperative if we aim to develop and implement effective lifestyle interventions targeting multiple unhealthy behaviors in LMICs, as such interventions may be inherently different from those for high-income countries (Breet et al., 2018; Liu et al., 2018). Given the LMIC context and the aforementioned gaps in the literature, the aim of the current study was to examine the association between PA and cannabis use in 21 LMICs.

2. Methods

2.1. The survey

Publicly available data from the GSHS were analyzed. Details on this survey can be found at http://www.who.int/chp/gshs and http://www.cdc.gov/gshs. Briefly, the GSHS was jointly developed by the WHO and the US Centers for Disease Control and Prevention (CDC), and other UN allies. The core aim of this survey was to assess and quantify risk and protective factors of major non-communicable diseases. The survey draws content from the CDC Youth Risk Behavior Survey (YRBS) for which test-retest reliability has been established (Brener et al., 1995). The survey used a standardized two-stage probability sampling design for the selection process within each participating country. For the first stage, schools were selected with probability proportional to size sampling. The second stage involved the random selection of classrooms which included students aged 13–15 years within each selected school. All students in the selected classrooms were eligible to participate in the survey regardless of age. Data collection was performed during one regular class period. The questionnaire was translated into the local language in each country and consisted of multiple choice response options; students recorded their response on computer scannable sheets. All GSHS surveys were approved, in each country, by both a national government administration (most often the Ministry of Health or Education) and an institutional review board or ethics committee. Student privacy was protected through anonymous and voluntary participation, and informed consent was obtained as appropriate from the students, parents and/or school officials. Ethical approval from the lead institution was not obtained as this was a secondary analysis of data that is publically available. Data were weighted for non-response and probability selection.

From all publicly available data, we selected all nationally representative datasets from LMICs that included the variables used in the current analysis. If there were more than two datasets from the same country, we chose the most recent dataset. Benin, Mozambique, and Laos were omitted because the low prevalence of adequate PA and/or cannabis use did not allow for the calculation of stable estimates. Thus, a total of 21 countries were included in the current study. The characteristics of each country or survey are provided in Table 1. For the included countries, the survey was conducted between 2010 and 2016, and consisted of 3 low-income, 11 lower middle-income, and 7 upper middle-income countries based on the World Bank classification at the time of the survey.

Table 1
Country and survey characteristics.

Country income[a]	Country	Year	Response rate (%)[b]	N[c]	Adequate physical activity (%)	Cannabis use (%)[d] Past	Cannabis use (%)[d] Current
Low	Cambodia	2013	85	1812	6.5	0.2	1.2
	Nepal	2015	69	4616	14.4	1.2	2.6
	Tanzania	2014	87	2615	21.1	1.0	2.5
Lower-middle	Bangladesh	2014	91	2753	41.2	0.1	1.6
	Bolivia	2012	88	2804	13.7	0.8	2.6
	East Timor	2015	79	1,631	8.2	2.0	6.0
	Ghana	2012	82	1110	8.9	1.8	7.6
	Indonesia	2015	94	8806	12.0	0.6	1.3
	Kiribati	2011	85	1340	17.4	0.8	4.6
	Mongolia	2013	88	3707	26.9	0.5	1.1
	Philippines	2015	79	6162	7.3	1.9	5.4
	Samoa	2011	79	2200	12.1	6.1	37.4
	Solomon Islands	2011	85	925	16.5	2.4	13.6
	Vanuatu	2011	72	852	10.5	0.7	2.8
Upper-middle	Argentina	2012	71	21528	16.8	2.4	6.0
	Fiji	2016	79	1537	19.2	0.8	5.2
	Malaysia	2012	89	16273	13.8	0.3	1.0
	Namibia	2013	89	1936	14.0	1.4	4.7
	Peru	2010	85	2359	15.0	0.9	2.9
	Thailand	2015	89	4132	12.2	2.3	5.4
	Tuvalu	2013	90	679	11.9	1.7	3.8

[a] Country income level was based on the World Bank classification at the year of the survey in the respective countries.
[b] Response rate was calculated as school response rate multiplied by student response rate.
[c] Based on sample aged 12–15 years.
[d] Current users referred to those who used cannabis on at least one day in the past 30 days, while those who had ever used cannabis (i.e., at least once) in their lifetime but not in the past 30 days were considered to be past users.

