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Is breakfast skipping associated with physical activity among US adolescents? A cross-sectional study of adolescents aged 12–19 years, National Health and Nutrition Examination Survey (NHANES)

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Abstract

Objective: To examine the association between breakfast skipping and physical activity among US adolescents aged 12–19 years.

Design: A cross-sectional study of nationally representative 2007–2008 National Health and Nutrition Examination Survey (NHANES) data.

Setting: Breakfast skipping was assessed by two 24 h dietary recalls. Physical activity was self-reported by participants and classified based on meeting national recommendations for physical activity for the appropriate age group. Multiple logistic regression analysis was used to model the association between breakfast skipping and physical activity while controlling for confounders.

Subjects: A total of 936 adolescents aged 12–19 years in the USA.

Results: After adjusting for family income, there was no association between breakfast skipping and meeting physical activity guidelines for age among adolescents aged 12–19 years (OR = 0·95, 95 % CI 0·56, 1·32).

Conclusions: Findings from the study differ from previous research findings on breakfast skipping and physical activity. Therefore, further research that uses large, nationally representative US samples and national recommended guidelines for physical activity is needed.

Keywords
Breakfast skipping
Physical activity
Adolescents

In 2007–2008, the prevalence of overweight and obesity in children and adolescents aged 6–19 years living in the USA was 15 % and 20 %, respectively[1]. From 1980 to 2008 the prevalence of obesity among 12–19-year-olds living in the USA increased from 5 % to 18 %, and a similar increase in the prevalence of overweight has also been seen among US adolescents[2,3]. Numerous risk factors for overweight and obesity during childhood and adolescence have been identified including genetic and perinatal factors, poor diet, lack of physical activity (PA), increased sedentary behaviour and family structure[4]. Over the past decade, numerous studies have examined the role that PA[5–9] plays in the increased prevalence of overweight and obesity in children and adolescents.

Among other health benefits, PA has been shown to reduce the risk of becoming overweight or obese and of developing other chronic diseases such as diabetes and CVD[10]. The US Department of Health and Human Services recommends at least 60 min of PA daily for children and adolescents aged 6–17 years[10]. In 2010, only 18·4 % of adolescents in high school met this requirement[11].

Along with PA levels, breakfast consumption among adolescents has also decreased over the past several decades. Data from the 1999–2006 National Health and Nutrition Examination Survey (NHANES) indicated that 31·5 % of adolescents aged 14–18 years did not consume breakfast daily (as measured by reporting no breakfast during one 24 h recall)[12]. Furthermore, from 1965 to 1991, there was a 13 % and 20 % decrease in breakfast consumption among adolescents aged 11–14 and 15–18 years, respectively[13]. Breakfast consumption is associated with diet quality throughout the day; specifically, those who consume breakfast have higher levels of daily fibre intake[14–17], higher vitamin and nutrient intakes[12,14–16,18,19], lower levels of added sugars[16,18] and lower daily percentage of fat[14]. Additionally, numerous studies have shown that breakfast skipping is associated with an increase in overweight, obesity and BMI among adolescents[12,17,19–26].

While it is possible that there is no direct causal relationship between breakfast skipping and PA, there are two potential biological mechanisms that may explain

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how breakfast consumption and PA are related. One hypothesis is that energy and nutrients obtained from breakfast allow for better PA performance. A review by Genton *et al.* discusses the evidence supporting the importance of ingesting energy and macronutrients at least 4 h prior to exercise in completing various PA assessments[27]. In one study, compared with children who consumed a breakfast that met 10 % of their daily energy needs, those who consumed a breakfast that met at least 20 % of their daily energy needs performed significantly better in a mid-morning PA endurance test[28]. Furthermore, participants randomized to receive a standardized high-carbohydrate breakfast had better aerobic performance than those randomized to a no breakfast group[29]. Additionally, it is possible that breakfast skipping is associated with mental and physical fatigue that leads to reduced PA. Previous research has shown that decreases in memory[30,31], attention level[30,31] and physical fatigue[32,33] occur after skipping breakfast or fasting. Both of these biological mechanisms suggest that breakfast skipping may lead to physical inactivity rather than physical inactivity leading to breakfast skipping. Thus, breakfast consumption will be considered the exposure and PA will be considered the outcome in the current study.

