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Original article

Patterns of dietary supplement use among college students

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SUMMARY

Background & aims: Dietary supplements (DS) are popular in many countries but little data are available on their use by sub-populations such as college students. Since students share a variety of characteristics and similar lifestyles, their DS use may differ from the general population. This study assessed DS use, factors associated with DS use, and reasons for use among U.S. college students.

Methods: College students ($N = 1248$) at 5 U.S. universities were surveyed. Survey questions included descriptive demographics, types and frequency of DS used, reasons for use and money spent on supplements. Supplements were classified using standard criteria. Logistic regression analyses examined relationships between demographic and lifestyle factors and DS use.

Results: Sixty-six percent of college students surveyed used DS at least once a week, while 12% consumed 5 or more supplements a week. Forty-two percent used multivitamins/multiminerals, 18% vitamin C, 17% protein/amino acids and 13% calcium at least once a week. Factors associated with supplement use included dietary patterns, exercise, and tobacco use. Students used supplements to promote general health (73%), provide more energy (29%), increase muscle strength (20%), and enhance performance (19%).

Conclusions: College students appear more likely to use DS than the general population and many use multiple types of supplements weekly. Habits established at a young age persist throughout life. Therefore, longitudinal research should be conducted to determine whether patterns of DS use established early in adulthood are maintained throughout life. Adequate scientific justification for widespread use of DS in healthy, young populations is lacking.

1. Introduction

Dietary supplements (DS) are popular in the U.S., the U.K. and many other countries [1], and their use has been increasing. Recently, in a strongly worded editorial, a leading medical journal advised the public, based on the available evidence, to "stop wasting money on vitamin and mineral supplements" [1]. The authors of the editorial were willing to provide such forceful guidance because they found no convincing evidence such supplements provide any benefit in well-nourished adults, and could be harmful. In 2010, Americans spent $28.1 billion on DS [2]. The most popular DS in the U.S. are multivitamin-multiminerals, botanicals, amino acids and individual vitamins and minerals including vitamins C, E, B-6, B-12, A, magnesium and zinc [3]. When surveyed, individuals state they use DS, in order of overall preference, to "promote general health", "enhance performance and energy", "treat specific

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health conditions", "improve nutrition", "because the doctor recommended it", "it is good for them" and to "change their lifestyle" [4]. The widespread and increasing use of DS by the American population is the result not only of increasing consumer demand for these products, but a major change in the regulatory status of DS. In 1994, the Dietary Supplements Health and Education Act (DSHEA) became law and dramatically increased the number and type of products that could be legally sold as DS in the U.S. and reduced or eliminated regulatory requirements that previously existed [5,6].

United States law requires that drugs and medical devices be thoroughly evaluated for their safety and efficacy by the Food and Drug Administration (FDA) before their sale is permitted; similar regulatory oversight is not mandated for DS. Claims manufacturers of DS are permitted to make regarding the health benefits of their products are limited, but their marketing can be misleading, and Americans take these products for their purported health benefits [7]. Popular supplements that are widely used by the population have, on a regular basis, been reported to have adverse effects or to be adulterated [8,9]. The FDA has issued warnings on multiple occasions regarding specific supplements, such as ephedra, resulting in their removal from the market [10,11].

Dietary supplements have a unique status in American society. Although they are used regularly by approximately half of the U.S. adult population [12–14] and over 30% of children and adolescents [15], scientific consensus on the efficacy and safety of most DS does not exist, and contradictory scientific studies regularly appear in the peer-reviewed literature [16–24]. Information on DS from a variety of media sources including television, radio, print and the internet is widely available, but the information is often contradictory and confusing.

A majority of DS contain various essential nutrients. In the U.S., the Food and Nutrition Board of the Institute of Medicine (IOM) is responsible for specifying national nutrient requirements as well as tolerable upper intake levels of essential nutrients to avoid adverse effects [25]. However, these national requirements are often ignored by DS manufacturers who include larger amounts of nutrients in their products than recommended by the IOM [26,27].

Although young people are frequently the target of advertising for DS, and specific products are formulated for the youth market, limited information on patterns of use, reasons for use, and predictors of DS intake is available for this population [28–31]. Much of the available information is out-of-date, particularly given the rapid changes in available DS, including continued frequent reformulation of DS by manufacturers to optimize their popularity or address safety concerns [32,33]. Limited data on efficacy of DS in younger populations are available as large clinical trials are often conducted with individuals with illnesses or conditions, such as heart disease, osteoarthritis, Alzheimer's disease and cancer, more likely to be present in older populations [34–38]. Studies, often sponsored by manufacturers of DS, focusing on some aspect of physical performance, have been conducted with younger populations, such as college students or trained athletes with mixed results [39–41].

This study was conducted to assess extent of DS use in five U.S. universities, the reasons for students' use of DS and demographic characteristics of DS users. College students may have different patterns of use than the general population since they have common demographic characteristics, including young age and higher socioeconomic status [42]. Students tend to engage in similar activities such as attending class, studying, participating in sports, attending sporting events and engaging in various other recreational activities. Patterns of DS use, like other personal choices established early in adulthood, may be maintained throughout life [43]. A recent large, longitudinal study that followed over 100,000 volunteers for 20 years clearly demonstrated that the cohort's DS use increased with age [44]. Furthermore, the nature of university life may encourage use of DS in the same way other activities, such as use of alcohol, are encouraged and facilitated by peer pressure [45]. Unlike previous reports, rather than assess DS use at a single college or university, in this study we collected extensive data from students at 5 different types of universities in different regions of the U.S [46].

2. Methods

2.1. Subjects

Five U.S. universities were sampled in 2009 and 2010 for this study: University of Massachusetts Amherst (UMASS), MA, Kent State University (Kent State), OH, California State University Fullerton (Cal State), CA, Louisiana State University (LSU), LA, and Tufts University (Tufts), MA. The final sample included surveys from 1248 students. Five collected surveys were not included in the sample due to incomplete or un-interpretable responses. The schools were chosen to be representative of the major types of American 4-year colleges and universities, including public and private institutions, residential and commuter schools, and various geographic regions of the U.S. College students were recruited through a convenience sample by either an informational booth (UMASS), online (Tufts), or in the classroom (Kent State, Cal State and LSU). Students at the UMASS and Tufts received a $10 incentive to complete the survey and students at Cal State and LSU received a class-based extra credit incentive. The survey was approved by the USARIEM Institutional Review Board and was anonymous.

