A systematic review of physical activity, sedentary behavior, and substance use in adolescents and emerging adults

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Abstract

The transition from adolescence into emerging adulthood is marked by changes in both physical activity and substance use. This systematic review characterized associations between movement behaviors (physical activity, sedentary behavior) and frequently used substances (alcohol, cannabis) among adolescents and emerging adults to inform lifestyle interventions that target multiple behavior change outcomes. This systematic review was guided by PRISMA. Electronic databases of PubMed, PsycINFO, and Web of Science were searched from inception through June 25, 2019. The search was designed to identify empirical studies reporting an association between physical activity or sedentary behavior and alcohol or cannabis, with search criteria determining eligibility based on several sampling characteristics (e.g., participants under 25 years of age). After identifying and screening 5,610 studies, data were extracted from 97 studies. Physical activity was positively associated with alcohol use among emerging adults, but the literature was mixed among adolescents. Sedentary behavior was positively associated with alcohol and cannabis use among adolescents, but evidence was limited among emerging adults. Self-report measures were used in all but one study to assess these behaviors. Physical activity is linked to greater alcohol use among emerging adults. Whereas existing studies demonstrate that sedentary behavior might serve as a risk marker for alcohol and cannabis use among adolescents, additional primary research is needed to explore these associations in emerging adults. Future work should also use device-based measures to account for timing of and contextual features surrounding activity and substance use in these populations.

Keywords

Systematic review, Physical activity, Sedentary behavior, Substance use, Alcohol, Cannabis

INTRODUCTION

Physical inactivity is a concern for adolescent (12–17 years old) and emerging adult (18–25 years old) populations. These developmental periods are also high-risk periods for initiating substance use, including, but not limited to, alcohol, cannabis, and tobacco [1]. The associations between physical activity and substance use appear to be complex, because physical activity has the potential to increase risk or protection depending on the substance of interest. If physical activity is associated with differential substance use behavior, it may be possible for

Implications

Practice: Distinct patterns in the associations between physical activity, sedentary behavior, and substance among adolescents and emerging adults can inform how clinicians and interventionists should approach these behaviors within and across these developmental life stages.

Policy: Policymakers who want to invest in interventions that target multiple behaviors among adolescents and emerging adults must consider the diverse associations between movement and substance use.

Research: Future research should be aimed at using device-based measures to account for timing of and contextual features surrounding movement and substance use.

interventions to modify multiple health behaviors in an efficient and effective manner [2]. Multiple behavior change interventions require an understanding of how health behaviors are associated with one another and how changing one behavior can impact another. This review seeks to describe the associations between physical activity, sedentary behavior, and common forms of substance use in adolescent and emerging adult samples.

Physical activity and substance use

Physical activity is characterized as any movement that requires energy expenditure above resting metabolic rate and, compared to inactivity, movement of any duration is considered to be beneficial to an individual's health [3]. Most adolescents (76%) engage in less than the recommended 60 min of moderate-to-vigorous intensity physical activity per day [4]. Similarly, as many as a quarter of emerging adults do not engage in the recommended 150 min of moderate-to-vigorous intensity physical activity per week [5]. The transition from adolescence into emerging adulthood is also marked by a decline of 5–7 min of moderate-to-vigorous intensity physical activity per day over the course of about

3 years [6]. On the other side of the movement spectrum, public health researchers and practitioners are increasingly recognizing that sedentary behavior (e.g., sitting time, screen time) is a concern among adolescents and emerging adults, with the potential for adverse health risks over-and-above the role of physical activity. Over the past decade, sedentary behavior has increased to approximately 8 hr per day for adolescents and 6 hr per day for emerging adults [7]. The prevalence of physical inactivity during these developmental stages coincides with increased risk of substance use.

Alcohol use

Previous reviews found a positive association between physical activity and alcohol use across the life span [8–10]. However, two significant limitations exist in these reviews. First, prior reviews were restricted to studies from the USA, despite insufficient physical activity and alcohol use being global concerns [11,12]. The legal drinking age differs between countries, which may impact how alcohol use is associated with other health behaviors (e.g., physical activity). Second, prior reviews have focused on adults, with particular emphasis on emerging adults attending college [8,9]. Alcohol use typically begins in adolescence, increases from adolescence into emerging adulthood, and typically peaks around age 25 [13,14]. Therefore, a more comprehensive review is needed to determine if associations between alcohol use and physical activity differ at each developmental stage (i.e., adolescence and emerging adulthood).

