Predictors of Weight Change in First-Year Undergraduate Students

Identifying the Pattern and Predictors of Weight Change in First-Year Undergraduate Students: Results from a Prospective Observational Study

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LIST OF ABBREVIATIONS

GENEiUS - Genetic and EnviroNmental Effects on weight in University Students

BW – Body Weight

BMI – Body Mass Index

WC – Waist Circumference

HC – Hip Circumference

WHR – Waist to Hip Ratio

Declaration of Academic Achievement

Chapter 1: My own work.

Chapter 2: This chapter is under review in a peer-reviewed journal. D.M. designed the study; D.M, T.S., R.E.M., and C.L. conducted research; T.S. and D.M. analyzed the data; T.S. and D.M. wrote the manuscript; R.E.M., and C.L. critically reviewed the manuscript.

Chapter 3: This chapter is under review in a peer-reviewed journal. D.M. designed the study; D.M, B.M., T.S., R.E.M., and C.L. conducted research; D.M. and T.S. analyzed the data; T.S., B.M., and D.M. wrote the manuscript; R.E.M., and C.L. critically reviewed the manuscript

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Chapter 5: My own work.

CHAPTER 1: Introduction to the thesis

Obesity: A major public health concern

Obesity is a multifactorial and largely preventable condition resulting from complex interactions between different biological and environmental factors.[1] In recent decades, the disease has reached epidemic proportions as over one-third of the global population today is either overweight or obese, and projections indicate that this proportion will likely surpass 50% by 2030.[2,3] Obesity is a major risk factor for several secondary conditions such as sleep apnea, depression, osteoarthritis, chronic back pain, asthma, gallbladder disease, type 2 diabetes, dyslipidemia, fatty liver, hypertension, pulmonary embolism, cardiovascular disease, congestive heart failure, and some cancers.[4] It can further reduce life expectancy by 20 years in its most severe forms.[5] In Canada, obesity affects approximately 1 in 4 adults.[6,7] It contributes to 20% of premature deaths in Canadian adults and accounts for $7.5 billion (5.1%) in Canadian healthcare expenses per year.[5,8,9] Despite the availability of different therapeutic options, ranging from bariatric surgery and pharmacologic interventions involving drugs such as Sibutramine or Orlistat, to lifestyle and dietary interventions, effective management of this disorder has proven challenging due to its complex and multifactorial nature.[10-13] Hence, understanding the determinants of obesity and overweight could help in optimizing current prevention and management strategies, and further developing effective therapies.

Measurement of Obesity

While different approaches can be used to measure obesity, most methods present certain limitations and vary in their ability to measure body mass, size, and composition. Some of the more direct measurement methods of body size and composition include dual-energy X-ray absorptiometry, bioelectric impedance analysis, air displacement plethysmography, hydrodensitometry, and magnetic resonance imaging.[14-17] While the measures obtained through these technologies are highly precise, many of these options are expensive and present practical challenges with respect to factors such as portability and accessibility. Hence, in many cases, using one or more of these technologies is not a viable option for studies from a feasibility perspective. In comparison, some of the more accessible alternatives that are frequently used in practice include anthropometric measures such as body weight, height, waist circumference, and hip circumference. These anthropometric indices, along with additional derivatives such as BMI and WHR, are often used as indicators of overall body mass and visceral adiposity due to their simplicity of assessment and low resource requirement. Nevertheless, while these indicators are widely adopted, they also present certain limitations. For instance, when considering BMI, which looks at total body mass in relation to height, some of its major drawbacks are that it does not differentiate between bone mass, lean mass, and fat mass, and it does not provide any information regarding adiposity.[17] Similarly, measures such as waist circumference and waist-to-hip ratio, which are useful indicators of abdominal fat, are limited in their ability to differentiate between intra-abdominal and subcutaneous fat compartments.[17-19]