2.2. Variables

The survey was based on a similar survey previously administered to a U.S. Army sample [47–49]. A total of 47 questions were included on the paper and pencil survey instrument, 14 of these directly addressed the use of DS. The survey included detailed questions on types of DS, frequency of use, reason for use, and money spent on DS. Ninety-two supplements were listed on the survey, which included 56 general supplement types such as multivitamins, combination antioxidants, and specific vitamins and minerals, as well as 36 specifically-named supplements. Participants were instructed to write in supplements they used but were not listed. Before data analysis, individual supplements and supplement types were grouped into standardized categories. Those DS that could not be placed in another category were termed "other". The survey instrument also assessed use of sports drinks, sports bars or gels, and meal-replacement beverages, products that are not considered to be DS for regulatory purposes [5]. The instrument included questions regarding reasons for use of each DS product, specifically: performance enhancement, general health, promoting energy, weight loss, increasing endurance, improving muscle strength, unsure, and other.

The survey collected information on a number of sociodemographic and lifestyle factors, including sex, age, race/ethnicity, family income, aerobic exercise duration, whether the student was attempting to gain or lose weight, overall fitness, and tobacco use. Self-reported height and weight were collected and body mass index (BMI) was calculated (BMI = weight in kilograms divided by squared height in meters, rounded to the nearest tenth). Individuals with BMI <18.5 were considered underweight, those with a BMI $\geq$18.5–24.9 were considered in the normal weight range, a BMI $\geq$25.0–29.9 was considered overweight, and those with a BMI $\geq$30.0 were classified as obese [50]. Students' dietary preference (high protein or low-fat diet) and reason for exercise (to

increase muscle mass, for strength or aerobic competition, and/or stress relief) were also assessed.

2.3. Survey administration

The survey was administered on-site by project staff at participating universities. Completed surveys were returned, scanned and responses tabulated using ScanTools® Plus with ScanFlex™ (version 6.301, 2006, Scantron Corporation, Eagan, Minnesota).

2.4. Statistics

The SAS (Version 9.2, 2008, SAS Institute, Cary, NC) statistical software program was used for data analysis (SAS Institute Inc. 2004). Cochran Mantel Haenszel chi-square tests were used to assess significant differences for categorical characteristics and ANOVA was used to assess significant differences among continuous characteristics, adjusting for survey site. Multiple logistic regression was employed to examine independent relationships between DS use and demographic and lifestyle characteristics of students. Odds ratios and their 95% confidence intervals were computed from these models.

3. Results

Approximately 66% of college students reported using a DS as defined by DSHEA (which excludes sports drinks, sports bars or gels, and meal replacements) ≥1 time/wk for the 6 mo before the survey. Approximately 35% of students used sports drinks, and 11% and 4%, respectively, reported using sports bars or gels and meal replacements (Table 1). The most popular DS among students surveyed were multivitamin or multimineral supplements (42%); individual vitamins (29%); protein or amino acids (17%); herbal supplements (9%); and combination products (6%) (Table 2). A large number of students, 24%, take DS that are classified as "other" using standard classification criteria employed by national surveys such as the National Health and Nutrition Examination Survey (NHANES). The most popular of these "other" DS among college students were: caffeine (16%), fish oil (8%), echinacea (5%), and body building/creatine supplements (5%) (Table 3).

Overall, 41% of respondents reported taking 1–2 different supplements ≥1 time/wk and 12% of respondents reported taking 5 + supplements/wk in the 6 mo before the survey (Table 2). The likelihood of taking 5 + DS at least once a week was significantly higher among males ($P < 0.001$), those trying to gain weight ($P < 0.001$), students who were eating a high protein ($P < 0.001$) or low fat ($P = 0.047$) diet, current tobacco users ($P < 0.001$), those who exercised to increase muscle mass ($P < 0.001$) or reduce stress ($P = 0.045$), and whose self-reported overall fitness was excellent ($P < 0.001$). Those who reported taking multivitamins or multiminerals were more likely to consume a high protein ($P < 0.001$) and low fat diet ($P = 0.003$) and exercise to increase muscle mass ($P = 0.024$) and relieve stress ($P < 0.001$). Taking protein and amino acids at least once a week was higher among males ($P < 0.001$), BMI ≥25.0 ($P < 0.001$), those trying to gain weight ($P < 0.001$), eating a high protein diet ($P < 0.001$), current tobacco users ($P = 0.002$), those who exercised >300 min/wk ($P < 0.001$), those who exercised to increase muscle mass ($P < 0.001$) and strength ($P = 0.005$), and whose overall fitness was excellent ($P < 0.001$).

Multiple logistic regression analysis demonstrated significant and independent relationships between several demographic and lifestyle characteristics and measures of supplement use (Table 4). Dietary patterns were significantly associated with DS use. Those who consumed a high protein (OR: 2.09; $P < 0.001$) and low fat diet (OR: 1.56; $P < 0.05$) were more likely to take any DS. Students who consumed a high protein diet were also more likely to take 5 + DS/wk (OR: 1.93; $P < 0.01$), multivitamins or multiminerals (OR:1.73; $P < 0.01$), protein and amino acids (OR:2.94; $P < 0.001$), and spend more than $30/mo on DS (OR: 2.04; $P < 0.001$). Students using tobacco products (OR: 2.70; $P < 0.001$) and exercising to increase muscle mass (OR: 2.04; $P < 0.01$) were also more likely to take 5 + DS/wk.

The regression analyses indicated males were more likely than females to use protein and amino acids (OR: 2.87; $P < 0.001$; Table 4). In addition, those who were exercising to increase muscle mass (OR: 2.57; $P < 0.001$; Table 4) were also more likely to take protein and amino acids. The intention to gain weight was also significantly associated with spending ≥$30 on DS/month. Respondents who were trying to gain weight were more likely than those who were trying to maintain weight to spend more than $30/month on DS (OR: 2.01; $P < 0.001$; Table 4). In addition, both current and former users of tobacco products (both OR: 1.61; $P < 0.05$; Table 4) and those who were exercising to increase muscle mass (OR: 1.97; $P < 0.001$; Table 4) were also more likely to spend more than $30/month on DS.