2.2. Cannabis use (independent variable)

Past 30-day and lifetime cannabis use was assessed with the question "During the past 30 days (or during your life), how many times have you used marijuana?" Country-specific slang terms for marijuana were also included in the question. A three-category variable on cannabis use was created: never, past, and current. Current use referred to using marijuana on at least one day in the past 30 days, while having ever used marijuana (i.e., at least once) in lifetime but not in the past 30 days was considered to be past use (Vidot et al., 2017). This variable was also used as a dichotomous variable [i.e., never (code = 0) or past/current (code = 1)] in some analyses.

2.3. Physical activity (dependent variable)

To assess levels of PA, questions that represented the PACE + Adolescent Physical Activity Measure (Prochaska et al., 2001) were asked. This measure has been tested for validity and reliability in adolescents in a variety of high-income settings (Prochaska et al., 2001; Martinez-Gomez et al., 2009). The questions asked about the number of days with PA of at least 60 min during the past 7 days. In line with WHO recommendations for adolescents (World Health Organization, 2015), those who engaged in 7 days of at least 60 min of PA in a week were considered to have a sufficient amount of PA (adequate levels of PA).

2.4. Control variables

The selection of control variables was based on past literature (Vidot et al., 2017) and included sex, age, food insecurity (hunger), suicide attempt, alcohol consumption, and tobacco smoking. As in previous studies using the same dataset (Balogun et al., 2014; Carvalho et al., 2019), food insecurity was used as a proxy for socioeconomic status as there were no variables on socioeconomic status in the GSHS. Also, suicide attempt was considered a proxy of psychiatric disorders as there were no variables on psychiatric disorders including depression in the dataset. Food insecurity was assessed by the question "During the past

30 days, how often did you go hungry because there was not enough food in your home?" Answer options were categorized as 'never', 'rarely/sometimes', and 'most of the time/always'. Suicide attempt was defined as at least one suicide attempt in the past 12 months. Alcohol consumption was defined as having had one drink containing alcohol for at least one day in the past 30 days. Tobacco smoking was defined as having smoked at least on one day during the past 30 days.

2.5. Statistical analysis

Statistical analyses were performed with Stata 14.1 (Stata Corp LP, College station, Texas). The analysis was restricted to those aged 12–15 years as most students were within this age range and the exact age out of this age range was not provided. Using the overall sample and country-wise samples, we conducted multivariable logistic regression analysis to estimate the association between cannabis use (independent variable) and PA (dependent variable). The analysis with the overall sample used the three-category cannabis variable (i.e., never, past, current) as the exposure variable. However, we used the dichotomous variable on cannabis use (i.e., never or past/current) for country-wise analyses as the sample size in each country was small and stable estimates could not be obtained otherwise.

In order to assess between-country heterogeneity in the association between any cannabis use and PA, we calculated the Higgins's I^2 which represents the degree of heterogeneity that is not explained by sampling error with a value of < 40% often considered as negligible and 40–60 % as moderate heterogeneity (Higgins and Thompson, 2002). A pooled estimate was obtained by combining the estimates for each country into a random effect meta-analysis. Furthermore, we explored whether the prevalence of adequate levels of PA and any cannabis use in each country or GDP per capita are potential sources of between-country heterogeneity in the association between any cannabis use and PA through random effect meta-regression analysis. The country-level variables were calculated from this data for PA and cannabis use, while the Central Intelligence Agency World Factbook was used for GDP per capita (Central Intelligence Agency, 2016).

The regression analyses were adjusted for sex, age, food insecurity, suicide attempt, alcohol consumption, tobacco smoking, and country with the exception of the country-wise analyses which were not adjusted for country. For the analysis using the overall sample, adjustment for country was done by using fixed effects models as in previous GSHS studies (Carvalho et al., 2019; Mckinnon et al., 2016). Although Body mass index (BMI) was also considered as a potential confound, since the estimates of cannabis use remained largely unchanged even after the inclusion of this covariate, BMI was not included in the model to maximize sample size. We did not use multilevel models as such analyses can produce biased estimates when used with complex study designs (Rabe-Hesketh and Skrondal, 2006). All variables were included in the regression analysis as categorical variables with the exception of age (continuous variable). Under 3.7 % of the data were missing for all the variables used in the analysis. Complete case analysis was done. Sampling weights and the clustered sampling design of the surveys were taken into account to obtain nationally representative estimates. The level of statistical significance was set at $p < 0.05$.