Several studies have examined the relationship between breakfast skipping and PA levels[17,21,22,26,34–37]. Results from studies examining breakfast consumption and PA have been somewhat inconsistent; most studies have found that adolescents who skip breakfast have lower levels of PA[17,21,26,35,36], other studies have found this to be true only for particular subgroups of adolescents (i.e. just boys or just girls)[34,37], and another found no relationship between the two[22]. All of these previous studies examined the breakfast skipping–PA relationship cross-sectionally[17,21,22,26,34–37]. While most used self-reported measures of PA[17,21,22,35,36], a few have used objective measures[34,37], and one used both self-reported and objective measures[26].

Several of the studies examining breakfast skipping and PA focused on younger adolescents or children (mean age of 14 years or younger)[21,22,34,36,37] and did not assess PA based on nationally recommended guidelines[21,22,26,34,35,37]. Additionally, many studies have failed to adequately consider all possible confounders such as parental education, BMI, sex, family income and family structure[21,22,26,34,37]. Lastly, the majority of studies examining this relationship have been conducted outside the USA[21,22,26,34,35,37]. Of the two studies that collected data from US adolescents, one study sampled students only in the Minneapolis/St. Paul, Minnesota region[17]; the other study was a collaborative study among many countries and no information was provided as to whether the US sample was nationally representative[36]. Thus, the objective of the current study was to examine the relationship between breakfast consumption and meeting nationally recommended guidelines for PA in a large, nationally representative sample of older adolescents (12–19 years) in the USA. Exploring the relationship between breakfast consumption and PA is of public health importance because dietary and PA habits in adolescence often carry over into adulthood[38,39].

Experimental methods

Study design and population

The present cross-sectional study used data from the 2007–2008 NHANES, which is a large, national survey designed to collect information on the diet and health of US adults and children[40]. NHANES uses interviews, physical examinations and laboratory tests to determine the prevalence of diseases and their risk factors, to monitor behaviour trends and to examine the relationship between nutrition and health[40]. NHANES was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by the National Center for Health Statistics review board. Written informed consent was obtained from all participants. Furthermore, the secondary data analysis protocol for the present study was approved by the University of North Carolina at Charlotte's institutional review board. Participants aged 16 years or older complete the health interviews (including questions on PA) at home using a computer-assisted personal interviewing system. Adolescents aged 12–15 years complete the health interviews during their visit to the mobile examination centre in privacy[41,42]. Physical examinations and laboratory tests are conducted in mobile examination centres, which allows for a standardized environment.

In 2007–2008, a total of 1448 adolescents aged 12–19 years were screened. Of these adolescents, 1238 individuals completed the health interview only and 1210 completed all aspects of the study (i.e. health interview and physical and laboratory components). The response rates for adolescents aged 12–19 years were approximately 85 % for completion of the health interview and 83 % for completion of all aspects of the study[43].

Exposure assessment

The main exposure in the present study was breakfast skipping. Breakfast skipping was determined from the dietary interview which consisted of two 24 h dietary recalls. These recalls were completed for two different days. One recall was completed during the in-person interview and the other was completed during a follow-up phone interview[31]. Adolescents who listed any food or beverage item (with the exception of water) during 'breakfast' or 'desyuano' for both of the 24 h dietary recalls were considered breakfast eaters. Adolescents who did not list any food or beverage item (or water only) eaten at 'breakfast' or 'desyuano' for at least one of

the 24 h dietary recalls were considered breakfast skippers. This method has been used in previous studies[12,18,25].