The survey included questions regarding reasons for DS use (Table 5). Among supplement users, the most frequent reason selected for DS use was to promote general health (73.3%) followed by providing more energy (29.1%), greater muscle strength (20.4%), and enhancing performance (18.9%). For individual DS types, there were substantial differences in reasons reported for use.

Among students who used DS, mean monthly expenditure on DS was $17, and almost one-fifth (19.5%) of students spent $30/mo or more on DS (Table 1). Although there was no significant difference between male and female students in the overall use of any DS defined by DSHEA; male students were more likely to report consuming sports drinks (46.3% males vs. 28.3% females; $P < 0.001$) and sports bars or gels (16.3% males vs. 7.5% females; $P < 0.001$), and spent more money on average ($24 males vs. $12 females; $P < 0.001$) a month on DS than females, with a greater portion spending over $30 a month (29.7% males vs. 13.9% females; $P < 0.001$) (Table 1). In general, DS use was higher among students eating a high protein (80.8%; $P < 0.001$) or low fat diet (77.7%; $P < 0.001$), exercising >150 min/wk (69.1%; $P = 0.016$), exercising to increase muscle mass (72.8%; $P = 0.003$) and reduce stress (68.9%; $P = 0.016$), and whose overall fitness was excellent (71.6%; $P < 0.001$) (Table 1). Amount of money spent on supplements was higher in males ($24; $P < 0.001$), students 23 + years ($29; $P < 0.001$), those with a BMI ≥25.0 ($23; $P = 0.003$), students trying to gain weight ($36; $P < 0.001$), and former tobacco users ($25; $P < 0.001$) (Table 1).

The most popular source of information on DS among men was the internet, for women it was their families (Fig. 1). A higher percentage of males were more likely than females to get their DS information from: friends (38.4% males vs. 31.8% females; $P < 0.05$), trainer/coach (12.8% males vs. 6.3% females; $P < 0.01$), magazines/newspapers (24.9% males vs. 19.0% females; $P < 0.05$), educational material (22.5% males vs. 10% females; $P < 0.001$), the internet (45.1% males vs. 26.1% females; $P < 0.001$), and store salesperson (15.2% males vs. 8.4% females; $P < 0.001$). Females were more likely than males to get their DS information from: family (43.3% females vs. 23.2% males; $P < 0.001$), healthcare professionals (30.8% females vs. 17.5% males; $P < 0.001$), and television (14.8% females vs. 7.1% males; $P < 0.01$).

4. Discussion

Almost two-thirds of college students surveyed (66%) regularly use DS; 41% take multiple supplements per week and 12% take 5 or more different supplements per week. The most popular products

Table 1
Reported use of any dietary supplement (DS), sports drink, sports bar/gel, and meal replacement beverage among students from 5 colleges according to demographic and lifestyle characteristics.

	Total sample	Any DS[a] ($n = 824$)		Any sports drink[b] ($n = 434$)		Any sports bar or gel[c] ($n = 133$)		Any Meal-replacement beverage[d] ($n = 53$)		Average $ spent on DS/month			≥$30 spent on DS/month ($n = 239$)	
	N	%	*P*[e]	%	*P*	%	*P*	%	*P*	Mean	(SD)	*P*	%	*P*
Total	**1248**	**66.0**		**34.8**		**10.7**		**4.2**		**17**	**(34)**		**19.5**	
Gender														
Male	449	66.1	0.763	46.3	<0.001	16.3	<0.001	4.7	0.396	24	(43)	<0.001	29.7	<0.001
Female	799	66.0		28.3		7.5		4.0		12	(26)		13.9	
Age														
16 to 19 years	399	62.4	0.274	34.3	0.740	10.3	0.470	3.5	0.346	13	(29)	<0.001	12.5	<0.001
20 to 22	653	66.9		35.4		10.0		4.1		15	(31)		20.0	
23+	196	70.4		33.7		13.8		6.1		29	(48)		32.0	
Race/Ethnicity														
Non-hispanic white	868	66.6	0.097	35.5	0.241	11.9	0.039	5.4	0.028	18	(35)	0.068	21.3	0.083
Non-hispanic black	87	71.3		46.0		2.3		1.1		12	(23)		19.5	
Hispanic/Latino	124	71.0		32.3		12.9		1.6		18	(38)		18.9	
Asian	111	53.2		28.8		7.2		1.8		9	(21)		9.3	
Other	58	63.8		24.1		6.9		1.7		13	(30)		14.0	
Family income														
≤$25,000	92	66.3	0.907	30.4	0.747	8.7	0.517	4.3	0.266	18	(41)	0.064	16.9	0.305
$25,000–$99,999	506	65.2		36.8		10.1		3.8		15	(27)		20.2	
$100,000–$200,000	315	65.7		37.1		11.1		4.8		19	(38)		23.5	
>$200,000	119	66.4		35.3		11.8		6.7		19	(40)		19.7	
Body mass index[f]														
<18.5	48	70.8	0.840	31.3	0.202	10.4	0.302	2.1	0.117	9	(16)	0.003	10.4	0.002
18.5–24.9	833	65.5		33.1		10.7		3.6		14	(29)		16.9	
25.0–29.9	260	66.2		41.5		12.7		5.4		23	(43)		27.5	
≤30.0	81	69.1		34.6		4.9		8.6		22	(41)		25.6	
Weight gain/lose														
Trying to lose	547	66.4	0.240	32.5	0.024	9.5	0.206	5.5	0.160	15	(30)	<0.001	19.7	<0.001
Trying to gain	119	73.9		43.7		16.0		5.9		36	(53)		40.9	
Maintaining weight	580	64.3		35.2		10.7		2.8		14	(30)		15.1	
Diet description														
High protein diet														
Yes	229	80.8	<0.001	42.4	0.015	21.0	<0.001	10.5	<0.001	37	(51)	<0.001	40.6	<0.001
No	1019	62.7		33.1		8.3		2.8		12	(26)		14.8	
Low fat														
Yes	202	77.7	<0.001	35.6	0.679	16.3	0.006	8.4	0.005	21	(35)	0.083	26.7	0.029
No	1046	63.8		34.6		9.6		3.4		16	(33)		18.2	
Tobacco use														
Never	892	64.0	0.098	34.0	0.163	10.2	0.078	3.5	0.148	14	(31)	<0.001	16.2	<0.001
Former	150	68.7		30.7		16.0		6.0		25	(42)		28.0	
Current	206	72.8		41.3		8.7		6.3		21	(38)		27.9	
Exercise duration (min/wk)														
≤30 min/wk	121	57.9	0.016	29.8	0.050	4.1	0.024	2.5	0.576	18	(39)	0.042	18.2	0.002
31–150 min/wk	380	62.6		31.8		9.5		3.7		12	(30)		13.2	
151–300 min/wk	366	71.6		33.9		10.1		4.9		17	(32)		20.9	
>300 min/wk	379	66.5		40.1		14.2		4.7		20	(37)		24.8	
Reason(s) for exercise														
Increase muscle mass														
Yes	372	72.8	0.003	41.1	0.008	15.3	0.003	6.7	0.009	29	(45)	<0.001	34.5	<0.001
No	855	63.5		32.4		8.9		3.3		12	(26)		13.4	
Strength or aerobic competition														
Yes	161	62.1	0.595	51.6	<0.001	18.6	0.001	1.9	0.219	16	(31)	0.914	19.5	0.722
No	1066	67.0		32.6		9.7		4.7		17	(34)		19.8	
Stress relief														
Yes	777	68.9	0.016	32.8	0.019	11.5	0.442	5.4	0.015	18	(35)	0.126	20.9	0.259
No	450	62.0		38.9		9.8		2.4		14	(32)		17.8	
Overall fitness level														
Excellent	222	71.6	<0.001	46.8	<0.001	18.5	<0.001	3.6	0.228	25	(44)	<0.001	28.0	<0.001
Good	705	66.1		32.5		11.6		5.1		16	(33)		19.4	
Fair	278	65.1		30.2		3.2		3.2		13	(26)		15.4	
Poor	42	42.9		40.5		2.4		0.0		5	(10)		4.9	