3. Results

The final sample consisted of 89,777 adolescents aged 12–15 years with a mean (SD) age of 13.7 (0.9) years and 49.2% were females (Table 2). The overall prevalence of past and current cannabis use were 1.0% and 2.9%, respectively while the prevalence of adequate levels of PA was 16.6%. The prevalence of adequate PA ranged from 6.5% (Cambodia) to 41.2% (Bangladesh), while the prevalence of any cannabis use ranged from 1.3% (Malaysia) to 43.5% (Samoa) (Table 1). Among adolescents who used cannabis in the past 30 days, the distribution of the frequency of use was as follows: 1–2 times 49%; 3–9 times 29.4%; 10–19 times 11.9%; ≥20 times 9.7%. Adolescents who use cannabis were more likely to be males, experience food insecurity, and have attempted suicide, while they were also more likely to consume alcohol and smoke (Table 2). The prevalence of adequate levels of PA was much lower among adolescents who currently use or have used cannabis as compared to those who have never used cannabis (Fig. 1). Specifically, 17.3% of the adolescents who never consumed cannabis engaged in adequate levels of PA, while the corresponding figures for past and current cannabis use were 7.3% and 6.9%, respectively. The association between cannabis use and PA estimated by multivariable logistic regression is shown in Table 3. After adjustment for a variety of potential confounds, compared to never cannabis use, past and current cannabis use were associated with significantly lower odds for adequate
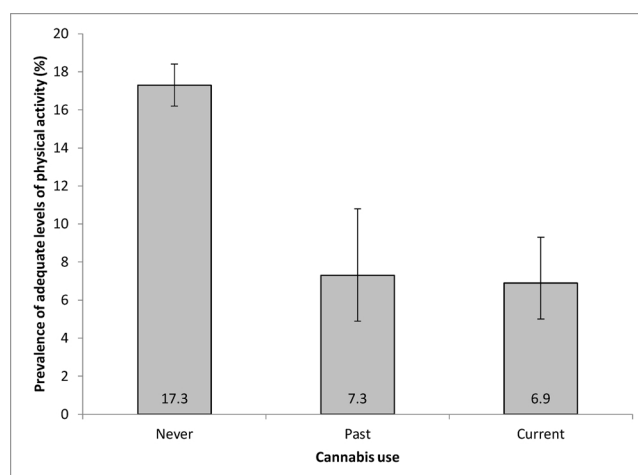

Fig. 1. Prevalence of adequate physical activity level by cannabis use.
Data are weighted estimates.
Bars denote 95% confidence intervals.
Current users referred to those who used cannabis on at least one day in the past 30 days, while those who had ever used cannabis (i.e., at least once) in their lifetime but not in the past 30 days were considered to be past users.

levels of PA with the corresponding odds ratio (OR) (95% confidence interval (CI)) being 0.62 (0.41-0.94) and 0.43 (0.30-0.63), respectively. The country-wise association between any cannabis use and PA is shown in Fig. 2. Any cannabis use was negatively associated with adequate levels of PA (i.e., OR < 1) in 17 of the 21 countries included in the study although statistical significance was not reached in all of these countries. The overall estimate based on a meta-analysis was OR = 0.76 (95%CI = 0.60-0.96) with a moderate level of between-country heterogeneity being observed (I^2 = 41.5%). The results from the meta-regression showed that the prevalence of adequate PA, any cannabis use at the country level or GDP per capita do not significantly explain the between-country heterogeneity (Supplementary Figs. S1, S2, and S3).

4. Discussion

In our study, after adjustment for a variety of confounds, compared to those who never used cannabis, adolescents who used cannabis in the past 30 days had a significantly lower odds (OR = 0.43) of engaging in

Table 2
Sample characteristics (overall and by cannabis use).