Obesity in young adults: Transition to university

Adolescence and young adulthood may be critical periods for obesity development as elevated BMI during these periods have been associated with chronic obesity later in life, as well as higher morbidity and premature mortality.[5,20-24] As such, young adulthood may be considered a favorable period for effective obesity prevention.[25] Interestingly, while education status is negatively correlated with BMI in the general population from high-income countries, young adults with higher education have been shown to be at greater risk for weight gain than those without post-secondary education.[26-28] The "Freshman 15" is a popular theory that suggests that undergraduate students gain 15 pounds during their first year in university. While previous studies have found this to be an exaggerated estimate, they have indicated that, on average, students still tend to gain around 3-5 pounds during this period.[29-31] This increase can be partially attributed to changes in environmental and lifestyle factors such as increased accessibility to unhealthy foods, decreased physical activity, and increased sedentary behavior, which are usually observed during the transition to university.[32-35] However, not everyone exposed to this 'obesogenic' environment gains weight.[36] Several biological factors such as gut microbiome, genetics, and epigenetics can modulate an individual's susceptibility to weight gain and can help explain a portion of the observed inter-individual variance in anthropometric change.[36,37] Hence, altogether, given that young adults pursuing university education are at increased risk of gaining weight and subsequently developing overweight/obesity, identifying the risk factors within this context may be a critical step forward towards effective obesity prevention.

Predictors of obesity

Several biological and environmental risk factors of obesity have been previously identified.[36,38,39] While increased caloric intake and decreased physical activity are the two major culprits, various additional factors have also been implicated within this context.[36,39] For instance, when considering biological factors, a considerable component of obesity development has been shown to result from genetic predisposition.[36,40] Recent genome-wide association studies (GWAS) have identified 227 genetic variants that are associated with both childhood and adult BMI/obesity.[36] Apart from that, demographic factors such as gender and ethnicity, which represent an intersection of both biological and social/behavioral constructs, have also been linked to body mass and obesity status.[41-49] In particular, individuals of Asian ethnicity have been found to have lower BMI on average than Europeans.[48] However, when comparing adiposity, Asians have been found to have a higher amount of body fat, with South Asians being particularly more susceptible to abdominal obesity development, compared to white Europeans of the same BMI.[42,45,46] Similarly, when considering the effect of sex within this context, previous studies have found significant disparities in the global prevalence of obesity between men and women, with more women being obese than men overall, and women of lower occupational status being at increased risk of developing obesity.[41,43,44,48,50]

When considering lifestyle and environmental factors, apart from diet and physical activity, several additional factors such as sleep quantity, occupational stress, and religiosity have been linked with obesity traits.[51-54] Within that context, living environment has also been found to play a critical role in one's ability to maintain weight.[55,56] For instance, one previous study among public housing residents found that having a supportive neighborhood environment, with easy accessibility to physical activity resources and amenities, was associated with lower BMI among residents.[57] When specifically considering 'freshman' weight gain in first-year university students, similar risk factors have been identified.[33,58-61] For instance, previous literature within this context has indicated that factors such as sex and living arrangement can have an impact on the weight change trajectory during first year of university.[33,58-61]

Rationale for further study

Given that young adults pursuing undergraduate studies represent an at-risk group for increased BMI and the development of obesity later in adulthood, the predictors of weight gain in this population should be explored for the development of effective prediction and prevention strategies. While weight gain in undergraduate students during first year of university has been extensively documented in previous studies from around the world, Canadian studies within this context have been relatively limited. This thesis investigates the effect of demographic and environmental factors on change in obesity traits among first-year university students from Canada. Chapter 2 provides a complete report on the investigation of sex/gender as a predictor, Chapter 3 documents the investigation of race/ethnicity as a predictor, and Chapter 4 describes the investigation of living arrangement as a predictor within this context. The thesis concludes with Chapter 5 which provides an overarching discussion of key findings, methodological limitations, practical lessons learned from study execution and implementation, and future directions.

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CHAPTER 2: The effect of sex/gender on obesity traits in first year university students from Canada: the GENEiUS study

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ABSTRACT

Background: While weight gain during first year of university has been well documented in North America, Canadian literature on sex-specific effects is scarce and inconsistent. The objective of this investigation was to explore sex-specific changes in obesity traits during first year of university at McMaster University in Ontario, Canada.

Methods: 245 first-year students were followed longitudinally with data collected early in the academic year and towards the end of the year. Obesity parameters including weight, BMI, waist and hip circumferences, and waist to hip ratio were investigated. The Mann-Whitney U test and the Wilcoxon signed-rank test were used for pairwise comparison of traits in the absence of adjustments. Additionally, repeated-measures ANOVA was used with covariate adjustments to investigate the interaction between sex and time.