[a] Any Dietary supplement included all dietary supplements as defined by the DSHEA legislation that were reported used at least once a week or more often over the last six months prior to the survey. Any dietary supplement excludes any sports drinks, any sports bars/gels and any meal replacement beverages. The n's in parentheses under each column heading are the number of respondents in the entire sample who report using DS or the specified type of product and are thus the total numerators for the percentages shown in that column.

[b] Any sports drink = persons who responded that they drank sports drinks as identified in the survey question nor self-named and validated as sports drinks by the research team at least once a week or more often over the six months prior to the survey.

[c] Any Sports bar/gel etc = persons who responded that they used sports bars, sports jelly beans, or sports gels as identified in the survey question or self-named and validated by the research team at least once a week or more often over the six months prior to the survey.

[d] Any meal replacement beverage = persons who responded that they used meal replacement drinks as identified in the survey question or self-named and validated as meal replacement beverages by the research team at least once a week or more often over the six months prior to the survey.

[e] *P* values are adjusted for survey site (one of 5 colleges), based on Cochran Mantel Haenszel chi-square for percentages and ANOVA for means.

[f] BMI was calculated from self-reported height and weight.

Table 2
Number and type dietary supplements (DS) used at least once per week over the past six months among students at 5 colleges according to demographic and lifestyle characteristics.