Characteristic	Category	Unweighted N	Overall	Never	Cannabis use[a]	
					Past	Current
Sex	Male	41655	50.8	49.9	63.7	65.6
	Female	47522	49.2	50.1	36.3	34.4
Age (years)	12	6603	12.6	12.7	10.4	11.4
	13	23647	28.1	28.2	24.5	25.6
	14	30416	33.0	33.0	34.4	31.9
	15	29111	26.4	26.1	30.7	31.1
Hunger	Never	43507	46.1	46.6	35.8	35.0
	Rarely/sometimes	39910	47.3	47.2	51.2	51.7
	Most of the time	5616	6.6	6.2	13.0	13.3
Suicide attempt	No	77038	90.0	92.2	59.3	47.8
	Yes	11783	10.0	7.8	40.7	52.2
Alcohol consumption	No	69574	90.3	92.9	43.1	30.0
	Yes	16991	9.7	7.1	56.9	70.0
Tobacco smoking	No	76293	88.4	91.8	40.1	24.9
	Yes	13127	11.6	8.2	59.9	75.1

Data are weighted column percentages.
[a] Current users referred to those who used cannabis on at least one day in the past 30 days, while those who had ever used cannabis (i.e., at least once) in their lifetime but not in the past 30 days were considered to be past users.

Table 3

Association of cannabis use and other covariates with adequate physical activity level estimated by multivariable logistic regression.

Characteristic	Category	OR	95%CI	P-value
Cannabis use[a]	Never	1.00		
	Past	0.62	[0.41,0.94]	0.024
	Current	0.43	[0.30,0.63]	< 0.001
Sex	Male	1.00		
	Female	0.76	[0.68,0.86]	< 0.001
Age (years)		1.09	[1.03,1.16]	0.006
Hunger	Never	1.00		
	Rarely/Sometimes	0.97	[0.86,1.09]	0.561
	Most of the time/always	1.13	[0.84,1.52]	0.427
Suicide attempt	No	1.00		
	Yes	0.78	[0.66,0.93]	0.006
Alcohol consumption	No	1.00		
	Yes	1.05	[0.90,1.23]	0.556
Tobacco smoking	No	1.00		
	Yes	1.09	[0.83,1.43]	0.529

Abbreviation: OR Odds ratio; CI Confidence interval.

Model is adjusted for all variables in the Table and country.

[a] Current users referred to those who used cannabis on at least one day in the past 30 days, while those who had ever used cannabis (i.e., at least once) in their lifetime but not in the past 30 days were considered to be past users.

adequate levels of PA. There was a wide variation in the prevalence of PA and cannabis use across countries, which may be related to differences in socio-cultural factors. To the best of our knowledge, this is the first study from LMICs to assess the association between cannabis use and PA, while it is also the first multi-country study on this topic. The strengths of the study include the large sample size and use of nationally representative samples.

Despite the fact that cannabis use may also theoretically facilitate

PA, we found that at a population level, cannabis use is related with low PA. This is in line with the findings from the three cross-sectional studies conducted in the USA among adolescents (Delisle et al., 2010; Pate et al., 1996) and adults (Vidot et al., 2017). The reasons that may underpin this potential relationship are yet to be elucidated but several mechanisms may explain the relationship. First, cannabis use has been shown to be associated with increased sensations of lethargy and physical effort (Ronen et al., 2008), which may lead to individuals being less likely to engage in activity. Relatedly, prolonged cannabis use has been found to lead to dopaminergic down-regulation, which may be linked to reduced reward sensitivity and thereby amotivation (Bloomfield et al., 2014). A systematic review in adults examining exercise and cannabis use reported that two studies found that marijuana precipitated angina, and also that due to adverse reactions from cannabis, some subjects could not complete the exercise protocol (Kennedy, 2017). These findings suggest that cannabis may decrease exercise tolerance and thereby the ability to engage in PA (Kennedy, 2017). Clearly future research to consider these concepts is required in adolescents. Finally, cannabis use can reduce exercise motivation via interference with the function of endocannabinoids (Gillman et al., 2015).