Results: Overall sample trends indicated a significant increase in mean weight by 1.55 kg (95% CI: 1.24 – 1.86) over the school year ($p<0.001$). This was also accompanied by significant gains in BMI, and waist and hip circumferences ($p<0.001$). At baseline, males presented with higher body weight, BMI, waist and hip circumferences, and WHR, compared to their females counterparts ($p<0.01$). Additionally, sex-stratified analysis indicated significant gains in weight, BMI, and waist and hip circumferences in both males and females ($p<0.01$). However, a comparison of the magnitude of change over time between the two sex groups revealed no significant difference for any of the investigated traits ($p>0.05$).

Conclusion: While our study confirms significant weight gain in both male and female first year university students in Ontario, Canada, it does not show sex specific differences within this context. Our investigation highlights the importance of accounting for sex and gender in health research and supports the need of further studies in this area.

INTRODUCTION

According to recent World Health Organization (WHO) estimates, the global prevalence of obesity and overweight has nearly tripled over the last four decades with over one-third of the global population now having an estimated body mass index (BMI) above 25 kg/m^2. Canada is one of several high-income countries that has a high prevalence of obesity and overweight [1]. Data from the 2018 Canadian Community Health Survey (CCHS) indicate that approximately 63.1% of Canadians are either overweight or obese, with a higher proportion of males (69.4%) being affected than females (56.7%). Interestingly, when examining the CCHS estimates of obesity/overweight prevalence in Canadians between 2010 and 2018, a considerable increase from approximately 23.24% to 31.2% is noted amongst individuals aged 18-19. This is highly concerning as previous studies have implicated elevated BMI during adolescence and young adulthood as an important risk factor for development of chronic obesity later in life, as well as higher morbidity and early mortality [2-5]. Despite the availability of different therapeutic interventions, ranging from diet adjustments to bariatric surgery, treatment of obesity remains a biomedical and public health challenge due to its multifactorial pathogenesis and, as such, the disorder tends to persist as a chronic condition in most affected individuals [6,7]. In that context, further research in this area for a better understanding of the disorder is critical to optimize the prediction, prevention, and treatment of obesity [8].

The period between the age of 17 and 25 years, sometimes referred to as “young adulthood,” encompasses important transition events for many young adults, one of which includes starting post-secondary education [9]. Interestingly, while education status is negatively correlated with BMI in the general population from high-income countries, students pursuing post-secondary education have been shown to be at greater risk for weight gain than those not pursuing university education in the United States [10-13]. The "Freshman 15" is a popular belief that undergraduate university students gain 15 pounds (6.8 kg) during their first year of university studies [10,11]. While previous studies have supported the theory of weight gain during the first year of university, the amount gained has been reported to be more modest at approximately 3 to 5 lbs (1.4 to 2.3 kg) [14-16]. This increase can be partially attributed to changes in environmental exposures and lifestyle habits such as an unhealthy diet, decreased physical activity, and increased sedentary behavior, which are usually observed during transition to university [17-20]. However, not everyone exposed to this 'obesogenic' environment becomes obese [21]. Several biological factors such as *in utero* programming, gut microbiome, epigenetics and genetics, can modulate an individual's susceptibility to weight gain and can help explain a portion of the observed inter-individual anthropometric variance [21,22]. Sex/gender (hereafter referred to as sex) represents an important risk factor at the interface of biology and environment as it encompasses both biological and sociological constructs [23,24].

Previous research examining obesity traits in post-secondary students indicates that males present with a higher BMI than their female counterparts on average [25,26]. However, the literature on the effect of sex on weight gain during the academic year is mixed [25,27,28]. Canadian studies within this context have been relatively limited and have also reported contradictory results [29-32]. While some reports have indicated sex-specific patterns of anthropometric change in first-year university students, others have found no significant differences [29-32]. Most recently, Beaudry et al. (2019) reported a significant sex effect amongst first-year students at a university in Ontario, showing that male students gain about twice as much weight as their female counterparts [29]. This has important implications as this report implicates sex as an important risk factor to be taken into consideration for prevention efforts [29]. Since we recruited first year students at a different university campus in Ontario, we carried out a follow-up investigation and attempted to replicate this observation in a multiethnic cohort of 245 undergraduate students at McMaster University.