	# of supplements taken at least once a week								Dietary supplements taken at least once a week													
	Any DS[a] ($n = 824$)		1–2 ($n = 515$)		3–4 ($n = 162$)		5+ ($n = 147$)		Multivitamin or Multimineral[b] ($n = 522$)		Proteins & amino acids[c] ($n = 213$)		Individual vitamins or minerals[d] ($n = 357$)		Combination products[e] ($n = 76$)		Herbal[f] ($n = 109$)		Purported steroid analogs[g] ($n = 11$)		Other[h]	
	%	P[i]	%	P	%	P	%	P	%	P	%	P	%	P	%	P	%	P	%	P	%	P
Total	**66.0**		**41.3**		**13.0**		**11.8**		**41.8**		**17.1**		**28.6**		**6.1**		**8.7**		**0.9**		**23.7**	
Gender																						
Male	66.1	0.763	36.1	0.024	12.7	0.790	17.4	<0.001	40.8	0.576	33.9	<0.001	22.7	<0.001	9.6	<0.001	9.8	0.405	2.2	<0.001	22.7	0.811
Female	66.0		44.2		13.1		8.6		42.4		7.6		31.9		4.1		8.1		0.1		24.3	
Age																						
16 to 19 years	62.4	0.274	41.9	0.795	11.8	0.789	8.8	0.620	38.8	0.549	12.5	0.092	29.6	0.338	2.8	0.006	8.0	0.415	0.8	0.672	21.6	0.014
20 to 22	66.9		41.5		13.0		12.4		42.3		17.9		29.1		6.7		8.3		0.8		22.8	
23+	70.4		39.3		15.3		15.8		46.4		23.5		25.0		10.7		11.7		1.5		31.1	
Body mass index[j]																						
<18.5	70.8	0.840	33.3	0.149	29.2	<0.001	8.3	0.524	52.1	0.366	8.3	0.001	47.9	0.020	0.0	0.094	8.3	0.957	0.0	0.687	33.3	0.137
18.5–24.9	65.5		43.8		10.9		10.8		41.8		14.6		28.3		5.2		8.9		0.6		22.0	
25.0–29.9	66.2		37.3		13.8		15.0		40.0		25.8		27.3		8.8		8.1		1.5		24.6	
≤30.0	69.1		35.8		19.8		13.6		43.2		17.3		23.5		7.4		9.9		1.2		30.9	
Weight gain/lose																						
Trying to lose	66.4	0.240	42.0	0.056	14.1	0.205	10.2	<0.001	39.9	0.146	12.8	<0.001	29.6	0.891	6.9	0.009	9.7	0.045	0.4	0.024	26.3	0.363
Trying to gain	73.9		29.4		18.5		26.1		47.9		43.7		30.3		12.6		13.4		3.4		22.7	
Maintaining weight	64.3		43.1		10.9		10.3		42.6		15.7		27.4		4.0		6.9		0.9		21.6	
Diet description																						
High protein																						
Yes	80.8	<0.001	37.1	0.383	17.0	0.094	26.6	<0.001	55.0	<0.001	45.4	<0.001	30.1	0.643	14.4	<0.001	11.4	0.143	3.9	<0.001	29.3	0.020
No	62.7		42.2		12.1		8.4		38.9		10.7		28.3		4.2		8.1		0.2		22.5	
Low fat																						
Yes	77.7	<0.001	42.6	0.629	18.3	0.036	16.8	0.047	52.5	0.003	22.8	0.067	35.6	0.028	9.4	0.106	8.9	0.921	2.0	0.135	30.2	0.039
No	63.8		41.0		12.0		10.8		39.8		16.0		27.2		5.4		8.7		0.7		22.5	
Tobacco use																						
Never	64.0	0.098	42.9	0.135	12.1	0.051	9.0	<0.001	40.1	0.146	14.6	0.002	27.4	0.243	5.8	0.947	7.6	0.115	0.7	0.310	21.0	0.002
Former	68.7		34.7		19.3		14.7		48.7		21.3		29.3		6.0		12.0		2.0		32.7	
Current	72.8		38.8		12.1		21.8		44.2		24.8		33.5		7.3		11.2		1.0		29.1	
Exercise (min/wk)																						
≤30 min/wk	57.9	0.016	37.2	0.329	9.1	0.611	11.6	<0.001	34.7	0.072	10.7	<0.001	19.8	0.052	5.8	<0.001	9.1	0.761	0.0	0.285	27.3	0.020
31–150 min/wk	62.6		43.7		13.4		5.5		39.5		11.8		27.1		2.4		7.6		0.3		19.7	
151–300 min/wk	71.6		44.0		13.9		13.7		47.0		17.2		32.5		6.0		9.8		1.4		29.2	
>300 min/wk	66.5		37.7		12.7		16.1		41.2		24.0		29.0		10.0		8.7		1.3		21.1	
Reason(s) for exercise																						
Increase muscle mass																						
Yes	72.8	0.003	35.8	0.033	15.1	0.329	22.0	<0.001	47.6	0.024	37.4	<0.001	29.6	0.807	11.6	<0.001	11.0	0.085	3.0	<0.001	27.4	0.054
No	63.5		43.7		12.2		7.6		39.4		8.7		28.4		3.9		7.8		0.0		22.5	
Strength or aerobic competition																						
Yes	62.1	0.595	39.8	0.944	11.8	0.843	10.6	0.629	39.8	0.873	24.2	0.005	26.7	0.789	9.3	0.019	6.2	0.247	1.2	0.668	14.3	0.013
No	67.0		41.6		13.2		12.2		42.2		16.3		29.1		5.7		9.2		0.8		25.4	
Stress relief																						
Yes	68.9	0.016	41.3	0.871	14.0	0.227	13.5	0.045	46.1	<0.001	18.3	0.371	30.8	0.048	6.9	0.183	10.0	0.043	1.3	0.070	24.7	0.393
No	62.0		41.3		11.3		9.3		34.7		15.8		25.3		4.9		6.7		0.2		22.7	
Overall fitness level																						
Excellent	71.6	<0.001	40.1	0.098	11.3	0.415	20.3	<0.001	45.9	0.100	35.6	<0.001	28.8	0.163	12.6	<0.001	9.5	0.444	3.2	0.003	23.9	0.850
Good	66.1		42.8		12.3		10.9		40.4		15.9		27.5		5.5		8.8		0.6		23.7	
Fair	65.1		40.6		15.8		8.6		43.9		7.6		32.7		3.2		9.0		0.0		23.0	
Poor	42.9		26.2		14.3		2.4		31.0		2.4		19.0		0.0		2.4		0.0		28.6	

[a] Any dietary supplement included all dietary supplements defined by the DSHEA legislation that were reported used at least once a week or more often over the six months prior to the survey. Any dietary supplement excluded any sports drinks, any sports bars/gels, and meal replacement beverages. The n's in parentheses under each column heading are the number of respondents in the entire sample who report using DS or the specified type of product and are thus the total numerators for the percentages shown in each column.

[b] Multivitamin/multimineral included dietary supplements that contain two or more minerals or vitamins and no additional supplement ingredients that were reported as used at least once a week or more often over the six months prior to the survey. This category does not include ingredients used in the manufacturing process as preservatives or colorants.

[c] Protein & amino acid supplements included amino acid mixes, protein powders etc. where the intention is to provide a single or complex protein source that was reported as used at least once a week or more often over the six months prior to the survey. These supplements do not include any additional supplement ingredients.

[d] Individual vitamins or minerals included dietary supplements that were single nutrient ingredient supplements, such as calcium or vitamin D, reported as used at least once a week or more often over the six months prior to the survey.

[e] Combination supplements included dietary supplements with mixtures of ingredients from the categories above that were reported as used at least once a week or more often over the six months prior to the survey. Combination supplements included two or more categories and multiple ingredients.

[f] Herbal supplements included one or more herbal dietary supplement ingredients with no nutrients or other supplement ingredients and were reported as used at least once a week or more often over the six months prior to the survey. This category also included plant derived ingredients such as citric acid.

[g] Purported steroid analogs included steroidal hormones or herbal substitutes for hormones that were marketed as dietary supplements and included the Supplements Facts panel on the label and were reported as used at least once a week or more often over the six months prior to the survey.

[h] Other supplements included those products marketed as dietary supplements that included the Supplement Facts panel on the label that did not meet the definitions for the other six dietary supplement categories and were reported as used at least once a week or more often over the six months prior to the survey. Examples included melatonin, lycopene, caffeine, Alpha lipoic acid, CoQ 10 (CoEnzyme Q10), GNC Fish body oils.