To date, no reviews have examined the association between sedentary behavior and alcohol use. Sedentary behavior refers to any waking behavior characterized by an energy expenditure of 1.5 metabolic equivalent of task (METs) or less when in a seated, reclined, or lying position [15]. Sedentary behavior and physical activity have demonstrated independent effects on a variety of health outcomes, including all-cause mortality and cardiovascular disease [16]. It is possible that sedentary behavior could also have unique associations with substance use.

Cannabis use

In contrast to tobacco and alcohol use, associations between physical activity and cannabis use have received limited attention. Although one systematic review examined the effects of cannabis during sport and exercise bouts (e.g., work capacity; onset of angina) [17], we are not aware of existing reviews targeting associations between cannabis use and either physical activity or sedentary behavior. The present review will fill that gap by summarizing research on associations between physical activity, sedentary behavior, and cannabis use.

Purpose

This systematic review was designed to summarize primary studies reporting associations between

movement-related behaviors (i.e., physical activity and sedentary behavior) and substance use (i.e., alcohol or cannabis) during two critical developmental periods. It extends the literature by drawing on an expanded search strategy that included terms for both physical activity and sedentary behavior. Whereas this systematic review included aggregative goals (i.e., exhaustive, assessing quality of literature, summarizing findings) we sought to descriptively characterize associations rather than employ statistical techniques related to the magnitude of these associations (i.e., meta-analysis). This decision was made because: (i) the novelty of this review demanded a broad scope regarding constructs and measures, and (ii) the breadth of study designs and measures limited the validity of statistical comparisons. Key hypotheses were that (i) physical activity and alcohol use would be positively associated among adolescents and emerging adults, (ii) physical activity and cannabis use would be negatively associated among adolescents and emerging adults, and (iii) sedentary behavior would be positively associated with both alcohol and cannabis use among adolescents and emerging adults.

METHODS

Search strategy

This systematic review was not preregistered. Electronic databases of PubMed, PsycINFO, and Web of Science were searched from inception of each database through June 25, 2019. Three main subject categories were included in all searches. The first subject category included search terms related to “physical activity” or “sedentary behavior” (e.g., “exercise,” “weight lifting,” “sitting”), which were combined with “or” statements. Search terms for this subject category were chosen based on the search terms used to compile the literature for the 2018 Physical Activity Guidelines Advisory Committee [18]. The second subject category included “alcohol,” “cannabis,” and any terms related to those two substances (e.g., “alcoholic beverage,” “marijuana”) combined with “or” statements. Search terms for this category were informed by earlier reviews on substance use [8,10,17]. Finally, a third set of search terms were used to define the population of interest, including, but not limited to, “adolescent,” “college student,” and “teenager,” which were also combined with “or” statements. Once searches had been completed for the three main subject categories individually, they were combined with “and” statements and the search was run again. Limits were placed on the final search restricting results to: (i) English studies only, (ii) human subjects, (iii) empirical studies (i.e., no reviews), and (iv) participants aged up to 25 years. A hand search of relevant, earlier reviews in this space was also conducted [8–10]. Complete search strategies for each database

can be found in the [Supplementary Material](#). This search strategy was reviewed and approved by a trained reference librarian and search specialist at the Pennsylvania State University.

Selection process

Inclusion criteria were set to obtain a comprehensive list of the published literature examining associations between single substance use and physical activity among those at high risk for engaging in risky substance use behaviors. Studies were included if physical activity or inactivity was a main outcome variable (i.e., analyzed as a separate construct/behavior) and if the results included measures of associations or effect size between physical activity or inactivity and either alcohol or cannabis use. Studies were included if they involved adolescents or emerging adults through age 25. Primary studies as well as gray literature (i.e., dissertations) were included if relevant.

Studies were excluded if the only substance of interest was tobacco. The greatest volume of evidence linking physical activity and substance use involves tobacco. Fortunately, the use of tobacco among adolescents and emerging adults, in many cases, is declining [19,20]. Based on this evidence, the present review excluded tobacco use and focused on physical activity, alcohol, and cannabis. Studies were also excluded if they did not test or report associations between a movement-related behavior and substance use. Finally, studies were excluded if the sample included anyone over the age of 25. This eligibility criterion was selected to focus conclusions on an important developmental transition and limit heterogeneity among studies. A detailed description of the inclusion/exclusion criteria can be found in the [Supplementary Material](#).

Titles and abstracts were independently reviewed in a blinded manner by the first author and one other trained coder using the described inclusion and exclusion criteria. Prior to discussion, interrater reliability (Cohen's unweighted kappa) was 0.78, good agreement between the coders. Disagreements between coders were resolved through discussion, and once consensus was reached, eligible studies were moved to full-text review. [Figure 1](#) details the flow of studies through the review process according to PRISMA guidelines [21].

