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REVIEW

# Identifying factors associated with obesity traits in undergraduate students: a scoping review

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## Abstract

**Objectives** This scoping review identifies factors associated with obesity traits including body mass index, weight, and body fat percentage in undergraduate students.

**Methods** We searched CINAHL, EMBASE, MEDLINE, and PsycINFO for original studies of undergraduate students where an obesity trait was associated with a risk factor.

**Results** Two-hundred sixty-eight articles were included comprising of 251 studies: 186 cross-sectional, 50 cohort, 11 interventional, and 4 qualitative. We extracted data on risk/protective factors, obesity traits, and the direction of effect between them. We identified a variety of factors including age, sex, ethnicity, socioeconomic status, religion, diet, eating habits, physical activity, sedentary activity, sleep, stress, university campus life, alcohol use, smoking, psychiatric disorders, body image, eating attitude, eating regulation, personality, sociocultural influences, and genetics. The majority of associations were cross-sectional. For longitudinal findings, usually only one study investigated each trait.

**Conclusions** This review identifies a need for higher quality evidence to support results from cross-sectional studies and replication of findings of longitudinal studies. This review identifies gaps in the literature, generates hypotheses, guides researchers to plan future studies, and helps decision-makers design obesity-prevention programs in universities.

**Keywords** Undergraduate students · Obesity · Freshman fifteen · Risk factors

## Introduction

Obesity is a global epidemic that affects over 650 million adults (Abarca-Gómez et al. 2017). The comorbidities of obesity include depression, sleep apnea, chronic back pain, osteoarthritis, gallbladder disease, type 2 diabetes, fatty liver, hypertension, cardiovascular disease, and some cancers (Guh et al. 2009; Luppino et al. 2010). Adolescence and young adulthood may be critical periods for the development of obesity as elevated body mass index (BMI) during this time is associated with chronic obesity, higher morbidity, and premature mortality (Hirko et al. 2015; Zheng et al. 2017). Furthermore, both duration and earlier onset of obesity are important risk factors in the development of type 2 diabetes (The et al. 2013). While the prevalence of obesity in young adults is not as high as older adults in North America, they have experienced the greatest increase in the incidence of overweight and obesity in recent years, compared to other adult age groups (Canada 2016; Fryar et al. 2018). While education status is negatively correlated with BMI in the general population from high-income countries, young adults in higher education gain more weight and are more likely to develop obesity than those without university education in the USA (Baum 2017; McLaren 2007; Mokdad et al. 1999). In the university student population, overweight and obesity

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affect 23% and 14% of American undergraduate students, respectively (Association 2018).

The "Freshman 15" is a popular notion that undergraduate students gain 15 lb (6.8 kg) during their first year of university. Previous studies have found this to be an exaggeration, estimating an average weight gain of 3–5 lbs (1.4–2.3 kg) (Crombie et al. 2009; Vadeboncoeur et al. 2015; Vella-Zarb and Elgar 2009). These observed weight changes may reflect underlying modifications in lifestyle habits and other health-related behaviours during the transition from secondary school to university (Wengreen and Moncur 2009). These include decreased quality of overall diet, decreased physical activity, increased sedentary behaviour, increased alcohol use, and decreased sleep quantity and quality (Deforche et al. 2015; Irwin 2004; Pullman et al. 2009; Wansink et al. 2013; White et al. 2006). University students are also disproportionately affected by mental illnesses (Stallman 2010), many of which are also positively associated with obesity (Simon et al. 2006). Psychiatric disorders such as anxiety, depression, and eating disorders each have a high prevalence of 23%, 18%, and over 3% in undergraduate students, respectively (Association 2018). However, the influence of these factors on weight change in undergraduate students remains elusive. More research is needed to identify at-risk individuals and design strategies to combat the obesity epidemic in university students.

Reviews and meta-analyses of the "Freshman 15" phenomenon have primarily focused on the evaluation of mean weight gain rather than on the predictors of such weight change (Crombie et al. 2009; Vadeboncoeur et al. 2015; Vella-Zarb and Elgar 2009). Since these reviews were primarily designed to evaluate weight changes in the undergraduate population, they may have excluded important studies on risk factors or discussed only select risk factors from the included papers. Therefore, an assessment of the existing literature is critical to identify areas for improvement to provide direction for future research. Unlike these previous reviews which only included longitudinal studies, we aim to systematically review the literature from all types of original research, including qualitative and interventional designs, to holistically examine predictors of weight gain in undergraduate students and identify risk factors not traditionally investigated in prospective studies. Furthermore, most of the studies included in the previous reviews were from the UK or North America, so we hope to find more studies globally with a broad review design. Altogether, this scoping review will provide a better understanding of a wide variety of factors influencing freshman weight change. The objective of this study is to examine risk factors associated with obesity trait level (i.e. cross-sectional) and change (i.e. longitudinal) in undergraduate university students. Given the broad aim of this study is to identify a comprehensive list of risk factors associated with many obesity traits, we performed a scoping review (Tricco et al. 2018).