Outcome assessment

The outcome of interest in the present study was PA. Information on PA was collected via computer-assisted personal interviewing for participants aged 16 years or older during their at-home interviews, while adolescents aged 12–15 years completed questions on PA during the mobile examination centre visit with a trained interviewer and computer-assisted personal interviewing. Participants completed these questions without a parent or guardian present, unless they were unable to answer these questions by themselves[41,42]. PA was measured based on daily minutes of vigorous or moderate PA, which has been shown to correlate moderately well with PA measured objectively by pedometers in adolescents[44]. Participants were asked 'Do you do any vigorous-intensity sports, fitness, or recreational activities that cause large increases in breathing or heart rate like running or basketball for at least 10 min continuously?' Those who answered 'yes' were then asked, 'How much time do you spend doing vigorous-intensity sports, fitness, or recreational activities on a typical day?' Participants were also asked about moderate activity: 'Do you do any moderate-intensity sports, fitness, or recreational activities that cause a small increase in breathing or heart rate such as brisk walking, bicycling, swimming, or golf for at least 10 min continuously?' Participants who answered 'yes' were also asked, 'How much time do you spend doing moderate-intensity sports, fitness, or recreational activities on a typical day?' Total average daily minutes of vigorous and moderate PA were added. PA was dichotomized into not meeting PA guidelines for the appropriate age group or meeting PA guidelines for the appropriate age group. For those aged 12–17 years, the US Department of Health and Human Services recommends at least 60 min of moderate to vigorous PA daily, while for those aged 18–19 years the recommendation is 150 min/week (or approximately 21 min/d)[10].

Covariate assessment

Information on demographic, lifestyle and family factors collected on the NHANES questionnaires were considered as potential confounding factors. Potential confounders considered included: sex, age, race/ethnicity, household income, household food security, BMI (calculated as kg/m^2 based on measured height and weight), parent's education level, parent's spouse/partner's education level, parent's marital status, tobacco or nicotine use within the last 5 d, and receiving school lunch[12,13,15–17,20–23,35,36,45,46].

Statistical analyses

Frequencies and percentages of all demographic, lifestyle and family characteristics were summarized for the participants in the study. Unadjusted OR and 95 % CI were calculated using logistic regression to examine the crude association between breakfast skipping and PA. Multiple logistic regression analysis was used to obtain adjusted OR and 95 % CI of the breakfast skipping–PA association while controlling for confounding. Additionally, unadjusted OR and 95 % CI were calculated for breakfast consumption and each of the covariates to examine which covariates were actually related to both exposure and outcome in the current sample. To assess confounding, each potential confounder was entered into the model separately. Any variable that changed the magnitude of the OR by 10 % or more was considered a confounder, based on the confounder selection strategy detailed by Maldonado and Greenland[47]. Additionally, stratified analysis was completed to assess whether sex was an effect modifier of the breakfast skipping–PA association. Data were analysed using the statistical software packages SAS-callable SUDAAN in SAS version 9·2 and SUDAAN release 10·0·1 due to the complex sampling of NHANES.

Results

Of the 10 149 individuals completing at least some components of the questionnaires and dietary interviews, 8911 were excluded because they were not between the ages of 12–19 years. Individuals were also excluded if they were missing information on the exposure (n 257), household income (n 27) or BMI (n 15). For covariates that had more than thirty participants with missing information, missing categories were created. Thus, a total of 936 adolescents were included in the present analysis.

Among the total sample, more than two-thirds met PA recommendations for the appropriate age group (67·1 %) and slightly less than half of the adolescents were breakfast skippers (42·9 %; Table 1). Approximately 44·5 % of younger adolescents aged 12–15 years were breakfast skippers, while 55·5 % of older adolescents aged 16–19 years were breakfast skippers. Among breakfast skippers, 61·4 % were non-Hispanic white, 15·9 % were non-Hispanic black, 18·6 % were Hispanic and 4·1 % were of other racial/ethnic background; among non-breakfast skippers a similar percentage were non-Hispanic white (63·4 %), Hispanic (18·9 %) and 'other' (6·7 %), however a lower percentage were non-Hispanic black (11·0 %).