Data extraction

All studies that met the inclusion criteria during full-text review were advanced for full data extraction and evaluation of relevance by the first author. Studies determined as relevant and eligible for extraction by the first author were then independently assessed in an unblinded manner by the first author and three trained coders, using a coding guide (see [Supplementary Material](#)). Two additional trained coders were brought in at this stage given

the volume of data extraction. The coding guide was developed to ensure that detailed descriptive information could be collected in order to characterize associations between behaviors. The coding guide was initially pilot-tested on 10 randomly selected studies and was refined when necessary. Once all coders agreed on how to use the coding guide for the 10 piloted studies, all coders moved forward with independent, unblinded coding and extracting data from the remaining studies. The first author coded and extracted data from all studies, whereas the three additional coders each coded and extracted data from a third of the studies. The first author compared extracted data between each of the three coders, and disagreements were resolved through discussion.

Sample characteristics extracted from each study included size, age, sex, race, ethnicity, education level, and country where the data were collected. Physical activity, sedentary behavior, alcohol use, and cannabis use were all characterized by assessment timeframe and measurement method. The research design was categorized as cross-sectional or longitudinal (no experimental studies were identified). For longitudinal studies, intervals between measures were coded when available. Relevant statistics were extracted when available; these included group means and standard deviations, effect sizes, *p*-values, odds ratios, *r* correlation coefficients, beta values, standard errors, and chi-square values. Based on the original statistical results reported in association to each authors' significance cutoff, coders characterized each association as positive, negative, or not significant. Finally, given that this literature was mostly observational and these data provide insufficient evidence for drawing causal inferences, the quality of evidence was not graded.

RESULTS

A total of 5,610 unique studies were identified during the initial search. Of these, 5,263 were excluded during title and abstract screening. Full-text review of the remaining 347 studies led to the exclusion of 250 studies. Ninety-seven studies were identified for inclusion in this review [22–118]. [Tables 1](#) and [2](#) summarize participant characteristics, organized by association, of the included studies. Participant characteristics, study design, measurement methods, and main findings from each of the included studies can be found in the [Supplementary Material](#).

Most studies sampled adolescents (67%) or emerging adults (32%); only one study explicitly set out to sample and analyze both age groups [55]. Sedentary behavior was assessed in one third of the studies (32%), and all but two of those studies sampled adolescents. Most studies focused on alcohol as the sole substance of interest (68%). Very few studies included cannabis as the sole substance of interest (2%). Both substances were examined in roughly

Fig 1 | Study flow diagram.

one third of studies (30%). Samples were recruited across the globe, but primarily from the USA (44%). Sample sizes ranged from 58 to 653,211 individuals.

Most study designs were cross-sectional (93%) with a few notable exceptions [22,39,51,54,60,65,95,109]. The earliest study found was published in 1985 but most studies (91%) were published since 2000. Three relevant studies were dissertations [65,94,95].

For physical activity and sedentary behavior, data were collected using self-report methods (99%), with the most popular measures including the Physical Activity Questionnaire for Adolescents, the International Physical Activity Questionnaire (IPAQ), and the Godin Leisure Time Exercise Questionnaire. The one exception used an Actigraph GT3X+ activity monitor to assess physical activity and sedentary behavior [56]. Substance use was measured using self-report methods exclusively, with the most popular measures including the National College Health Assessment, Youth Risk Behavior Survey, AUDIT, Daily Drinking Questionnaire, European School Survey on Alcohol and other Drugs, and the Global School-based Student Health Survey.

Physical activity and alcohol use

Adolescents

Among adolescents, null associations ($k = 17$, mean $N = 2,573$, $SD = 5,299$) [27,36,41–44,50,57,58,64,77,87,98,100,104,105,112] were slightly more common than positive associations between physical activity and alcohol use ($k = 14$, mean $N = 23,305$, $SD = 31,248$) [23,31,37,48,49,53,61,69,80,83,86,88,91,114]. Negative associations between physical activity and alcohol use were relatively uncommon ($k = 6$, mean $N = 2,837$, $SD = 4,016$) [35,38,66,81,103,108]. As seen in Table 1, samples were recruited in the USA, Canada, Europe, Brazil, and South Africa. Self-report measures were used in all studies.