## Methods

A protocol for this scoping review was registered on PROSPERO (2017 #CRD42017068742). Criteria for search methods, article eligibility, factors associated with obesity traits (e.g. diet), and obesity trait outcomes (e.g. BMI) were determined a priori. The PRISMA-ScR statement was used to guide reporting of this scoping review (Tricco et al. 2018) (Table S1).

### Literature search

In collaboration with an information specialist (LEB), we developed search strategies tailored to each database and conducted a systematic search of CINAHL, EMBASE, MEDLINE, and PsycINFO to identify studies investigating obesity trait level and change in undergraduate students. We used search terms such as "undergraduate", "college", "university", "bachelor", "higher education", "student", "body mass index", "weight loss", "weight gain", "weight change", "lean", "overweight", "obesity", "body fat", "waist-to-hip ratio", "waist circumference", "skinfold thickness", "adiposity", "body composition", and "freshman fifteen" with Boolean operators to identify studies investigating undergraduate weight/body composition change (see Table S2 for the full search strategy). The search was conducted from the inception of each database to 11 June 2017 and updated on 6 January 2019.

### Article review

Title and abstract screening was conducted in duplicate by REM and CT to identify studies for full-text review. Observational, interventional, or qualitative studies on samples of undergraduate university students were included for full-text review. Medical students were excluded since they are not universally direct-entry programs from high school, especially in North America, and because the demands of their training put them at increased risk of burnout and mental illness (Puthran et al. 2016). The outcomes for this study were self-reported or measured obesity traits including BMI, body adiposity index, conicity index, corpulence index, fat mass, fat mass index, fat mass percentage, muscle mass, muscle mass percentage, fat-free mass, fat-free mass index, fat-free mass percentage, hip circumference, waist circumference, waist-to-hip ratio, and weight. For this review, we collected either obesity trait level or change. For instance, we define "BMI level" as a

student's BMI measured at a specific timepoint (i.e. cross-sectional) and "BMI change" as the amount a student's BMI changed between two or more timepoints (i.e. from longitudinal data). Articles were excluded if they had a sample size less than 30 (for the whole set or relevant subgroup analysis) as a quality measure since samples greater than 30 approximate population distributions better according to the central limit theorem or had obesity traits only associated with pregnancy or physical medical conditions (e.g. polycystic ovarian syndrome, bone fractures), cardiovascular/metabolic/biochemical factors (e.g. serum blood glucose, hypertension), or other anthropometric measurements (e.g. height, neck circumference). Only English full-text, original research journal articles were eligible for inclusion (excluding reviews, commentaries, editorials, gray literature, reports etc.). A sample of 100 abstracts was screened in a training exercise by REM, CT, and a subject matter expert (DM). Disagreements at the screening stage were reconciled through discussion by REM and CT. After full-text review, papers which contained original research showing a statistically significant association between an obesity trait and a factor in undergraduate students were included. We extracted associations which the original study authors considered statistically significant in quantitative analyses. For qualitative studies, we included associations the original authors thought were important. Full-text articles were assessed for eligibility by REM and a subject matter expert (DM). Additional references were identified from previous reviews on the "Freshman 15" (Crombie et al. 2009; Vadeboncoeur et al. 2015; Vella-Zarb and Elgar 2009).

### Data extraction and analysis

Study characteristics, participant demographics, type of factor and its method of measurement, direction of effect, obesity trait, and its method of measurement were extracted by REM. Forms were developed based on a sample of included studies, tested by REM, and approved by DM before extraction. No calibration exercise as data extraction was performed independently. A descriptive analysis is presented for this scoping review. Data are summarized first by obesity trait and then by its associated factor. The direction of effect (positive, negative, or other) reported by studies is summarized as a percent. This was calculated by taking the number of studies reporting a certain direction (e.g. positive or negative) over the total number of studies reporting a direction. The direction reported by the majority of studies (i.e. $> 50\%$) is summarized. If there was an even split between directions (i.e. 50% positive and 50% negative), we reported this as "uncertain".