Females were statistically significantly less likely to meet PA recommendations for age group than males (OR = 0·50, 95 % CI 0·35, 0·71; Table 2). Hispanic adolescents were statistically significantly less likely to meet PA recommendations for age group compared with non-Hispanic white adolescents (OR = 0·54, 95 % CI 0·32, 0·90). Although not statistically significant, the likelihood of meeting PA recommendations for age group was reduced among non-Hispanic black adolescents (OR = 0·72, 95 % CI 0·48, 1·08) and was slightly increased among adolescents in

Table 1 Study sample characteristics of adolescents who participated in NHANES according to breakfast consumption, 2007–2008

	Non-breakfast skipper		Breakfast skipper	
Outcome and demographic variables	*n*	%*	*n*	%*
Meets PA recommendations for age				
Yes	323	68·7	264	65·0
No	191	31·3	158	35·0
Sex				
Female	271	51·0	216	50·9
Male	243	49·0	206	49·2
Age (years)				
12–15	301	57·3	190	44·5
16–19	213	42·7	232	55·5
Race/ethnicity				
Non-Hispanic white	171	63·4	133	61·4
Non-Hispanic black	107	11·0	134	15·9
Hispanic	211	18·9	139	18·6
Other	25	6·7	16	4·1
Annual household income				
<$US 25 000	146	17·6	135	25·2
$US 25 000–49 999	134	24·1	128	27·1
≥$US 50 000	234	61·3	159	47·7
Household food security				
Full	339	77·0	250	67·7
Marginal	58	7·0	57	10·5
Low	74	9·6	74	13·6
Very low	43	6·3	41	8·2
Education level of parent				
<High school	152	18·5	118	19·4
High school	102	18·9	100	23·5
>High school	240	56·8	193	53·2
Missing	20	5·8	11	3·9
Education level of parent's spouse				
<High school	76	12·2	50	8·2
High school	58	14·2	53	17·1
>High school	150	38·5	93	27·7
Missing	230	35·1	226	47·0
Marital status of parent				
Married	308	70·0	219	58·5
Divorced/separated/widowed	113	18·9	87	19·9
Single	49	5·0	55	9·4
Living with partner	22	3·3	16	3·6
Missing	22	2·9	45	5·6
Tobacco/nicotine use in last 5 d				
Yes	41	8·5	56	15·7
No	441	86·8	348	20·2
Missing	32	4·7	18	4·0
Receives school lunch				
Always (5 d/week)	261	45·8	191	42·0
Sometimes (1–4 d/week)	66	11·6	66	20·3
Never (0 d/week)	88	22·1	69	22·6
Missing	99	20·9	96	22·6
Trying to lose weight?				
Yes	61	11·7	55	12·6
No	417	82·6	348	84·2
Missing	36	5·7	19	3·2
BMI†				
Normal weight (<85th percentile)	326	69·7	260	62·7
Overweight (85th–95th percentile)	85	14·3	70	17·7
Obese (≥95th percentile)	103	17·0	92	19·6

NHANES, National Health and Nutrition Examination Survey; PA, physical activity.
*Weighted percentages.
†To determine weight status in children and adolescents aged 2–19 years, BMI was calculated by dividing weight in kilograms by the square of height in metres (kg/m^2) and this number was then compared on a standardized growth chart. Children and adolescents who were at the 85th but below the 95th percentile were considered overweight; those at or above the 95th percentile were considered obese.

other racial/ethnic groups (OR = 1·07, 95 % CI 0·41, 2·80) compared with non-Hispanic white adolescents.