METHODS

Study design and participants

Genetic and EnviroNmental Effects on weight in University Students (GENEiUS) is a prospective observational study investigating the environmental and biological determinants of obesity trait changes in Canadian undergraduate students [8]. As part of this study, undergraduate students from McMaster University (Hamilton, Ontario) were followed every six months over four years beginning in September of their first year of study. First year undergraduate students enrolled at McMaster University, between the ages of 17 and 25, were eligible to participate in the study. Students were primarily recruited via in-class advertising on main university campus and through social media promotion. Individuals who were pregnant, had previously given birth, or had a medical condition that could have impacted BMI for a long period of time (e.g. bariatric surgery, immobilization from injury) were excluded from the study. Additional details regarding the GENEiUS study have been described previously [8]. Written informed consent was obtained directly from the participants. All methods and procedures for this study were in accordance with the Declaration of Helsinki principles and were reviewed and approved by the Hamilton Integrated Research Ethics Board (REB#0524).

Data collection

Four cohorts of participants (2015–2016, 2016-2017, 2017-2018, 2018-2019) were followed longitudinally with data collected at two study visits: the beginning of their first-year (September/October) and towards the end of their first-year (March/April). A total of 361 participants were enrolled in the study. Two-hundred forty-five of them completed the baseline and follow-up visits and represent the analyzed sample in this report. Data analyzed in this study included anthropometric (weight, BMI, waist and hip circumference, waist to hip ratio), and demographic data (sex, ethnicity, living arrangement, program of study). Anthropometric traits, including weight, height, waist circumference (WC), hip circumference (HC), were measured at baseline (September/October) and again approximately 6 months post-baseline (March/April). Weight was measured to the nearest 0.1 kg using a digital scale (Seca, Hamburg, Germany) and height was measured to the nearest 0.1 cm using a portable stadiometer (Seca 225, Hamburg, Germany). WC was measured at the midpoint of the last palpable rib and the superior portion of the iliac crest to the nearest 0.1 cm and HC was measured at the widest part of the buttocks to the nearest 0.1 cm using a stretch-resistant tape measure, in accordance with WHO guidelines. All anthropometric measurements were performed by trained research assistants. Additional obesity trait outcomes, including BMI and waist to hip ratio (WHR), were calculated. BMI (kg/m^2) was calculated by dividing weight by squared height and WHR was calculated by dividing WC by HC. Information about demographic characteristics was collected at the first appointment using an online, self-reported questionnaire.

Statistical analysis

All statistical analyses were performed using IBM SPSS Version 25 statistical package. Descriptive analysis was carried out to assess the preliminary distribution of traits within the study sample. Data for continuous variables have been reported using means and SD while categorical data have been reported by counts and percentages. Anthropometric data at each time point were screened for potential outliers. Any identified outlying data points were individually cross-checked to determine if they were true outliers, representing participants who truly fell outside the general distribution of our data, or if the outliers were a result of inaccuracies in measurement or data transcription. Data inaccuracies were corrected while all other outliers were left in the dataset. All data were assessed graphically and statistically for normality of distribution prior to analysis. The Mann-Whitney U test was used for a pairwise comparison of outcomes at baseline between males and females, in absence of adjustments for covariates. The Wilcoxon signed-rank test was used for a pairwise comparison of change in obesity traits from the beginning to the end of first year university, in absence of adjustments for covariates. Differences in anthropometric outcomes over the year and the effect of sex on anthropometric change was tested using a repeated measures analysis of variance (RMANOVA). An inverse normal rank transformation was applied to the anthropometric data for each time point. Sex was treated as a between-subject factor while time was treated as the within subject factor. Different covariates including cohort of recruitment (i.e. 2015–2016, 2016-2017, 2017-2018, 2018-2019), faculty of study (i.e. science vs. non-science), and living arrangement (i.e. living in residence on campus, living at home, living in student housing off campus) were tested separately in each RMANOVA model. The covariates were only retained if their interaction with time was significant or marginally significant, otherwise reduced models were presented. We followed the covariate adjustment strategy used by Beaudry *et al.* (2019) for the available traits [29]. Partial eta-squared values ($\eta 2$) from the RMANOVA were also presented as a measure of effect size. In this case, $\eta 2$ value of around 0.02 was considered a small effect, $\eta 2$ value of around 0.13 a medium effect, and η2 value of around 0.26 a large effect [33]. Based on the fact that i) the present study is hypothesis-driven; ii) the research questions have been previously tested in literature; iii) tested obesity outcomes are not independent, a Bonferroni correction was not applied in this case as even though it reduces the chance of making type I errors, it can increase the chance of making type II errors [34,35]. Therefore, the level of statistical significance was set at $p < 0.05$ for all tests.