## Results

### Literature flow

Our search yielded 17,940 titles and abstracts to be screened, after the removal of 7102 duplicates (Fig. 1). One additional article identified by a "freshman 15" review paper not captured in the initial search was also added (Edmonds et al. 2008). After completion of title and abstract screening, 965 records proceeded to full-text review. Six hundred ninety-seven articles were excluded for the following: 413 non-undergraduate student sample, 172 non-full text original research journal articles, 42 for having no factors associated with an obesity trait, 32 non-English, 16 for not having an obesity trait as an outcome, 13 for having a sample size less than 30 in the whole set or relevant subgroup, 4 duplicates, 3 review articles, and 2 which had an inappropriate comparator group of non-undergraduate students. Two hundred sixty-eight articles met eligibility criteria.

### Overview of studies

The 268 included papers comprised of 251 studies: 186 cross-sectional, 49 prospective cohort, 1 retrospective cohort, 11 interventional, and 4 qualitative studies (Table S3). Papers from 1953 to 2018 were included, with a median publication date of 2012. Fifty-nine percent of studies were conducted in North America followed by 15% in Europe, 10% in Asia, 6% in the Middle East, 4% in South America, 2% in Oceania, 2% in Africa, and 2% international. Only 50% of studies reported an ethnicity. In total, 22 studies (9% of all studies) were comprised predominately of one ethnic group ($\geq$ 90%). Among studies, the median sample size was 241 individuals and ranged from 30 to 24,613. The median proportion of males in studies was 33%, with studies ranging from 0 to 100% male. The median mean BMI of participants in studies was 23.0 (study means ranged from 19.9 to 29.2). Of the prospective studies, the median follow-up time was 8 months, reflecting the first year of undergraduate education. Follow-up times ranged from 1 months to 3 years, the latter reflecting time to fourth-year undergraduate education.

### Factors associated with BMI level

We identified associations between BMI level and factors related to demographic characteristics including ethnicity, religion, and calendar year; diet/nutrition; eating habits; physical activity; sedentary activity; healthy lifestyle; sleep; stress; university campus life; substance use;