Mixed associations between physical activity and alcohol use among adolescents were reported in six studies. Mixed associations refer to cases where findings varied across subsamples within the study as a function of sex, grade level, and physical activity type. Two studies offered conflicting reports on biological sex as a moderator. A study of Japanese adolescents ($N = 1,466$) revealed that

Table 1 | Summary characteristics of studies investigating associations between physical activity, alcohol, and cannabis use

	Alcohol		Cannabis	
	Adolescent	Emerging adult	Adolescent	Emerging adult
Total number of studies	37	21	13	5
Sample size range (<i>n</i>)	88–109,104	58–34,208	88–653,211	129–67,861
Age range (years)	10–19	18–25	10–19	18–24
Age <i>M</i> (<i>SD</i>) (years)	15.1 (1.8)	20.7 (1.1)	15.1 (1.8)	19.4 (1.2)
Female (%)	52	57	58	47
Positive associations				
Studies (<i>n</i>)	14	14	4	1
Sample size range (<i>n</i>)	643–109,104	129–34,208	323–1,978	1,915
Age range (years)	12–19	18–25	13–18	NR
Age <i>M</i> (<i>SD</i>) (years)	15.8 (1.4)	21 (0.8)	14.2 (1.1)	20.2 (0.5)
Female (%)	56	56	67	61
Null associations				
Studies (<i>n</i>)	17	5	2	2
Sample size range (<i>n</i>)	88–22,084	58–589	2,230–45,298	391–67,861
Age range (years)	10–19	18–25	10–17	18–24
Age <i>M</i> (<i>SD</i>) (years)	14.8 (2)	20 (1.9)	NR	NR
Female (%)	49	56	51	61
Negative associations				
Studies (<i>n</i>)	6	2	7	2
Sample size range (<i>n</i>)	444–10,590	252–1,356	88–653,211	129–4,748
Age range (years)	13–19	NR	12–19	NR
Age <i>M</i> (<i>SD</i>) (years)	14.3 (NR)	20.6 (NR)	17 (NR)	19 (1.4)
Female (%)	53	60	52	52

NR Not Reported.

physical activity was negatively associated with alcohol use for girls but unassociated with alcohol use for boys [101]. A study of U.S. adolescents ($N = 1,245$) revealed the opposite pattern: physical activity was positively associated with alcohol use for boys but unassociated with alcohol use for girls [22]. Three studies reported associations that differed as a function of the type of physical activity. A study of U.S. adolescents ($N = 2,054$) found that structured (organized sport)—but not unstructured (recreational hobbies)—physical activity was positively associated with alcohol use [94]. Similarly, U.S. adolescents' sport participation was positively associated with alcohol use for those involved in skateboarding, surfing, and tennis, but was negatively associated with alcohol use for those involved in basketball ($N = 891$) [72]. Among Norwegian adolescents ($N = 2,060$), organized physical activity was negatively associated with alcohol misuse, whereas nonorganized physical activity was not associated with alcohol misuse [115]. Finally, one study identified grade as a possible moderator. In U.S. adolescents ($N = 653,211$), physical activity was negatively associated with alcohol use among middle school students, but positively associated among high school students [102].

Emerging adults

Among the emerging adult population, the majority of the literature reported a positive association between physical activity and alcohol use ($k = 14$, mean $N = 4,876$, $SD = 9,270$) [25,52,54,68,73–75,78,79,82,111,113,116,118]. Fewer studies reported a null association ($k = 5$, mean $N = 284$, $SD = 234$) [28,56,90,92,95] or a negative association ($k = 2$, mean $N = 804$, $SD = 781$) [59,67]. Data in these studies were mostly collected within the USA as well as Canada, Europe, Asia, and Australia. As seen in Table 1, self-report measures were used in all studies except for one that used an activity monitor to track physical activity [56].

Associations between physical activity and risky drinking patterns (i.e., binge drinking and heavy episodic drinking) were also identified among emerging adult college students. Meeting physical activity guidelines was associated with greater binge drinking [47,113], whereas engaging in more physical activity in general was positively associated with both binge drinking [29,111,118] and heavy episodic drinking [74,75].

A selection of studies ($k = 6$) reported mixed findings between physical activity and alcohol use among emerging adults. Results varied as a function of study design, physical activity type, sex,

Table 2 | Summary characteristics of studies investigating associations between sedentary behavior, alcohol, and cannabis use