Conversely, it has also been shown prospectively that engaging in sports or exercise may decrease risk for cannabis use among young Swiss men (Henchoz et al., 2014). Furthermore, a systematic review (Kwan et al., 2014) examined longitudinal studies that had investigated whether sport participation has an effect on future illicit drug use, and found that among high school aged adolescents, four studies confirmed that participation in sport was protective against future marijuana use (Barber et al., 2001; Darling, 2005; Dawkins et al., 2006; Terry-McElrath and O'malley, 2011). Although these studies were on sports participation or exercise and not specifically on PA, the results of these studies suggest that PA may also lead to less cannabis use and
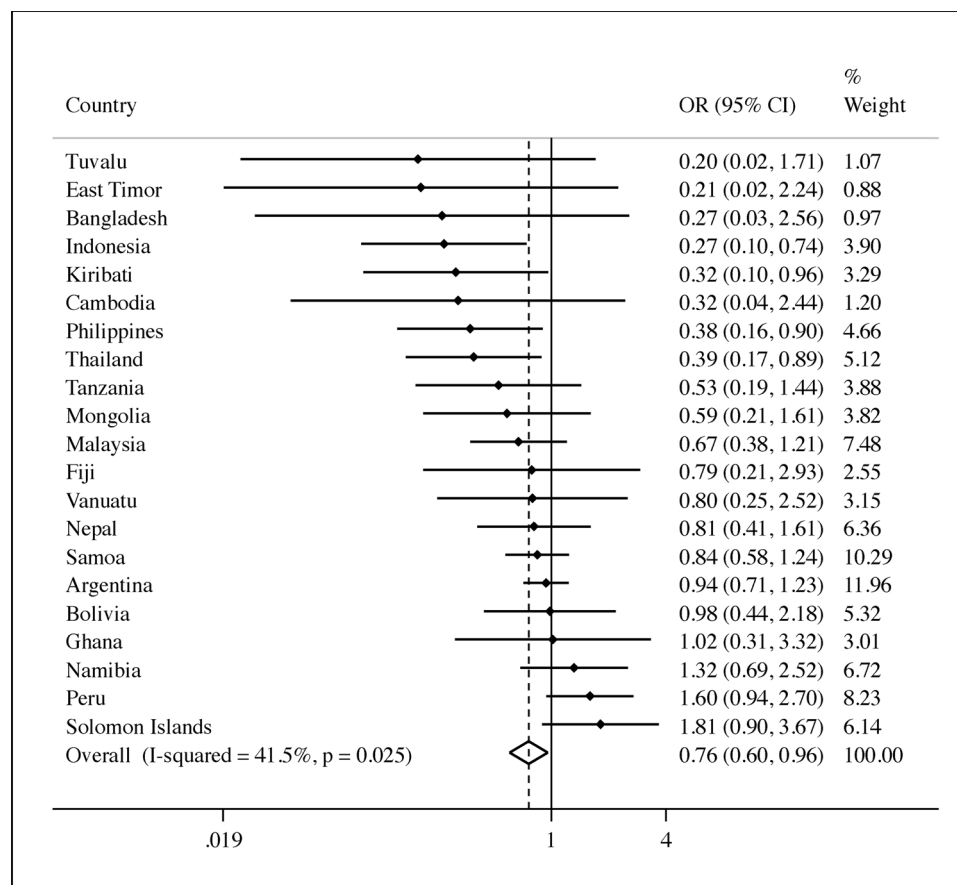

Fig. 2. Country-wise association between any cannabis use and adequate physical activity estimated by multivariable logistic regression. Abbreviation: OR Odds ratio; CI Confidence interval.

Models are adjusted for sex, age, hunger, suicide attempt, alcohol consumption, and tobacco smoking.

Overall estimate was obtained by meta-analysis with random effects.

Country	OR (95% CI)	% Weight
Tuvalu	0.20 (0.02, 1.71)	1.07
East Timor	0.21 (0.02, 2.24)	0.88
Bangladesh	0.27 (0.03, 2.56)	0.97
Indonesia	0.27 (0.10, 0.74)	3.90
Kiribati	0.32 (0.10, 0.96)	3.29
Cambodia	0.32 (0.04, 2.44)	1.20
Philippines	0.38 (0.16, 0.90)	4.66
Thailand	0.39 (0.17, 0.89)	5.12
Tanzania	0.53 (0.19, 1.44)	3.88
Mongolia	0.59 (0.21, 1.61)	3.82
Malaysia	0.67 (0.38, 1.21)	7.48
Fiji	0.79 (0.21, 2.93)	2.55
Vanuatu	0.80 (0.25, 2.52)	3.15
Nepal	0.81 (0.41, 1.61)	6.36
Samoa	0.84 (0.58, 1.24)	10.29
Argentina	0.94 (0.71, 1.23)	11.96
Bolivia	0.98 (0.44, 2.18)	5.32
Ghana	1.02 (0.31, 3.32)	3.01
Namibia	1.32 (0.69, 2.52)	6.72
Peru	1.60 (0.94, 2.70)	8.23
Solomon Islands	1.81 (0.90, 3.67)	6.14
Overall (I-squared = 41.5%, p = 0.025)	0.76 (0.60, 0.96)	100.00

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suggest a complex relationship. While the exact mechanisms underpinning this relationship are unclear, it may be that PA and marijuana use are simply incompatible as behaviors and are behavioral tradeoffs, i.e., spending time engaging in substance use will decrease the time one can spend in another behavior such as exercising (Brellenthin and Lee, 2018). We also found that those who used cannabis had higher rates of using other substances including tobacco and alcohol, compared to those who did not use cannabis. Importantly, polysubstance abuse has been found in other studies and has been associated with decreased PA (Moore et al., 2007).