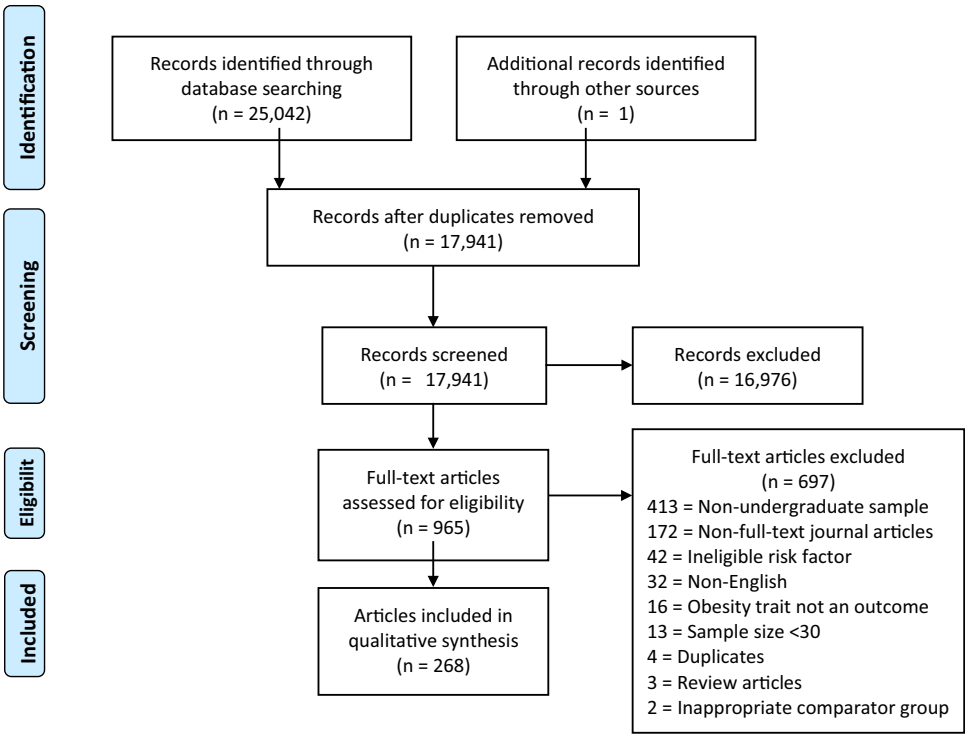


**Fig. 1** PRISMA literature flow diagram of eligible studies

medical history; psychiatric illness/symptoms; body image; eating attitudes; eating regulation; personality/emotions; and social/cultural influences (Fig. 2, Table S4) from cross-sectional, prospective, and interventional studies. Specifically, the following traits were positively associated with BMI: age, male sex (vs. female sex), darker skin color (using color matching), number of children, single (vs. dating), married (vs. single), African/Hispanic/Native American/other minority ethnicity (vs. European), Christian (vs. Muslim), religiosity, calendar year, fat intake, protein intake, meat and egg consumption, junk food consumption, coffee/tea/energy drink consumption, Western diet (vs. Chinese diet), unhealthy eating, junk food cravings, high appetite/plate-clearing behaviour, skipping meals, being an athlete, exercising for appearance/weight control, electronic screen time, evening chronotype (going to sleep late), stress, being enrolled in greater than first-year undergraduate studies, alcohol use, prescription medication use, smoking, family history of overweight/obesity, anxiety, depression/suicide attempts, post-traumatic stress disorder, binge eating disorder/bingeing, bulimia, orthorexia, "drunkorexia" (co-occurrence of disordered eating, binge drinking and moderate/vigorous physical activity), risk or being treated for an eating disorder, psychosocial impairment from eating disorders, body dissatisfaction/desire to lose weight, body image/

**Factors increasing BMI level**

- Age
- Male sex
- African/Hispanic/Native ethnicity (vs. European)
- Fat and protein intake
- Western diet
- Skipping meals
- Electronic screen time
- Enrollment in first year undergraduate study
- Alcohol consumption
- Smoking
- Family history of overweight or obesity
- Anxiety, depression, PTSD, bulimia
- Body image dissatisfaction
- Emotional eating, eating beyond satiety
- Fasting, dieting
- Abuse during childhood
- Poor social support

**Factors decreasing BMI level**

- Socioeconomic status
- Asian ethnicity (vs. European)
- Fiber, dairy, fruit/vegetable intake
- Diet quality
- Snacking, nighttime eating
- Physical activity
- Living on university campus
- Walkability/bikeability of campus
- Problems with alcohol use
- Obsessive compulsive disorder
- Body affect
- Intuitive eating, controlled eating
- Being aware of own illnesses
- Self-esteem
- Social support
- Socio-cultural pressure

**Fig. 2** Abbreviated list of factors associated with body mass index level. *BMI* body mass index, *PTSD* post-traumatic stress disorder

shape/weight concern, clothing for assurance or camouflage, ideal body size, perceived body size, weight fluctuations, emotional eating, eating concern, dieting, eating restraint, external eating, eating beyond satiety/poor control, over eating/food preoccupation, fasting, changing eating behaviours, amotivation, autonomous eating regulation, willing to change eating pattern, agreeableness, anger, attention/concentration, emotional stability, loneliness, impulsivity, psychological distress, abuse during childhood, directive support (support persons repeatedly reminding someone of their weight goals), encouragement to diet/negative comments about weight, racism, and romantic relationship satisfaction. Conversely, BMI was negatively associated with number of family members, socioeconomic status, Asian ethnicity (vs. European), Buddhist (vs. Muslim), avoiding high carbohydrate meals, fiber intake, dairy consumption, fruit/vegetable intake, rice and grains consumption, calcium supplement use, diet quality/guideline adherence, eating while bored, night eating, snacking, choosing healthy foods, exercise motivation, physical activity, healthy lifestyle, being a nutrition major or sorority member, living on-campus, the walkability or bikeability of university campus, problems with alcohol use, flu immunization in the past year, obsessive compulsive disorder, body affect/ability to tolerate negative thoughts about weight, acceptance of cosmetic surgery, weight overestimation, eating until full, hunger, intuitive eating, controlled eating regulation, coping, illness orientation (being self-aware of illnesses), psychologically secure, satisfaction with life, self-concept, self-determination, social withdrawal, emotional reactivity or fearful temperament, being told to gain weight, intense-personal (loving celebrities) or entertainment-social (to keep up with celebrities for entertainment) attitudes towards celebrities, social support, and sociocultural influences/pressures. Factors which were associated but showed an uncertain direction in effect (i.e. 50% of studies showed positive associations and 50% showed negative associations) include energy intake, legume consumption, physical fitness, sleep quality, sleep quantity, and extraversion. Other associated factors with no specified direction included ethnicity, location of mealtime, type of exercise, university institution, and laxative use.

## Factors associated with BMI change

Similar factors were identified with BMI change, including the addition of genetic factors and weight loss interventions (Table 1). In general, male sex (vs. female sex), being heterozygous AT (vs. TT) for the *FTO* single nucleotide polymorphism rs9939609, fatty food preference, eating quickly, skipping meals, eating after consuming alcohol, eating at a friend's house, electronic screen time, going to sleep late, living on-campus, meal plan use, accessibility of dining halls, proximity to gyms, smoking, desire to lose weight, emotional eating, eating restraint, and controlled eating regulation were positively associated with BMI change. Conversely, age, Native American (vs. European) ethnicity, fruit and vegetable intake, physical activity, behavioural/educational weight loss interventions, having a bicycle-sharing program on- campus, summer months, proximity to grocery stores, number of vending machines in dorms choosing healthy foods, perceived success in dieting, autonomous eating regulation, and autonomous support were negatively associated with BMI change. Associations were also identified for alcohol consumption, frequent weighing behaviour, and stress; however, the direction of these effects are uncertain.