RESULTS

Participant characteristics

A total of 361 participants were enrolled into the study between 2015 and 2018 of which 245 (68%) completed one year of follow up (i.e. completed the first baseline visit around September/October and a second follow-up visit in March/April) between 2016 and 2019. The mean length of time between the baseline and follow-up visits was 21.6 (SD = 2.18) weeks. Participants displayed an average age of 17.87 (SD = 0.48) years at baseline and female participants accounted for 80.4% of the sample. Thirty one percent of the participants were East Asian (n = 76), 24.9% were white-Caucasian (n = 61), 18.8% were South Asian (n = 46), 12.7% were mixed (n = 31), 6.9% were Middle Eastern (n =17), and 5.7% (n=14) collectively belonged to other ethnicity groups including African, Latin American, and Pacific Islander. In terms of living arrangement, 69.4% percent of the sample reported living in university residence on campus (n = 170), 19.6% reported living at home with family (n = 48), and 10.6% reported living in a student house off campus (n = 26). Among those who reported their program of study, 86.2% reported being enrolled in a science based academic program (e.g. Health Science, Life

Science, Kinesiology, Engineering) while 13.8% reported being in enrolled a non-science academic program (e.g. Humanities, Business, Arts).

Anthropometric patterns in first year of university: overall trends

At baseline, the average body weight, BMI, WC, HC, and WHR for the overall sample was 60.42kg (SD = 11.98), 21.52 kg/m^2 (SD = 3.34), 75.08cm (SD = 8.69), 97.18cm (SD = 7.73), and 0.772 (0.050) respectively. Approximately 78.4% (n=192) of the participants had a normal BMI at baseline, 12.2% were underweight (n=30), 6.5% were overweight (n=16), and 2.9% (n=7) were obese. By the end of the academic year, an average increase was noted across all anthropometric traits when compared to earlier on in the year. Table 1 summarizes the aggregated anthropometric data at each time point. There was a significant increase in average body weight, by 1.55 kg (95% CI: 1.24 – 1.86; p<0.001), and in mean BMI, from 21.52 kg/m^2 to 22.16 kg/m^2 between the two time points(0.65 kg/m^2, 95% CI: 0.53 – 0.76, p<0.001). Notably, however, the mean BMI at both time points remained below 25 kg/m^2 (21.52 ± 3.34 and 22.16 ± 3.45 at the beginning and at the end of the year respectively), indicating that the sample, on average, remained within the 'normal weight' category throughout the year. WC and HC also increased significantly, by 1.14 cm (95% CI: 0.63 – 1.66, p<0.001) and 0.93 cm (95% CI: 0.55 – 1.31, p<0.001) respectively. While a modest rise in WHR was noted between the two time points, it did not reach the threshold for statistical significance (P=0.083). There was no significant difference in anthropometric change (i.e. change in weight, BMI, WC, HC, and WHR) between those who were followed for less than, or more than, the average follow-up time (21.6 weeks).

Sex-specific trends: anthropometric presentation at baseline

Table 2 presents the sex-specific trends across all investigated obesity traits at the beginning of the year (i.e. baseline). Overall, males presented with larger body weight ($p<0.001$), higher BMI ($p=0.008$), larger WC ($p<0.001$), larger HC ($p<0.001$), and a higher WHR ($p<0.001$) at baseline, compared to their females counterparts.