Regardless of whether cannabis use is causally related with low PA, the mere co-existence may be particularly hazardous for health. While the deleterious effects of low PA in adolescence on a number of health outcomes have been well established (e.g., type-2 diabetes, cardiovascular disease, obesity, mortality, depression and suicidal ideation (Kumar et al., 2015; Schuch et al., 2018; Vancampfort et al., 2018), there is emerging evidence that cannabis use in adolescence is also associated with increased risks for suicide attempts, psychotic symptoms, depression, generalized anxiety symptoms, other illicit drug use, and worse performance on cognitive tasks (Moore et al., 2007; Carvalho et al., 2019; Silins et al., 2014; Orr et al., 2019; Gobbi et al., 2019). Thus, it is possible that cannabis use in adolescents who are physically inactive may further compound future health risks.

This is of particular concern as globally, the rates of cannabis use among youth are increasing in developing countries, while decreasing in developed countries (Ter Bogt et al., 2014). Furthermore, changes in cannabis liberalization in the countries included in this analysis may affect adolescent cannabis use among these countries (Stevens, 2019. Shi et al., 2015). There appear to be important regional differences in the current study, with associations between physical activity and cannabis use being more pronounced among Southeast Asian and Western Pacific region countries. Although speculative, these regional differences may be related to factors such as intensity of cannabis consumption, or levels of cannabinoid content in cannabis, which could not be assessed in our study. Alternatively, there may be factors that make cannabis use and physical activity more incompatible in some regions. The reasons behind these regional differences represent an important area of future research.

Given the negative association between current or past cannabis use and adequate levels of PA, our study adds to the need for a multidisciplinary approach in supporting adolescents who use such substances. This may not only help prevent long-term cannabis use and its reported adverse events but also have a positive impact on other behaviors such as PA, smoking and alcohol use. These approaches must also take into account the sociodemographic context of such countries, and be aware of how poverty, political instability and food insecurity may affect the relationship between cannabis use and PA (Breet et al., 2018; Cluver et al., 2015; Swahn et al., 2012).

While this study has many strengths, it also has its limitations. Importantly, the data were self-reported. For example, PA was based on a subjective measure, and it is well recognized that self-reported measures of PA can be reported inaccurately in both high-income countries and LMICs (Ainsworth et al., 2006). Future research may benefit from examining PA objectively, and also consider the type and intensity of activity. Relatedly, the validity of the PACE + Adolescent Physical Activity Measure, which was used to assess PA levels in our study, is not known in the countries included in our study. Furthermore, it may be that different countries have different views towards cannabis use (Mauseth et al., 2016), which might have led to social desirability bias. Second, although we did adjust for suicide attempts as a proxy for mental disorders, it would have been preferable to adjust for specific measures on mental disorders such as depression and anxiety (Bélair et al., 2018). Third, the study was only conducted among school attending adolescents. Thus, the results may not be generalizable to adolescents who do not attend school. Next, although there were no information in our dataset, there is also evidence to suggest that type of

cannabis use (i.e., smoking vs. ingesting), as well as the composition of cannabis vary widely between countries and have differential effects on health, which warrants further research (Hall, 2015; WHO, 2016). Finally, causality and directionality cannot be inferred between PA and cannabis use as this was a cross-sectional study. Thus, we suggest that future long-term studies are required to better understand the relationships observed.

In conclusion, we found a negative association between cannabis use and adequate PA in LMICs. More research is needed to understand the underlying mechanisms. In particular, studies of longitudinal design are warranted to provide more information on possible causality. Furthermore, more epidemiological studies on cannabis use and physical activity specifically from LMICs are warranted given their distinct socio-economic and cultural characteristics, compared with high-income countries.

Contributors

AK and BS led on the statistical analyses. GAF led on the paper writing, with input from BS and AK. All authors contributed to study design and approved the final draft of the manuscript.

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None.

Declaration of Competing Interest

No conflict declared.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.drugalcdep.2019.107584.

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