## Factors associated with weight

Similar factors were found to influence weight and weight change (Tables S5–S6). Specifically, age, male sex (vs. female sex), African ethnicity (vs. European), calendar year, junk food consumption, physical activity, playing volleyball (vs. doing ballet), living in a dorm with an on-site dining hall, alcohol consumption, bulimia, body dissatisfaction, shape concern, perceived body size, dieting, emotional eating, disinhibited eating, disordered eating, positive effect, and weight loss-related comments by friends and family were positively associated with weight. Factors negatively associated with weight included stress, being a nutrition major, self-esteem, and pressure to eat more.

Factors positively associated with weight change included male sex (vs. female sex), foreign nationality (vs. American), being heterozygous AT (vs. TT) for *FTO* single nucleotide polymorphism rs9939609, high-calorie foods, energy intake, fat intake, dairy intake, unhealthy eating habits, alcohol-related food consumption, eating while bored/studying/socializing, snacking, sedentary activity, being in first year undergraduate studies, being a member of a student group, living on-campus/without parents or undergoing a change in housing, dining hall accessibility, fast food accessibility, having buffet-style meals, frequency of meal plan use, attending a rural mid-size university (vs. urban), alcohol consumption, smoking, depression, bulimia, mental health issues, body dissatisfaction (change and at follow-up), perceived unattractive appearance, emotional eating, eating beyond satiety, disordered eating (change and at baseline, follow-up), greater freedom in making food choices, confidence in academic ability, impulsivity, negative well-being in females, self-esteem in males, body image comments from friends/family, relationship with parents in females, and roommate's weight. On the other hand, socioeconomic

**Table 1** Factors associated with body mass index change

| Phenotypic category | Trait | Method of measurement | Direction of effect[a] | Study cohort type | References |
|---|---|---|---|---|---|
| Demographics | Age | – | Negative (100%) | Prospective | Meisel et al. (2015) |
| | Sex (male) | – | Positive (80%) | Prospective | Brandao et al. (2011), Deliens et al. (2013, 2015), Gropper et al. (2012a, b), Wengreen and Moncur (2009) and Yamane et al. (2014) |
| | | | Negative (100%) | Interventional | Annesi et al. (2015) and Kapinos et al. (2014) |
| Ethnicity (vs. European) | Native American | – | Negative (100%) | Prospective | Stice et al. (2015) |
| Genetics | *FTO* SNP rs9939609 risk allele A (vs. T) | Genotyping | Positive (100%) | Prospective | Meisel et al. (2015) |
| Diet/nutrition | Fatty food preference | Self-reported items | Positive (100%) | Prospective | Goto et al. (2010) |
| | Fruit and vegetable intake | Self-reported | Negative (100%) | Prospective | Pliner and Saunders (2008) |
| Eating habits | Eating quickly | – | Positive (100%) | Prospective | Yamane et al. (2014) |
| | Skipping meals | – | Positive (100%) | Prospective | Goto et al. (2010) |
| | Alcohol-related food consumption | EAUQ | Positive (100%) | Prospective | Lloyd-Richardson et al. (2008) |
| | Eating at a friend's house | – | Positive (100%) | Prospective | Deliens et al. (2013) |
| Physical activity | Physical activity | Adaptations of NLSCY and YRBSS; self-reported items | Negative (100%) | Prospective | Edmonds et al. (2008) and Goto et al. (2010) |
| Sedentary activity | Electronic screen time | – | Positive (100%) | Prospective | Deliens et al. (2013) |
| Weight loss intervention | Autonomous support to lose weight | – | Negative (100%) | Interventional | Powers et al. (2008) |
| | Behavioural healthy weight intervention | | Negative (100%) | Interventional | Stice et al. (2012, 2013) |
| | Nutrition education | | Negative (100%) | Interventional | Sutliffe and Carnot (2011) |
| Sleep | Evening chronotype | rMEQ | Positive (100%) | Prospective | Culnan et al. (2013) |
| Stress | Stress | DASS; PSS | Uncertain (50%) | Prospective | Calitri et al. (2010) and Hootman et al. (2018) |
| University campus life | Living on-campus | – | Positive (100%) | Prospective | Pliner and Saunders (2008) |
| | Bicycle sharing program | — | Negative (100%) | Prospective | Molina-Garcia et al. (2015) |
| | Summer | – | Negative (100%) | Prospective | Hull et al. (2007) |
| | Meal plan use | Total number of meal card swipes; meal card swipes/day; number of days a meal card was used | Positive (100%) | Prospective | Hootman et al. (2017, 2018) |
| | Accessibility of dining halls | – | Positive (100%) | Interventional | Kapinos et al. (2014) |