As household income decreased, the likelihood of meeting PA recommendations for age group decreased (<$US 25 000/year: OR = 0·35, 95 % CI 0·27, 0·47; $US 25 000–$49 999/year: OR = 0·54, 95 % CI 0·32, 0·90; referent category: ≥$US 50 000/year). Adolescents of a parent whose marital status was single or living with a

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Table 2 Unadjusted odds ratios and 95 % confidence intervals of the associations between breakfast skipping, demographic and lifestyle characteristics and PA among adolescents who participated in NHANES, 2007–2008

	Meets PA recommendations for age	
Exposure and demographic variables	OR	95 % CI
Breakfast skipper		
Yes	0·85	0·55, 1·30
No	1·00	Referent
Sex		
Female	0·50	0·35, 0·71
Male	1·00	Referent
Age (years)		
12–15	0·83	0·63, 1·09
16–19	1·00	Referent
Race/ethnicity		
Non-Hispanic white	1·00	Referent
Non-Hispanic black	0·72	0·48, 1·08
Hispanic	0·54	0·32, 0·90
Other	1·07	0·41, 2·80
Annual household income		
<$US 25 000	0·35	0·27, 0·47
$US 25 000–49 999	0·54	0·32, 0·90
≥$US 50 000	1·00	Referent
Household food security		
Full	1·00	Referent
Marginal	0·57	0·29, 1·12
Low	0·51	0·33, 0·79
Very low	0·98	0·39, 2·45
Education level of parent		
<High school	0·50	0·36, 0·70
High school	0·62	0·39, 0·99
>High school	1·00	Referent
Missing	0·81	0·24, 2·71
Education level of parent's spouse		
<High school	0·53	0·27, 1·02
High school	0·89	0·44, 1·83
>High school	1·00	Referent
Missing	0·52	0·29, 0·93
Marital status of parent		
Married	1·00	Referent
Divorced/separated/widowed	0·69	0·38, 1·27
Single	0·48	0·25, 0·90
Living with partner	0·23	0·06, 0·94
Missing	0·91	0·49, 1·68
Tobacco/nicotine use in last 5 d		
Yes	0·80	0·45, 1·43
No	1·00	Referent
Missing	0·24	0·08, 0·72
Receives school lunch		
Always (5 d/week)	0·89	0·47, 1·68
Sometimes (1–4 d/week)	0·90	0·43, 1·89
Never (0 d/week)	1·00	Referent
Missing	0·67	0·27, 1·64
Trying to lose weight?		
Yes	0·91	0·43, 1·43
No	1·00	Referent
Missing	0·23	0·08, 0·65
BMI*		
Normal weight (<85th percentile)	1·00	Referent
Overweight (85th–95th percentile)	0·80	0·45, 1·40
Obese (≥95th percentile)	0·67	0·41, 1·08

PA, physical activity; NHANES, National Health and Nutrition Examination Survey.
*To determine weight status in children and adolescents aged 2–19 years, BMI was calculated by dividing weight in kilograms by the square of height in metres (kg/m^2) and this number was then compared on a standardized growth chart. Children and adolescents who were at the 85th but below the 95th percentile were considered overweight; those at or above the 95th percentile were considered obese.

partner were statistically significantly less likely to meet PA recommendations for age group compared with adolescents of a parent who was married (OR = 0·48, 95 % CI 0·25, 0·90 and OR = 0·23, 95 % CI 0·06, 0·94, respectively). Adolescents of a parent whose marital status was divorced/separated/widowed were less likely

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Table 3 Unadjusted odds ratios and 95 % confidence intervals of the associations between PA, demographic and lifestyle characteristics and breakfast consumption among adolescents who participated in NHANES, 2007–2008