[i] *P* values are adjusted for survey site (one of 5 colleges), based on Cochran Mantel Haenszel chi-square.

[j] BMI was calculated from self-reported height and weight.

Table 3
Type and frequency (%) of students at 5 colleges regularly taking "Other" dietary supplements (DS) at least once per week over the past six months. "Other" DS are those that were not classified as falling into one of the 6 defined categories.

"Other" DS taken	% Taking
Caffeine	16
Fish oil	8
Echinacea	5
Body building/creatine supplements	5
Melatonin	1
CoEnzyme Q10	0.5
Alpha lipoic acid	0.4
Lycopene	0.4

college students that were surveyed take to supplement their diet are: multivitamin/multiminerals (42%), sports drinks (35%), vitamin C (18%), protein/amino acids (17%), calcium (13%), sport bar or gel (11%), herbals (9%), vitamin D (7%), iron (7%), and vitamin E (6%). Sports drinks and bars are not considered to be DS for regulatory purposes. Recent data from national studies establish that approximately 50% of adults [12–14] and approximately 32% of children [15] regularly used DS; therefore, our data indicate college students are more likely to regularly use DS than the general population since we found that 66% of them regularly use DS. Representative surveys of the U.S. population consistently report that DS use increases with age with 71% of adults aged 71 or older reporting use of DS [3]. A longitudinal study conducted for 20 years of over 100,000 volunteers, who were over 40 years old, found that

Table 4
Adjusted Odds Ratios for the association between selected demographic and lifestyle characteristics and aspects of dietary supplement (DS) use among students at 5 colleges.[a]

Characteristic	Dietary supplements taken at least once a week				≥$30 spent on DS/month
	Any DS[b]	≥5 DS	Multivitamin or multimineral[c]	Protein or amino acid[d]	
	Adjusted odds ratio (95% confidence interval)				
Sex					
Male	0.77 (0.57, 1.06)	0.88 (0.54, 1.45)	0.80 (0.59, 1.09)	2.87 (1.85, 4.45)***	1.33 (0.89, 1.99)
Female	1.00	1.00	1.00	1.00	1.00
Body mass index[e]					
<18.5	1.19 (0.59, 2.38)	0.88 (0.28, 2.79)	1.41 (0.73, 2.70)	0.69 (0.22, 2.19)	0.61 (0.22, 1.70)
25.0–29.9	0.94 (0.67, 1.31)	1.10 (0.68, 1.78)	0.88 (0.64, 1.21)	1.33 (0.85, 2.08)	1.33 (0.90, 1.98)
≥30.0	1.43 (0.81, 2.51)	1.42 (0.65, 3.08)	1.25 (0.74, 2.09)	1.26 (0.58, 2.74)	1.63 (0.86, 3.07)
18.5–24.9	1.00	1.00	1.00	1.00	1.00
Weight gain/lose					
Trying to gain	1.24 (0.75, 2.05)	1.69 (0.92, 3.08)	0.97 (0.61, 1.52)	1.53 (0.88, 2.67)	2.01 (1.19, 3.41)**
Trying to lose	0.98 (0.73, 1.31)	0.95 (0.59, 1.52)	0.77 (0.58, 1.02)	0.94 (0.60, 1.46)	1.27 (0.87, 1.87)
Maintaining weight	1.00	1.00	1.00	1.00	1.00
Follows high protein diet					
Yes	2.09 (1.40, 3.11)***	1.93 (1.23, 3.04)**	1.73 (1.23, 2.42)**	2.94 (1.95, 4.42)***	2.04 (1.38, 3.00)***
No	1.00[b]	1.00	1.00	1.00	1.00
Follows low fat diet					
Yes	1.56 (1.06, 2.29)*	1.33 (0.82, 2.16)	1.38 (0.99, 1.92)	1.38 (0.86, 2.21)	1.34 (0.89, 2.02)
No	1.00[b]	1.00	1.00	1.00	1.00
Tobacco use					
Current	1.37 (0.95, 1.97)	2.70 (1.71, 4.26)***	1.18 (0.84, 1.64)	1.49 (0.94, 2.36)	1.61 (1.08, 2.41)*
Former	1.21 (0.81, 1.80)	1.44 (0.82, 2.53)	1.43 (0.99, 2.07)	1.22 (0.71, 2.11)	1.61 (1.02, 2.54)*
Never	1.00	1.00	1.00	1.00	1.00
Exercise					
≤30 min/wk	0.79 (0.48, 1.28)	0.88 (0.43, 1.79)	0.83 (0.52, 1.35)	0.75 (0.34, 1.68)	1.06 (0.57, 1.96)
31–150 min/wk	0.93 (0.66, 1.30)	0.37 (0.21, 0.66)***	1.01 (0.73, 1.41)	0.78 (0.48, 1.27)	0.60 (0.38, 0.92)*
151–300 min/wk	1.27 (0.91, 1.79)	1.01 (0.64, 1.58)	1.32 (0.97, 1.81)	1.06 (0.68, 1.65)	0.97 (0.65, 1.44)
>300 min/wk	1.00	1.00	1.00	1.00	1.00
Exercises to increase muscle mass					
Yes	1.26 (0.92, 1.72)	2.04 (1.32, 3.15)**	1.20 (0.90, 1.61)	2.57 (1.75, 3.78)***	1.97 (1.38, 2.82)***
No	1.00	1.00	1.00	1.00	1.00
Exercises for competition					
Yes	0.75 (0.50, 1.13)	0.58 (0.30, 1.09)	0.91 (0.61, 1.35)	1.21 (0.71, 2.04)	0.91 (0.55, 1.51)
No	1.00	1.00	1.00	1.00	1.00
Exercises for stress relief					
Yes	1.16 (0.89, 1.51)	1.33 (0.87, 2.03)	1.42 (1.10, 1.84)**	1.07 (0.73, 1.58)	1.09 (0.78, 1.54)
No	1.00	1.00	1.00	1.00	1.00
Overall fitness level					
Poor	0.31 (0.14, 0.72)**	0.21 (0.02, 1.69)	0.70 (0.30, 1.63)	0.16 (0.02, 1.33)	0.25 (0.05, 1.20)
Fair	0.72 (0.44, 1.17)	0.63 (0.32, 1.24)	1.09 (0.69, 1.71)	0.34 (0.17, 0.67)**	0.72 (0.40, 1.29)
Good	0.68 (0.46, 1.00)*	0.58 (0.35, 0.95)*	0.80 (0.56, 1.15)	0.52 (0.33, 0.82)**	0.79 (0.51, 1.23)
Excellent	1.00	1.00	1.00	1.00	1.00

[a] Logistic regression models reported as odds ratios and the 95% confidence interval of the odds ratio.* = $P < 0.05$;** = $P < 0.01$;*** = $P < 0.001$. Note that the models also adjust for survey location (one of five colleges). There is a separate logistic regression model for each of the dependent variables (aspect of DS use shown at the top of each column).