**Table 1** (continued)

| Phenotypic category | Trait | Method of measurement | Direction of effect[a] | Study cohort type | References |
|---|---|---|---|---|---|
| | Dorm proximity to grocery store | – | Negative (100%) | Interventional | Kapinos et al. (2014) |
| | Number of vending machines in dorm | – | Negative (100%) | Interventional | Kapinos et al. (2014) |
| | Dorm proximity to gym | – | Positive (100%) | Interventional | Kapinos et al. (2014) |
| Substance use | Alcohol | AUDIT | Positive (100%) | Prospective | Lloyd-Richardson et al. (2008) |
| | | – | Negative (100%) | Retrospective | Goto et al. (2010) |
| | Smoking | Items adapted from (Johnston et al. 2000) | Positive (100%) | Prospective | Stice et al. (2015) |
| Body image | Frequent weighing | Wi-Fi scale and weight feedback; self-logging | Uncertain (50%) | Interventional | Bertz et al. (2015) and Strimas and Dionne (2010) |
| | Desire to lose weight | – | Positive (100%) | Prospective | Pullman et al. (2009) |
| Eating attitude | Eating to cope and emotional eating | Emotional Stroop tests (color identification) | Positive (100%) | Prospective | Calitri et al. (2010) |
| | Eating restraint | Revised Restraint scale | Positive (100%) | Prospective | Pliner and Saunders (2008) |
| | | Restraint scale | Positive (100%) | Interventional | Strimas and Dionne (2010) |
| | Tendency to choose healthy foods | Reaction time test | Negative (100%) | Prospective | Calitri et al. (2010) |
| | Perceived success in dieting | PSRSDS | Negative (100%) | Prospective | Meule et al. (2017) |
| Eating regulation | Autonomous eating regulation | REBS (intrinsic motivation, integrated regulation, and identified regulation subscales) | Negative (100%) | Prospective | Gropper et al. (2014) |
| | Controlled eating regulation | REBS (introjected regulation subscale) | Positive (100%) | Prospective | Gropper et al. (2014) |
| Social/cultural influences | Autonomy support | Items adapted from (Williams et al. 1996) | Negative (100%) | Interventional | Powers et al |

*AUDIT* Alcohol Use Disorders Identification Test, *DASS* Depression Anxiety Stress Scales, *EAUQ* Eating and Alcohol Use Questionnaire, *NLSCY* National Longitudinal Survey of Children and Youth, *PSRSDS* Perceived Self-Regulatory Success in Dieting Scale, *PSS* Perceived Stress Scale, *REBS* Regulation of Eating Behaviour Scale, *rMEQ* reduced Morningness–Eveningness Questionnaire, *SNP* single nucleotide polymorphism, *YRBSS* Youth Risk Behaviour Surveillance System

[a]Percentage calculated per study; direction of majority (> 50%) is shown

status, food and vegetable consumption, consumption of satiating foods, being health responsible, having autonomous support to lose weight, academic performance, vending machines accessibility, education about healthy eating, summer, having more free time, body image, frequent weighing behaviour, carefully making food choices, autonomous eating regulation, happiness, self-motivation, negative well-being in males, negative feelings about transitioning to university, self-esteem in females, autonomy support from others, perceived success in finding a romantic partner, and relationship with parents in males were negatively associated with weight change. Some studies reported more complex relationships between factors and weight change. Stress exemplified a more complex relationship whereby high stress was associated with both weight gain and weight loss. In addition, a decrease in salty/sweet/sour taste intensity was also associated with both weight gain and weight loss. Associations for sleep

quantity, body dissatisfaction (at baseline), dieting, and eating restraint were also identified; however, the direction of these effects is uncertain. Prospective studies indicated that physical activity was positively associated with weight gain while qualitative study found physical activity to be negatively associated. Consumption of healthy or junk foods, eating at restaurants or pay-cash facilities, number of meals in the evening or weekend, dormitory location, negative effect, and concern about interpersonal relationships were also related to weight change although no direction was reported.