	Alcohol		Cannabis	
	Adolescent	Emerging adult	Adolescent	Emerging adult
Total number of studies	26	1	9	1
Sample size range (<i>n</i>)	394–32,696	475	1,211–24,593	1,915
Age range (years)	10–19	NR	10–18	NR
Age <i>M</i> (<i>SD</i>) (years)	15.2 (1.1)	22.1 (0.6)	16.1 (0.5)	20.2 (0.5)
Female (%)	47	54	52	61
Positive associations				
Studies (<i>n</i>)	22	NA	5	1
Sample size range (<i>n</i>)	394–32,696		2,942–24,593	1,915
Age range (years)	10–18		10–18	NR
Age <i>M</i> (<i>SD</i>) (years)	15.2 (1.2)		NR	20.2 (0.5)
Female (%)	46		52	61
Null associations				
Studies (<i>n</i>)	3	NA	2	NA
Sample size range (<i>n</i>)	862–2,105		4,887–22,084	
Age range (years)	13–18		12–17	
Age <i>M</i> (<i>SD</i>) (years)	14.9 (0.8)		16.7 (NR)	
Female (%)	61		51	
Negative associations				
Studies (<i>n</i>)	1	1	2	NA
Sample size range (<i>n</i>)	3,992	475	1,211–10,828	
Age range (years)	14–19	NR	NR	
Age <i>M</i> (<i>SD</i>) (years)	NR	22.1 (0.6)	15.9 (0.1)	
Female (%)	61	54	53	

NR Not Reported; NA Not Applicable.

and measurement of alcohol use. Two studies that employed multilevel analyses with responses clustered within individuals over time revealed differing findings regarding associations at the between-person level (i.e., person-mean) compared to the within-person level (i.e., daily/weekly deviation from person-mean). Among a sample of 89 U.S. emerging adults, a positive association was reported between people, but a negative within-person association was reported [24]. When vigorous physical activity was specifically assessed, a 2018 study showed that among 396 U.S. emerging adults the between-person association was null, whereas the within-person association was positive between vigorous activity and alcohol use [51]. Two studies identified alcohol use measures as potential moderators, with both studies revealing similar positive associations when measuring alcohol quantity. Davis and colleagues [39] found that among 524 U.S. emerging adults alcohol use quantity was positively associated with strenuous activity, but alcohol use frequency was negatively associated with strenuous activity among women. Similarly, total physical activity was positively associated with alcohol quantity among 206 U.S. emerging adult women, but null findings were reported when frequency or binge were measured [32]. One study identified

physical activity type as a possible moderator. In 22,488 U.S. emerging adults, moderate activity was *negatively* associated with drinking, whereas vigorous and strength training activities were *positively* associated with drinking [29]. Finally, sex was identified as a potential moderator in one study. Among 2,051 Spanish emerging adults, a null association was reported between physical activity and alcohol use for men but this association was negative among women [93].

In the only study that sampled both adolescents and emerging adults, physical activity and alcohol use were positively associated ($N = 12,120$) [55]. These data were collected in Canada. Physical activity and alcohol use were both measured using the National Population Health Survey.

Physical activity and cannabis use

Adolescents

Physical activity and cannabis use tended to have a negative association among adolescents ($k = 7$, mean $n = 99,343$, $SD = 244,349$) [44,57,80,86,100,102,117]. Four studies reported a positive association between these behaviors ($k = 4$, mean $N = 1,216$, $SD = 751$) [36,61,72,112]. Only two studies reported a null association ($k = 2$, mean $N = 23,764$, $SD = 30,454$) [42,53]. As seen in Table 1, samples were recruited

from the USA, Canada, Europe, and South Africa. Self-report measures were used in all studies.

Three studies reported mixed findings on the associations between physical activity and cannabis use among adolescents. Results varied as a function of sex and physical activity intensity level. Two studies showed conflicting reports on sex as a moderator. Among 16,343 U.S. adolescents physical activity was positively associated to cannabis use among girls but null findings were reported for boys [48]. However, among 3,581 South African adolescents physical activity was negatively associated with cannabis use for girls but positively associated for boys [104]. One study identified physical activity intensity level as a potential moderator. With 738 Canadian adolescents, high-intensity activity was negatively associated with cannabis use but low-intensity activity was positively associated with cannabis use [69].

Emerging adults

The literature on physical activity and cannabis use among emerging adults was mixed. Two studies each reported negative (mean $N = 2,439$, $SD = 3,266$) [28,54] and null associations (mean $N = 34,126$, $SD = 47,708$) [47,73]. Only one study reported a positive association ($N = 1,915$) [60]. As seen in Table 1, data were collected from samples in the USA and Switzerland and included only self-report measures.

Sedentary behavior and alcohol use

Adolescents

Sedentary behavior was typically operationalized as screen time (e.g., watching TV, playing computer or video games, time on social network sites). A positive association between sedentary behavior and alcohol use was common among adolescents ($k = 22$, mean $N = 10,083$, $SD = 10,839$) [23,26,30,45,46,57,62–65,83–85,87,89,96,99,106,107,109,110,114]. Few studies reported null ($k = 3$, mean $N = 1,532$, $SD = 627$) [27,76,97] or negative associations ($k = 1$, $N = 3,992$) [40]. Data were collected from samples in the USA, Canada, Europe, Brazil, Africa, and Asia. As seen in Table 2, self-report measures were used in all studies.