Sex-specific trends: anthropometric changes in first year of university

In terms of change from the beginning to the end of the year, both sexes saw an increase across all investigated traits. Particularly, sex-stratified analyses of anthropometric change over the academic year revealed significant gains in body weight (males: $p<0.001$, females: $p<0.001$), BMI (males: $p<0.001$, females: $p<0.001$), WC (males: $p=0.006$, females: $p<0.001$), and HC (males: $p=0.006$, females: $p<0.001$) among both gender groups (Supplementary Table 1). In comparison, no significant change in WHR was noted in both subgroups (males: $p = 0.173$, females: $p = 0.193$). Comparing the magnitude of change between the two sex groups showed that males gained slightly more body weight than females (1.90 kg *vs.*1.46 kg respectively). Overall, this trend was consistent across the other measured obesity traits as well, wherein males displayed moderately larger gains in BMI (0.74 kg/m^2 vs. 0.62 kg/m^2), WC (1.76 cm vs. 0.99 cm), HC (1.08cm vs. 0.89cm), and WHR (0.0085 vs. 0.0030) towards the end of first year in university, compared to females. However, none of the observed differences in the magnitude of change between males and females were found to be statistically significant (interaction: $p>0.05$ across all traits). Table 3 summarizes the sex-specific anthropometric trends from the beginning and end of first year university.

DISCUSSION

In this investigation, we examined the effect of sex on obesity traits in first year of university. The investigation yielded several important results. Firstly, we found that males on average presented with larger body weight, BMI, WC, HC, and WHR at baseline as compared to females. Secondly, a net increase was observed in the overall sample, across all measured outcomes, towards the end of the academic year when compared to early on in the year. Notably, in this case, while significant gains in body weight, BMI, WC, and HC were noted, the change in WHR was not found to be significant. Thirdly, a consistent trend was observed in the two separate sex subgroups as both males and females experienced significant increases in body weight, BMI, WC, and HC, but not WHR, during first year of university. Lastly, we found that while males displayed slightly larger gains than females over time, across all investigated obesity parameters, the differences in the magnitude of change were modest with no significant sex-specific effect being found within this context.

Weight gain in undergraduate students during first year of university has been extensively documented in previous studies from around the world [15,16]. Through our study, we confirmed this trend at McMaster University in Ontario, Canada. While the popular North American notion of ‘Freshman 15’ suggests that students gain approximately 15lbs (6.8kg) in first year of university, our results indicate a more modest overall increase of about 3.4lbs (1.55kg) on average. Our result is in line with the pooled weight gain estimates of 1.36 kg and 1.75kg, determined via previous meta-analyses by Vadeboncoeur *et al.* (2015), and Vella-Zarb and Elgar (2009) respectively [15,16]. Additionally, based on their subgroup investigation of Canadian studies, Vadeboncoeur *et al.* further reported a pooled weight gain estimate of 1.71kg for first-year university students from Canada, which is also consistent with our finding [15]. However, in their study, Vadeboncoeur *et al.* detected significant heterogeneity ($I^2 = 86.5\%$) [15]. This is particularly interesting because the reported estimates of overall weight gain in Canadian reports, that include both males and females, have varied from 0.79kg to 1.5kg [15]. With respect to BMI, the increasing trend that we found is also consistent with what has been previously reported by Mifsud *et al.* (2008) and Beaudry *et al.* (2019) [29,30]. It is noteworthy that most studies within this context have primarily investigated only two anthropometric traits (i.e. body weight and BMI), with only a few examining additional obesity parameters such as WC, HC, and WHR. With respect to WC, while our data indicates a significant increase over the academic year, consistent with the findings of Mifsud *et al.,* this result differs from that of Beaudry *et al.* which indicates no significant overall change in WC over time [29,30]. A similar inconsistency is noted between our result for WHR, which indicates no significant change over time, and that of Beaudry *et al.,* which indicates a significant rise over the academic year [29]. Overall, the observed heterogeneity in these findings can be partly attributed to the differences in either demographic factors (e.g. differences in ethnic distribution, baseline BMI distribution, sex ratios, living arrangement, academic programs), or environmental factors (e.g. differences in campus environments and resources available on campus) across the different universities in Canada. Apart from that, this heterogeneity can be further attributed to variation in methodological factors across the different studies (e.g. differences in sampling strategies, measurement strategies).

When examining differences between males and females, our results reveal sexual dimorphism of obesity traits at baseline, with males displaying significantly higher body weight, BMI, WC, HC, and WHR than females. While most Canadian studies within this context have reported consistent sex specific trends at baseline, most prominently with respect to body weight and BMI, formal statistical testing of these baseline differences has been limited [29,30,36,37]. The sexual dimorphism of obesity traits has been extensively studied and can be attributed to fundamental biological differences between men and women across various age windows, such as differences in skeletal size, bone mass density, hormonal activity, and adipose tissue deposition [38-40].