### Factors associated with adiposity measures

Similar associations were also found for obesity traits measuring adiposity (i.e. body adiposity index, body fat mass, body fat percentage, fat mass index, triceps skinfold thickness, visceral fat, conicity index) (Tables S7–14). Age, African ethnicity or other ethnic minority (vs. European), calendar year, energy intake, exercising for appearance, exercising to avoid feeling guilty for not exercising, stress, being in fourth-year undergraduate studies, smoking, body dissatisfaction, ideal body size, perceived body size, putting effort into physical appearance, eating restraint, autonomous eating regulation, controlled eating regulation, disinhibited eating, emotional eating, having achievement self-esteem based on appearance, and having a history of abuse during childhood were positively associated with adiposity measures. In contrast, male sex (vs. female sex), socioeconomic status, Muslim religion (vs. Christian), dairy intake, fiber intake, eating a healthy diet, exercising for competence, physical activity, body satisfaction, and having self-acceptance self-esteem based on performance were negatively associated with adiposity measures.

For changes in adiposity measures, male sex (vs. female sex), being in first year for undergraduate studies, living on-campus, summer months, amotivation in eating regulation, and disinhibition in eating were positively associated. Conversely, physical activity, being in second-year undergraduate studies (vs. first or third year), studying, putting effort into physical appearance, and autonomous eating regulation were negatively associated with changes in adiposity measures.

### Factors associated with lean/muscle mass measures

We also found associations for lean/muscle mass measures (i.e. muscle mass, muscle mass percentage, fat-free mass, fat-free mass index, fat-free mass percentage) (Tables S15–19). Male sex (vs. female sex), physical activity, responsiveness to food environments, being in second-year undergraduate studies (vs. third year), and being in a nutritional course were positively related to changes in lean/muscle mass. Male sex (vs. female sex), physical activity, body building (vs. playing soccer), and playing volleyball (vs. doing ballet) were positively associated with lean/muscle mass measures while calendar year and summer months were negatively associated.

### Factors associated with other obesity traits

Waist circumference was positively associated with age, male sex (vs. female sex), being married, socioeconomic status, energy intake, avoiding fatty foods, following a Western diet (vs. Chinese diet), hunger and overeating, inconsistent meal times, skipping meals, preference for sweets, sleep quality, academic performance, family history of obesity, body dissatisfaction, emotional eating, disordered eating, eating disinhibition, and binge eating (Table S20). Conversely, African ethnicity, fiber intake, diet quality, physical activity, physical fitness, following a healthy lifestyle, sleep quantity, stress, considering changing eating habits, attention deficit hyperactivity disorder, and being psychologically secure were negatively associated with waist circumference. Academic year and university campus were associated with waist circumference however no direction was reported. Male sex (vs. female sex), stress, and meal plan use were positively associated with waist circumference change.

Positive associations were identified for age and disordered eating with hip circumference. male sex (vs. female sex), physical activity, and body dissatisfaction were negatively associated with hip circumference. Hip circumference change was negatively associated with male sex (vs. female sex) (Table S21). Waist-to-hip ratio was positively associated with male sex (vs. female sex), age, and disordered eating and negatively associated with African ethnicity (Table S22). Being in fourth-year undergraduate studies (vs. other years) was positively associated with corpulence index (Table S23). Male sex (vs. female sex) was positively associated with body surface area (Table S24). Various nationalities (i.e. country of residence) were also found to be associated with BMI level, weight, and waist circumference. Given the diversity of nationalities and comparators, only a summary is reported in Tables S4, S5, and S20. A summary overview of findings by outcome and risk factor group can be found in Table S25.

## Discussion

This review was conducted to generate hypotheses and guide the design of high-quality studies on the determinants of undergraduate student weight change. We