Three studies reported mixed findings between sedentary behavior and alcohol use among adolescents. Type of screen and measurement of alcohol use were identified as potential moderators. Two studies revealed type of screen as a potential moderator but the associations varied. Among 9,137 Canadian adolescents using the computer or video games frequently was negatively associated with binge drinking, but null findings were reported when looking at television use [34]. Among 1,897 Spanish adolescents watching television and using a computer were positively associated with alcohol use for girls, yet being sedentary while doing homework

was negatively associated with alcohol use for both girls and boys [50]. One study identified measurement of alcohol use as a potential moderator. Among 2,425 Dutch adolescents, null findings were reported between binge drinking and screen time; however, recent alcohol use was positively associated with excessive Internet use [33].

Emerging adults

Only one study examined sedentary behavior and alcohol use among emerging adults [56]. In the study, 475 Australian emerging adults wore an activity monitor for 7 days and self-reported alcohol use over the past week. As seen in Table 2, a negative association was reported between sedentary behavior and alcohol use [56].

Sedentary behavior and cannabis use

Adolescents

Five studies reported positive associations between cannabis use and sedentary behavior among adolescents (mean $N = 13,860$, $SD = 10,033$) [26,30,45,63,83]. Four other studies reported negative (mean $N = 6,020$, $SD = 6,800$) [65,89] or null (mean $N = 13,486$, $SD = 12,160$) [57,99] associations between cannabis use sedentary behavior in adolescents. Data were collected from samples in the USA, Canada, Europe, and Africa. As seen in Table 2, self-report measures were used in all studies.

Emerging adults

Only one study examined sedentary behavior and cannabis use among emerging adults ($N = 1,915$) [60]. As seen in Table 2, these data were collected in the USA and the association was positive in that occasional cannabis users reported more sedentary behavior than nonusers [60].

Physical activity and polysubstance use

Two studies examined physical activity and polysubstance use among college students in the USA (mean $N = 282$, $SD = 108$) [70,71]. Polysubstance use was defined as participating in heavy drinking, cannabis use, and at least one other illicit drug. Those who only participated in heavy drinking (without cannabis or illicit drugs other than cannabis) reported the most physical activity, whereas those engaging in polysubstance use reported the least physical activity when compared to those who only drank heavily or drank heavily and used cannabis but no other drug.

DISCUSSION

This systematic review examined movement-related behaviors and substance use in adolescents and emerging adults, a developmental period characterized by adverse changes in these health behaviors.

Research in this area dates back to 1985 and has been conducted on six continents. However, most studies have been published over the past two decades with samples from North America or Europe. The general conclusions from the 97 eligible studies identified were that (i) physical activity is positively associated with alcohol use in both adolescents and emerging adults, (ii) physical activity is negatively associated with cannabis use among adolescents, and (iii) sedentary behavior is positively associated with substance use among adolescents.

The positive association between physical activity and alcohol was consistent with our first hypothesis and prior reviews [8–10]. This finding also matched findings in other populations, such as the general adult population (up to age 89) and in overweight or obese adults [119–123]. The negative association between physical activity and cannabis use among adolescents partially supported our second hypothesis. Findings on physical activity and cannabis use among emerging adults were mixed, preventing us from determining whether the association was more likely to be negative or null. The negative association between physical activity and cannabis use also matched the negative association that has typically been reported between physical activity and tobacco use. Recent systematic reviews examining tobacco have indicated that physical activity may protect against smoking and reduce negative side effects of smoking (e.g., cigarette cravings, withdrawal symptoms, and negative affect) [124–126]. Finally, the positive association between sedentary behavior and substance use among adolescents partially supported our third hypothesis. Literature examining sedentary behavior and substance use among emerging adults was scarce; therefore, conclusions could not be drawn about these associations in this population. This review supported conclusions from less comprehensive reviews of research on physical activity and alcohol use among emerging adults, and extended the literature by providing conclusions about movement-related behaviors and substance use among adolescents.