	Breakfast consumer	
Demographic and lifestyle variables	OR	95 % CI
Meets PA recommendations for age		
Yes	1·19	0·83, 1·70
No	1·00	Referent
Sex		
Female	0·93	0·61, 1·41
Male	1·00	Referent
Age (years)		
12–15	1·67	1·17, 2·39
16–19	1·00	Referent
Race/ethnicity		
Non-Hispanic white	1·00	Referent
Non-Hispanic black	0·57	0·39, 0·83
Hispanic	1·15	0·78, 1·70
Other	1·60	0·68, 3·75
Annual household income		
<$US 25 000	0·54	0·33, 0·88
$US 25 000–49 999	0·61	0·42, 0·88
≥$US 50 000	1·00	Referent
Household food security		
Full	1·00	Referent
Marginal	0·59	0·38, 0·92
Low	0·62	0·38, 1·02
Very low	0·68	0·39, 1·18
Education level of parent		
<High school	0·89	0·68, 1·17
High school	0·75	0·48, 1·17
>High school	1·00	Referent
Missing	1·2	0·40, 4·98
Education level of parent's spouse		
<High school	1·07	0·63, 1·82
High school	0·60	0·36, 0·98
>High school	1·00	Referent
Missing	0·54	0·32, 0·90
Marital status of parent		
Married	1·00	Referent
Divorced/separated/widowed	0·80	0·45, 1·42
Single	0·44	0·25, 0·77
Living with partner	0·76	0·32, 1·79
Missing	0·28	0·10, 0·75
Tobacco/nicotine use in last 5 d		
Yes	0·50	0·24, 1·03
No	1·00	Referent
Missing	1·09	0·41, 2·89
Receives school lunch		
Always (5 d/week)	1·00	0·60, 1·68
Sometimes (1–4 d/week)	0·69	0·36, 1·29
Never (0 d/week)	1·00	Referent
Missing	0·85	0·49, 1·47
Trying to lose weight?		
Yes	0·94	0·58, 1·53
No	1·00	Referent
Missing	1·83	0·89, 3·76
BMI*		
Normal weight (<85th percentile)	1·00	Referent
Overweight (85th–95th percentile)	0·74	0·38, 1·42
Obese (≥95th percentile)	0·79	0·52, 1·20

PA, physical activity; NHANES, National Health and Nutrition Examination Survey.
*To determine weight status in children and adolescents aged 2–19 years, BMI was calculated by dividing weight in kilograms by the square of height in metres (kg/m^2) and this number was then compared on a standardized growth chart. Children and adolescents who were at the 85th but below the 95th percentile were considered overweight; those at or above the 95th percentile were considered obese.

to meet PA recommendations for age group than adolescents of a parent who was married, although the finding was not statistically significant (OR = 0·69, 95 % CI 0·38, 1·27).

The unadjusted OR and 95 % CI for each of the covariates as they relate to breakfast consumption are presented in Table 3. There was no relationship between being a breakfast consumer and sex (females: OR = 0·93, 95 % CI 0·61, 1·41; referent category: males). Younger adolescents had increased likelihood of consuming breakfast compared with older adolescents (OR = 1·67, 95 % CI 1·17, 2·39). Non-Hispanic blacks were less likely to be breakfast consumers than non-Hispanic whites (OR = 0·57, 95 % CI 0·39, 0·83). Hispanics and those whose race was 'other' had increased likelihood of consuming breakfast, but the findings were not statistically significant. As household income decreased, the likelihood of being a breakfast consumer decreased (<$US 25 000/year: OR = 0·54, 95 % CI 0·33, 0·88; $US 25 000–$49 999/year: OR = 0·61, 95 % CI 0·42, 0·88; referent category: ≥$US 50 000/year).

In the unadjusted model, adolescents who were breakfast skippers were slightly less likely to meet PA recommendations for their age group compared with adolescents who did not skip breakfast; however, the association was not statistically significant (OR = 0·85, 95 % CI 0·55, 1·30). After adjustment for household income, the results were attenuated and remained not statistically significant (OR = 0·95, 95 % CI 0·60, 1·49; Table 4). Furthermore, sex was not found to be an effect modifier of the skipping breakfast–PA association (boys: OR = 0·90, 95 % CI 0·48, 1·70; girls: OR = 1·00, 95 % CI 0·57, 1·75).

Discussion

The present study of a nationally representative sample of US adolescents found that adolescents who skipped breakfast were slightly less likely to meet PA recommendations for age compared with adolescents who did not skip breakfast; however, the finding was not statistically significant. After adjustment for household income, there was no association between skipping breakfast and meeting PA guidelines.