identified a broad range of factors associated with obesity traits including demographics, calendar year, diet/nutrition, eating habits, physical activity, sedentary activity, weight loss interventions, lifestyle, sleep, stress, university campus life, substance use, medical history, psychiatric illness/symptoms, body image, eating attitude, eating regulation, personality/emotions, social/cultural influences, and genetics. Specifically we identified several factors associated with obesity traits which had not been previously shown in other reviews on undergraduate weight change, including anxiety, depression, history of childhood abuse, genetics, and electronic screen time (Crombie et al. 2009; Vadeboncoeur et al. 2015; Vella-Zarb and Elgar 2009). Our finding shows that the most commonly reported obesity outcomes of the included studies were BMI and weight. In general, the factors we identified had similar directions of effect between these two outcomes (e.g. body dissatisfaction was positively associated with both weight and BMI level). The direction of effects also agreed with previous studies in the general population such that age and female sex are positively associated with body fat percentage; individuals of Asian ethnicity have lower BMI while other ethnic minorities have higher BMI when compared to Europeans; diets high in refined carbohydrates, fast foods, and low in fruits and vegetables are related to increased adiposity; physical inactivity leads to increased BMI; body dissatisfaction is associated with increased BMI; bulimia and binge-eating disorder are positively associated with BMI; anxiety and depression are associated with obesity; high alcohol consumption is associated with excess weight and weight gain; and stress is related to weight gain and weight loss (Drewnowski 2007; Gariepy et al. 2010; Jackson et al. 2002; Kivimaki et al. 2006; Luppino et al. 2010; Pietiläinen et al. 2008; Traversy and Chaput 2015; Villarejo et al. 2012; Wang and Beydoun 2007). However, most of the analyses were linear and failed to look at more complex associations such as with sleep, which shows a U-shaped relationship with BMI (Taheri et al. 2004). Moreover, when comparing cross-sectional and longitudinal studies of BMI (i.e. BMI level vs. BMI change), the direction of associations differed in some cases. One illustration is Native American ethnicity being negatively associated with BMI change but positively associated with BMI level, as compared to Europeans. Since Native Americans seem to have a higher baseline BMI, it is possible they lose more weight or gain less weight during undergraduate education than other students. Additionally, BMI and weight do not consider the composition of fat or muscle mass. This is an important point to consider. For instance, this review found living closer to gyms was positively associated with BMI change which seemingly contradicts the finding that physical activity is negatively associated with BMI change. However, this BMI change may have reflected an increase in muscle mass instead of adiposity. Effects may also differ by sex as evidenced by self-esteem, negative well-being, and one's relationship with their parents on weight change. In addition, some studies investigated differences in obesity traits between individuals of different nationalities. While variation in body composition may exist between ethnic groups, the results of these studies should be interpreted with caution as more comprehensive international multi-centre studies are needed to gain a better understanding of these differences.

## Strengths and limitations

This study finds strength in using broad search criteria to increase the likelihood of finding relevant papers. This is supported by the fact that only one relevant article was not found in the search results and included in the analysis of this review. We also considered qualitative studies in addition to observational and interventional studies to obtain a more holistic understanding of factors affecting weight changes in undergraduates. These qualitative findings generally agreed with the findings from the quantitative studies, but also provided some unique information that quantitative studies do not usually capture (e.g. feelings about buffet-style meals, having greater freedom to make food choices). With respect to external validity, our study is strong in that it included papers from diverse countries. This is in contrast to previous reviews of the longitudinal "Freshman 15" studies which mainly included studies from North America and the United Kingdom (Crombie et al. 2009; Vadeboncoeur et al. 2015; Vella-Zarb and Elgar 2009). However, studies had a low proportion of male participants (median = 33%) which may affect generalizability. Another limitation of this review is that data extraction was not performed in duplicate which could bias results. However, this is an accepted practice in scoping reviews and since our objective was to identify broad themes and gaps in knowledge, we felt data extraction in duplicate would be more appropriate for a study where meta-analysis is possible (Tricco et al. 2018). Since no meta-analysis was conducted, the strength of the identified associations could not be determined. Given the small number of papers investigating each specific factor, variety of analytic methods used (e.g. correlational, *t* tests, regression models both adjusted and unadjusted), and the great diversity of measurement tools used in the included studies (e.g. self-reported, directly measured, validated questionnaires); scarcity of data and heterogeneity would have posed major problems. Although we included both self-reported and measured outcomes, we do not expect this to affect the validity of our findings since the method of measurement did not significantly alter the results in a

previous meta-analysis (Vadeboncoeur et al. 2015). Additionally, the quality of evidence cannot be inferred as no risk of bias assessment was conducted, owing to the important number of studies included ($N = 251$). Another limitation is that many studies did not use validated questionnaires to measure some factors nor did they describe the methods used which may lead to bias from measurement error. Finally, the majority of associations were from cross-sectional studies and are therefore correlational in nature. Any inference of causality is therefore limited as unmeasured confounders could affect significance, magnitude, and direction of associations.

## Implications

This is the first review to synthesize the factors associated with obesity traits in undergraduate students globally. For those factors which were investigated in a longitudinal manner, usually only one study investigated each trait. Therefore, a need exists for both higher quality longitudinal studies to support the results from cross-sectional studies and replication of findings from prospective and interventional studies. This review will also help guide the design of high-quality longitudinal studies by prompting the selection of variables which are under-investigated and require further research. *Blinded* is one such study which, will investigate the effect of adverse life experiences on body composition, a factor for which we only found cross-sectional associations in this review. This is a critical area of interest given the high prevalence (about 14–44%) of students ever-experiencing sexual assault during their undergraduate education (Fedina et al. 2016). Our review also highlights the need to investigate changes in both fat and muscle mass, as these reflect important changes that BMI alone cannot capture. In addition, it revealed some factors which had complex relationships with body composition, suggesting future studies conduct sex-specific or nonlinear analyses. Finally, these findings will help universities understand potential factors which influence body composition change and design more effective obesity prevention programs.

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## Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

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