Across adolescence and emerging adulthood, physical activity was positively associated with alcohol use, including risky drinking patterns (e.g., binge drinking); however, the evidence for these associations was more consistent among emerging adults. The literature on adolescents slightly favored a null association between activity and alcohol use, but from 18 to 25 years old the literature strongly favored positive associations. Considering the potential for this pattern to suggest developmental change, the emergence of an association with age could be explained by a shift in outcome expectancies or motives for these two behaviors. This review did not seek to assess drinking motives or expectancies; however, given that adolescence can be characterized by frequent shifts in attitudes and beliefs,

it is possible that motivations to drink among this group are centered around experimentation with alcohol. Whereas many adolescents have yet to form outcome expectancies or motives for alcohol consumption, emerging adults' motives and expectancies have crystallized—often including motives to drink with goals ranging from producing euphoria, to decreasing negative affect or anxiety [13]. These alcohol expectancies can also align with outcome expectations for physical activity [127]. As adolescents transition into emerging adulthood they may become aware of and seek out activities such as physical activity and alcohol use to produce positive affect or cope with stress and anxiety. An exception may be among adolescents participating in team sports, where the literature indicates a positive association. Adolescents participating in sports likely find physical activity to be enjoyable, and may also have increased opportunities to experiment with alcohol within this peer group [128]. Another explanation for the differential coupling of physical activity and alcohol use across this developmental transition may also relate to differences in how alcohol use is measured, or differences in the time spans used when measuring physical activity and alcohol use. Among adolescents it is more common to assess alcohol use with binary questions such as “Have you ever tried alcohol,” whereas studies with emerging adults more commonly measured as past month or 2-week use and assessed frequency and/or quantity. Among adolescents, 24% of the studies assessed alcohol use with a binary question compared to one study among emerging adults. In both populations, physical activity is typically measured on a shorter time scale (e.g., past week, past month) compared to alcohol use and frequency is often assessed. Identifying a positive association might require assessment of the behaviors within a similar time period and by measuring the same outcome (e.g., frequency).

This review also found positive associations between physical activity and risky drinking patterns (i.e., binge drinking and heavy episodic drinking), but this literature was mostly restricted to college student samples. Positive associations between physical activity and binge drinking appear to be robust across a variety of alcohol use measures [9]; however, some research with undergraduate students has reported a negative association between physical activity and risky drinking [129]. Positive associations between physical activity and risky drinking patterns may be more pronounced among emerging adults compared to adolescents for several reasons. First, binge drinking is more prevalent among emerging adults than adolescents [130–133]. Second, emerging adults may be locked in a compensatory cycle of engaging in binge drinking and then balancing the increased caloric consumption by exercising excessively and restricting their diet, a phenomenon known as “drunkorexia” [134]. This

trend among emerging adults has not yet become common among adolescents.

Contrary to the literature on alcohol use, associations between physical activity and cannabis use were more consistent for adolescents than emerging adults. During adolescence, physical activity may serve as a protective factor against cannabis use; however, the literature is still young and it is too early to draw conclusions about why the association tends to be negative during this developmental period. With emerging adults, the literature equally supported null and negative associations. Cannabis is increasingly available with the rise in legalization, and is becoming a popular drug to co-use alongside alcohol among emerging adults [135]. Given the increased availability and social acceptance of using cannabis, emerging adults who use may have different motivations than adolescents who use, making it difficult to draw conclusions about associations between physical activity and cannabis use in this population.

On the other side of the movement spectrum, sedentary behavior was positively associated with substance use among adolescents. Positive associations were more consistently reported for studies on alcohol (85%) than cannabis (56%). Although this is a relatively new area of research, sedentary behavior has been positively associated with use of other substances (i.e., tobacco) across adulthood [136]. Across the adolescent period the literature suggests sedentary behavior could be a risk factor for substance use. The available evidence does not indicate if the association is bidirectional. Sedentary behavior has typically been operationalized as screen time rather than total sitting time. To date, it is unknown how the association would change with different measures of sedentary behavior. It may be that the association is specific to certain domains of sedentary behavior.

Literature examining sedentary behavior and substance use among emerging adults was limited. Notwithstanding this gap, sedentary behavior is a growing concern among emerging adults given that it is a time of transition and many life changes (e.g., school, career, family) [137]. Demands associated with coursework such as time spent using a computer or studying can also lead to increased sedentary behaviors and these demands tend to increase as students advance through school [138]. Further, multiple social opportunities exist for emerging adults to engage not only in increased sedentary behavior but also increased alcohol use such as hanging out at a bar or sporting event; however, the lack of research in this area limited us from drawing conclusions on how sedentary behavior domains may impact substance use. Cannabis is becoming increasingly available, and this increase has been linked to an increase in the prevalence of cannabis users [139]. However, the lack of research limits our ability to draw

conclusions about how this increased prevalence in cannabis use could impact the sedentary behaviors of emerging adults.