In a study conducted by Vereecken *et al.*, US adolescents who were non-breakfast skippers had slightly increased odds of being physically active compared with breakfast skippers, in contrast to the current study (OR = 1·33, 95 % CI 1·16, 1·53). While that study also used self-reported information, the questions asked were more straightforward than those asked in NHANES (e.g. participants were asked how many days per week they skipped breakfast and how many days per week they participated in moderate to vigorous PA for at least 60 min)[36]. These differences in how the exposure and

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Table 4 Adjusted odds ratio and 95 % confidence interval of the association between breakfast skipping and PA among adolescents who participated in NHANES, 2007–2008

	Meets PA recommendations for age	
Exposure variable	OR*	95 % CI
Breakfast skipper		
Yes	0·95	0·60, 1·49
No	1·00	Referent

PA, physical activity; NHANES, National Health and Nutrition Examination Survey.
*Adjusted for household income.

outcome were asked, as well as the difference in sample size (*n* 3769 for the Vereecken study *v.* *n* 936 for the current study), may explain why findings differed with respect to magnitude and statistical significance.

Only one additional previous study on the relationship between breakfast skipping and PA levels was conducted in the USA; however, this was a secondary objective of the study. Timlin *et al.* found that adolescents living in the Minneapolis/St. Paul area who ate breakfast daily were more likely to participate in strenuous PA than those who never ate breakfast (26·5 % *v.* 16·1 %, $P < 0·01$)[17]; these findings are inconsistent with the findings from the current study. One difference between the two studies was assessment of PA. The study by Timlin *et al.* used self-report of PA as mild, moderate or strenuous; the current study used self-reported minutes of PA in accordance with national recommendations. Additionally, the sample size (*n* 2216) in the former was much larger than in the current study, which could explain why the studies differed in regard to their findings.

A previous study by Utter *et al.* of 3735 children and adolescents (ages 5–14 years) in New Zealand found no strong association between breakfast skipping and PA (OR = 0·75, 95 % CI 0·50, 1·10)[22]. In that study, an individual was considered as physically active if he/she was at or above the 75th percentile of the Physical Activity Questionnaire for Children. Another large study among 68 606 primary-school children in Hong Kong found a slight statistically significant increase in PA levels among breakfast consumers compared with skippers (OR = 1·15, 95 % CI 1·05, 1·26)[21], a finding that differed from the current study. The Hong Kong study examined PA levels as <3 times/week or ≥3 times/week, while the current study measured PA as meeting PA guidelines for age group. The difference in sample size and measurement of PA between the studies could explain the discrepancy in findings.

Some previous studies of the breakfast skipping–PA association have investigated whether sex is an effect modifier of the association with somewhat inconsistent findings[26,34,37]. While some findings suggest sex is an effect modifier[34], others do not[34,37]. While it is possible that the breakfast skipping–PA association differs for boys and girls, it is not likely that there is a biological explanation for this difference. Fatigue experienced from breakfast skipping, which decreases voluntary PA endurance, is not known to differ by sex[28].

There were several limitations in the present study. Non-differential misclassification may have occurred for the exposure and the outcome. The exposure, breakfast skipping, was measured based on the 24 h dietary recall. It is possible that adolescents may have given socially desirable responses by reporting eating breakfast when they actually did not consume any food during breakfast. Furthermore, the two 24 h dietary recalls may not have appropriately captured participants' typical dietary behaviours. For example, it may not be accurate to classify someone who skipped breakfast on one day as a breakfast skipper, even though this method has been used in previous studies[12,18,25]. To account for this, three categories of breakfast skipping (skipped on both days, skipped on one day, did not skip on either day) were created. However, since the magnitudes of the OR for skipped on both days and skipped on one day were similar, those groups were ultimately collapsed in order to improve precision. Lastly, anyone consuming any food or beverage item at breakfast, with the exception of water, was considered a breakfast consumer. Therefore, someone who consumed just coffee would have been classified as a breakfast eater. Although this method of classification has been used by other investigators, it does not consider the quality of food or beverage items consumed[12,18,25]. Due to this concern, we also examined breakfast consumption using a cut-point of 209 kJ (50 kcal), since this method has been employed in other studies[37]. The OR calculated using this method was similar to the OR calculated when classifying adolescents who consumed any food or beverage at breakfast as breakfast consumers. Since the OR were similar between the two methods and because the majority of previous studies have examined breakfast consumption as any food or beverage item consumed, we ultimately decided to use this method to allow easier comparison between studies.