[b] Any Dietary Supplement included all dietary supplements defined by the DSHEA legislation that were reported used at least once a week or more often over the six months prior to the survey. Any dietary supplement excluded any sports drinks, any sports bars/gels, and meal replacement beverages.

[c] Multivitamin/multiminerals included dietary supplements that contain two or more minerals or vitamins and no additional supplement ingredients that were reported as used at least once a week or more often over the six months prior to the survey. This category does not include ingredients used in the manufacturing process as preservatives or colorants.

[d] Protein & amino acid supplements included amino acid mixes, protein powders etc. where the intention is to provide a single or complex protein source that was reported as used at least once a week or more often over the six months prior to the survey. These supplements do not include any additional supplement ingredients.

[e] BMI was calculated from self-reported height and weight.

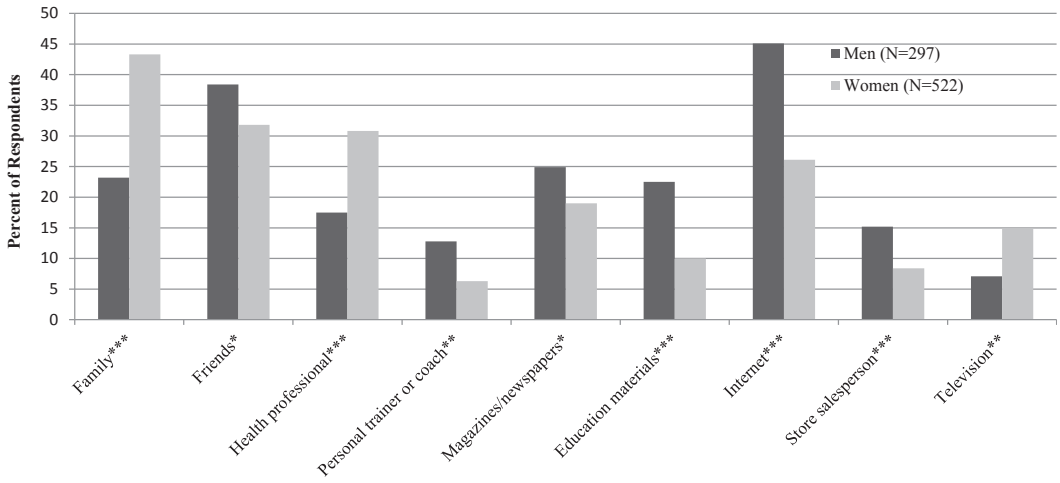
Table 5
Reported reasons for taking dietary supplements (DS) at least once per week over the six months prior to the survey among college students who use dietary supplements.

Reported reasons for DS use[a]	Any DS[b] (*N* = 824)	Multivitamin or multimineral[c] (*N* = 522)	Protein & amino acids[d] (*N* = 213)	Individual vitamins or minerals[e] (*N* = 357)	Combination supplements[f] (*N* = 76)	Herbals[g] (*N* = 109)	Purported steroid analogs[h] (*N* = 11)	Other[i] (*N* = 296)
	%	%	%	%	%	%	%	%
Promote general health	73.3	87.5	25.8	77.3	22.4	35.8	18.2	30.7
Give more energy	29.1	7.9	14.1	10.1	30.3	15.6	18.2	49.7
Greater muscle strength	20.4	3.8	70.0	2.8	31.6	1.8	72.7	2.0
Performance enhancer	18.9	10.0	31.9	7.3	39.5	9.2	36.4	11.1
Weight loss	8.1	3.3	10.8	1.4	28.9	17.4	18.2	3.0
Increased endurance	7.0	2.7	15.0	1.7	23.7	0.0	27.3	3.4
Not sure	5.6	1.0	0.5	2.5	1.3	17.4	0.0	6.8
Other reason	15.0	3.1	5.6	14.8	11.8	17.4	0.0	12.5

[a] Respondents could indicate multiple reasons and may have indicated different reasons for use of different products. Percentages indicate the percentage of respondents who reported using a particular type of DS that cited the given reason for use of that type of DS. Numbers in parentheses under the column headings are the total number of survey respondents reporting using any DS or particular type of DS at least once per week and are thus the denominators for the given percentages.
[b] Any dietary supplement included all dietary supplements defined by the DSHEA legislation that were reported used at least once a week or more often over the six months prior to the survey. Any dietary supplement excluded any sports drinks, any sports bars/gels, and meal replacement beverages.
[c] Multivitamin/multimineral included dietary supplements that contain two or more minerals or vitamins and no additional supplement ingredients that were reported as used at least once a week or more often over the six months prior to the survey. This category does not include ingredients used in the manufacturing process as preservatives or colorants.
[d] Protein & amino acid supplements included amino acid mixes, protein powders etc. where the intention is to provide a single or complex protein source that was reported as used at least once a week or more often over the six months prior to the survey. These supplements do not include any additional supplement ingredients.
[e] Individual vitamins or minerals included dietary supplements that were single nutrient ingredient supplements, such as calcium or vitamin D, reported as used at least once a week or more often over the six months prior to the survey.
[f] Combination supplements included dietary supplements with mixtures of ingredients from the categories above that were reported as used at least once a week or more often over the six months prior to the survey. Combination supplements included two or more categories and multiple ingredients.
[g] Herbal supplements included one or more herbal dietary supplement ingredients with no nutrients or other supplement ingredients and were reported as used at least once a week or more often over the six months prior to the survey. This category also included plant derived ingredients such as citric acid.
[h] Purported steroid analogs included steroidal hormones or herbal substitutes for hormones that were marketed as dietary supplements and included the Supplements Facts panel on the label and were reported as used at least once a week or more often over the six months prior to the survey.
[i] Other supplements included those products marketed as dietary supplements that included the Supplement Facts panel on the label that did not meet the definitions for the other six dietary supplement categories and were reported as used at least once a week or more often over the six months prior to the survey. Examples included melatonin, lycopene, caffeine, Alpha lipoic acid, CoQ 10 (CoEnzyme Q10), GNC Fish body oils.