This review identified preliminary geographical differences in the associations between physical activity and alcohol use. Across adolescence and emerging adulthood, most studies ($k = 13$) revealing *null* associations were based on samples collected outside of the USA, whereas studies revealing *positive* associations were commonly based on samples from the USA ($k = 18$). Negative associations were only identified *outside* of the USA, typically in European countries.

Adolescents are greatly influenced by their peers and social groups and this influence has been identified as a key risk factor for alcohol use [140]. As such, different countries and cultures may have different norms that would influence the patterns of physical activity or alcohol use as well as their association. However, these differences likely cannot be attributed to prevalence rates given that adolescent alcohol use is equally prevalent across the USA and Europe [141]. Certain peer groups, such as athletes, may be more accepting of using alcohol in certain countries or cultures. For athletes in the USA, drinking may be more of a normative behavior than in other countries. Drinking ages also differ between the USA and Europe. The higher legal drinking age in the USA could entice alcohol consumption, particularly among adolescents and emerging adults who are experimenting with substances and seeking independence [142]. Among adolescents, the association between physical activity and alcohol use is mixed and it is unclear what contexts or mechanisms moderate the association. Cross-cultural research is needed to examine whether associations are a function of alcohol-related attitudes and policies.

Limitations

For this review, the definition of emerging adults included those up to age 25. This cutoff was deemed appropriate given the peak of substance use at this age. Research on adults aged 26–30 were not included and therefore we cannot draw conclusions on how associations between movement behaviors and substance use may differ when emerging adults near age 30 and transition into middle adulthood. Conclusions from this review may not generalize to adults over the age of 25.

This review described the direction of associations but did not estimate the strength of the associations. All studies reviewed were observational, so causal inferences cannot be drawn. For this reason, the evidence was not graded and effect sizes were not estimated. As a consequence, dose-response associations, bias within the evidence base, magnitude of association, and evidence of between-study moderators are all unclear.

Future directions

The literature on movement behaviors and substance use has largely been based on adolescent samples. When included, emerging adults were typically undergraduate college students, and this constrains generalizability to emerging adults who had already complete (or did not complete) postsecondary education. Primary studies are needed that include diverse groups of emerging adults, including noncollege-bound emerging adults.

The literature reviewed was based almost entirely on self-reported behaviors. Recall and social desirability biases are common threats in self-report research [143] and are no less common when reporting activity and substance use behaviors [144,145]. Device-based measures have been widely used in research that seeks to track movement-related behaviors [146,147], and device-based measures that can track alcohol use are increasing in popularity [144]. Sedentary behavior was typically operationalized as screen time and total sitting time throughout the day was often not considered. This review provides a starting point for understanding whether certain screens (e.g., television, computer) or domains of sedentary behavior are associated with substance use, but it is presently unclear if individuals who are more sedentary throughout the day engage in more or less substance use. Future work in this space should incorporate devices alongside self-report measures to limit biases as well as provide contextual details to these associations.

It was uncommon for descriptive details (e.g., means, standard deviations) to be provided consistently across all behaviors. Inadequate reporting will compromise future meta-analyses of this literature. Detailed reporting of all descriptive information as well as increased standardization in measures used to assess these associations will allow the field to understand dose-response associations as well as contexts of these associations. Over 90% of the studies were cross-sectional, so causal inferences cannot be drawn. The temporal sequence of movement-related behaviors and substance use needs to be clarified in future research. Finally, ethnicity and Socioeconomic Status (SES) were not consistently reported across the studies. Both ethnicity and SES may play an important role in whether an individual meets the physical activity guidelines or engages in substance use. As such, future research should consistently report these demographic characteristics so that patterns across populations and cultures can be identified.

CONCLUSIONS

In sum, this review provides the most comprehensive insight to date into associations between movement-related behaviors and substance use among adolescents and emerging adults around the world. Results show that physical activity is positively associated with alcohol use among emerging adults, but associations

between these associations vary among adolescents. This systematic review also showed sedentary behavior might serve as a risk marker for substance use in adolescents, but additional work is needed to explore associations between sedentary behavior and substance use among emerging adults. Research in this space has grown substantially in the past decade, but the literature has not examined the temporal sequence of associations nor has it examined contextual moderators of associations. Polysubstance use patterns should receive more attention because of evidence that co-use of alcohol and cannabis increases harm [135]. Future work can increase the rigor of this literature by using device-based measures to account for timing of and contextual features surrounding movement and substance use, and incorporating longitudinal designs and standardized measures for reporting these behaviors.

SUPPLEMENTARY MATERIAL

Supplementary material is available at *Translational Behavioral Medicine* online.

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Compliance with Ethical Standards

Conflicts of Interest: The authors declare that they have no conflicts of interest.

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