For measurement of the outcome, adolescents may have provided socially desirable responses or they may have had problems with accurately remembering how much time they spent participating in PA. Therefore, it is possible that non-differential misclassification occurred because this outcome was ascertained using a self-reported questionnaire and was not confirmed by objective measurements of PA. Although objective accelerometer data were not

collected in 2007–2008, accelerometer data were collected during 2005–2006. Using methods employed by Troiano *et al.*, we assessed the average number of minutes spent in moderate/vigorous PA based on the number of days the accelerometer was worn (only participants with at least 4 d out of 7 d of wear time were included) and compared this with national recommendations for PA[48]. We found that the OR was similar in magnitude to the OR from self-reported PA in 2007–2008. Different questions were used to self-report PA in 2005–2006; however, the self-reported data from these years also indicated that breakfast skipping was associated with a non-statistically significant decreased likelihood of meeting PA recommendations. Since the magnitudes of the OR were similar and 95 % CI overlapped, we decided to use the 2007–2008 data since these data are more recent and there was not an improvement in sample size when the older data were considered.

NHANES uses a complex sampling method to select participants for the survey. The average response rate for the adolescents included in the study was approximately 83 % for those completing the interviews, physical examination and laboratory components. It is possible that adolescents who participated in NHANES differed from those who did not participate. However, given the high response rate, it is unlikely that selection bias occurred. Temporal bias is also a concern since a cross-sectional study design was used. Thus, causality cannot be inferred from the present study.

Due to the use of secondary data, examination of covariates was limited to variables asked in the NHANES questionnaires and interview. Of covariates examined, only household income was found to be a confounder of the breakfast skipping–PA relationship. Other potential confounders of the relationship found in the literature, such as alcohol consumption, could not be examined in the current study because information on alcohol consumption was not collected for individuals under the age of 20 years. There may be additional unknown confounders of skipping breakfast and PA. Failure to control for these confounders could have resulted in an over- or underestimation of the true association.

The present study also has several strengths. Few studies examining the breakfast skipping–PA relationship have been conducted in the USA, and none of the US studies used a nationally representative sample. Furthermore, the current study examined meeting PA recommendations based on national standards, rather than selecting an arbitrary cut-point. Also, unlike previous studies, the current study examined breakfast skipping and PA levels among adolescents, a population known to have increased breakfast skipping behaviours and decreased PA behaviours compared with children. A final strength of the study is that the results should be generalizable to other US adolescents aged 12–19 years since NHANES utilized a complex, multistage probability sampling method to ensure a nationally representative sample.

Conclusion

Findings from the current study suggest that there is no association between skipping breakfast and meeting PA guidelines for age among US adolescents aged 12–19 years. Although no association was found, breakfast consumption remains an important issue among adolescents. Nearly half of adolescents in the current study were breakfast skippers. Breakfast skipping has also been shown to be associated with lower daily fibre and nutrient intakes[12,15,17,18], lower daily intakes of fruits and vegetables[21,22,36,49,50], higher intake of junk foods or snacks[21,22,49–51], poorer academic performance[24] and increased hunger during the day[52].

Additional studies are needed to account for the type and quality of breakfast consumed, instead of considering intake of any food or beverage item as breakfast. Furthermore, it may be more accurate to ask participants how many days per week they skip breakfast than to use two 24 h dietary recalls to classify someone as a breakfast skipper or consumer. If future studies also used national guidelines for assessment of PA it would be possible to make better comparisons among studies. While several longitudinal studies have shown that breakfast consumption and PA are independently associated with weight gain, studies examining breakfast consumption and PA have been cross-sectional. If future longitudinal studies find an association between breakfast skipping and PA, more support will be added to the importance of current programmes and policies designed to increase breakfast consumption, PA and healthy weight status among US adolescents.

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