there was a significant increase in DS use over time [44]. This suggests that in spite of the already heavy use of DS by college students, their use of these products will increase as they age. Our data are consistent with this hypothesis as students over 23 use more DS than their younger peers ($P < 0.001$).

Seventy-three percent of the college students we surveyed that use DS stated they used them to promote their general health, but students are among the healthiest of U.S. populations. Furthermore, national studies indicate few young, healthy Americans have inadequate intake of required dietary components including protein and most vitamins and minerals, yet these are the primary components of DS that most college students in our sample were taking. In one of the few studies of college students, only 1–2% were deficient in vitamin C, one of the most popular DS on campus [51]. When vitamin C is chronically consumed in excess, it substantially increases kidney stone formulation [52]. It appears most students are taking DS to fix a problem that they probably do not have and that is not present in the majority of the general U.S. population.



*p<0.05; **p<0.01; ***p<0.001

Fig. 1. Sources of dietary supplement information among DS users.

The second most common reason college students take DS is to provide more energy. For consumers, energy appears to represent the ability to engage in typical daily activities without becoming fatigued, a concept closer to mental rather than physical energy or caloric intake [53–55]. Few American college students are underconsuming calories and our survey found many, including students not taking DS, are more likely to be attempting to lose weight regardless of whether they are taking DS (44%; $N = 547/1248$ for the total survey) rather than gain it (10%; $N = 119/1248$ for the total survey). Therefore, we hypothesize most students taking DS to provide more energy are doing so with the intention of increasing mental energy, although most DS do not increase mental energy or motivation. Caffeine, which is present in certain classes of DS such as combination products and weight loss products, and was taken in the form of DS by 16% of college students in our survey, does appear to increase mental energy, enthusiasm and motivation to exercise [49,56,57]. Other reasons identified by college students for use of DS include increasing muscle strength, endurance and enhancing performance. Most DS used by college students do not enhance these functions or have not been tested sufficiently to determine if they are efficacious [58,59].

The apparent overuse of DS by college students is of particular concern because many habits established in college appear to persist through life [42]. Although taking DS with no actual benefit may cause little direct physical harm unless they are adulterated, which does occur regularly, there are potentially a variety of negative consequences of consuming large amounts of such DS. In this report, we document that college students spend substantial amounts of money on DS, and over the course of a lifetime, this will amount to thousands of dollars. Another possible negative consequence of use of unnecessary DS is that individuals may incorrectly perceive them to be a substitute for other healthy behaviors. For example, taking vitamins and minerals in pill form may cause individuals to consume fewer healthy foods or adopt other unhealthy lifestyles. Future surveys of students should assess the consumption of healthy vs. unhealthy foods in DS users vs. non-users. Our data demonstrating students on an extreme diet (high protein) are more likely to consume DS support this interpretation. That students using tobacco products are more likely than their peers to take 5 or more DS a week and spend more money on DS also supports this hypothesis. National nutrition policies encourage consumption of healthy foods as opposed to use of DS to compensate for unhealthy eating [60].

Excessive use of DS may also result in adverse medical consequences. Many adulterated DS have been identified by the FDA and withdrawn from the market. According to the FDA and DSHEA, a dietary supplement is defined as a "product intended for ingestion that contains a 'dietary ingredient' intended to add further nutritional value to (supplement) the diet. A 'dietary ingredient' may be one, or any combination, of the following substances: a vitamin, a mineral, a herb or other botanical, an amino acid, a dietary substance for use by people to supplement the diet by increasing the total dietary intake, and/or a concentrate, metabolite, constituent, or extract" [5].

It has been reported in both epidemiologic and clinical trials that regular consumption of some DS is associated with increases in morbidity and mortality [61–63]. Use of certain DS may cause significant harm including side effects such as liver or kidney damage, cancer, heart attack or stroke [64–67]. A number of deaths of apparently healthy young individuals have been attributed to use of certain DS such as 1,3-dimethylamylamine (DMAA), ephedra, and Hydroxycut™. Recent comprehensive reviews of the evidence-based literature have concluded that healthy adults will not benefit from vitamin and mineral supplements [1,68]. Unless benefits of DS are verified by evidence-based research, their widespread use among college students seems difficult to justify.

Limitations of this study include the fact that only five colleges and universities were surveyed so it cannot be stated that the students surveyed were fully representative of the general U.S. college student population. In addition, data obtained in this survey may not be directly comparable to national surveys such as the NHANES since different methods were employed in each.

In conclusion, U.S. college students from five universities consume more DS than the general population, and many consume multiple classes of DS a week. Students frequently consume DS in spite of the lack of scientific evidence to support their use and the possibility of experiencing adverse events. Students should be educated to consume healthy diets consistent with accepted nutrition policies and discouraged from substituting DS for poor nutritional choices, so that lifelong healthy eating habits are established in early adulthood.

Statement of authorship

Harris R. Lieberman wrote the paper and had final responsibility for its content.

Bernadette P. Marriott analyzed data and performed statistical analyses, and had final responsibility for its content.

Christianna Williams analyzed data and performed statistical analyses.

Daniel A. Judelson conducted research.

Ellen L. Glickman conducted research.

Paula Geiselman conducted research.

Laura Dotson analyzed data and performed statistical analyses.

Caroline R. Mahoney designed research and had primary responsibility for final content.

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Conflict of interest

None of the authors had any personal or financial conflicts of interest.

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