With respect to change in obesity traits, our results indicate that both males and females experience significant gains across all measured obesity traits in first year of university. This indicates that both males and females are susceptible to gains in body weight and adiposity in first year of university. This trend is consistent with what has been previously reported for both male and female Canadian students within this context [15]. However, most notably, when comparing the average magnitude of change between males and females, we found no significant difference for any of the investigated outcomes. Our finding aligns with that of a pooled subgroup analysis of 14 studies, by Vadeboncoeur *et al.*, which also indicates no difference in the amount of weight gained between male and female students [15]. Nevertheless, previous Canadian studies within this context have reported mixed results. While the findings reported by Pliner and Saunders (2007), and Vella-Zarb and Elgar (2010) indicate no sex-based differences with respect to change in BMI and body weight respectively, studies by Mifsud *et al.* (2008), and Beaudry *et al.* (2019) have evidenced significant sex-specific trends for changes in body weight, BMI, WC, and WHR, but not HC [29-32]. Interestingly, all the aforementioned studies have been conducted in Ontario, Canada [29-32]. There are several possible reasons for the observed heterogeneity in findings, ranging from differences in population characteristics and campus environments at each university, to differences in study methodology. For instance, the ethnic distribution in our sample differs considerably from the aforementioned studies. Particularly, the samples in the studies by Mifsud *et al.,* Vella-Zarb RA *et al.,* and Beaudry *et al* are predominantly white Caucasian (>50%), with the latter two including only a modest proportion of Asian and African-Canadian students [29,30,32]. In comparison, our study sample presents a more multiethnic distribution, with the majority of the students being from the East Asian ethnic group, followed by considerable proportion of students from white Caucasian, South Asian, and Middle Eastern ethnic groups. Such factors can have an impact on the observed sex-specific trajectories of weight gain. Hence, our results highlight the importance of conducting multiple studies not only across Canada but also within each province because multiple factors may differentiate university campuses from each other. Ultimately, a systematic review and meta-analysis of studies, with exploration of between-study heterogeneity, may provide conclusive answers on the sexual dimorphism in change of obesity traits in first year, and its associated predictors in the Canadian undergraduate student population.

Our follow up investigation has several strengths including a longitudinal study design, examination of the same obesity parameters as the most recent study by Beaudry *et al*, investigation of participants from the same geographic region (i.e. Ontario), and the use of the same statistical methodology as Beaudry *et al*. Furthermore, given that most Canadian studies so far have primarily examined either body weight or BMI outcomes within this context, our study provides valuable data on additional obesity parameters including WC, HC, and WHR, which is lacking in current literature. Limitations of our study include a modest sample size (N = 245) which is insufficiently powered to detect small effects. We also did not incorporate physical activity as a covariate in our models, as done by Beaudry *et al.* in their study, due to a change in our methods of measurement after the first two waves of recruitment. Additionally, we witnessed a higher attrition rate in our study than Beaudry *et al.* which may have potentially biased our study results. Lastly, we acknowledge that our sample had a significant imbalance in the ratio of male to female participants (approximately 20:80). This imbalance in the sex ratio, along with insufficient power for the detection of small effects, may have prevented us from detecting subtle sex differences in anthropometric change. However, it is important to note that most previous studies within this context have included a disproportionately larger percentage of female participants [15]. Furthermore, previous Canadian reports have shown varied results and our study results are consistent with some of those previous reports.

In conclusion, our data confirms the pattern of ‘freshman’ weight gain in both male and female first-year university students from Ontario, Canada. However, our data does not indicate sex specific differences within this context. Ultimately, our study contributes to the current evidence on this unresolved topic and highlights the need for further studies in this area. It further highlights the importance of accounting for sex and gender in health research to make the findings more applicable to the population. Given the association of obesity with higher morbidity and mortality, understanding the predictors of weight gain in young adulthood may be critical in optimizing the prediction, prevention and treatment of obesity.

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Author's contribution

D.M. designed the study; D.M, T.S., R.E.M., and C.L. conducted research; D.M. and T.S. analyzed the data; T.S. and D.M. wrote the manuscript; R.E.M., and C.L. critically reviewed the manuscript for important intellectual content; D.M. has primary responsibility for final content. All authors read and approved the final manuscript.

Conflict of Interest statement

The authors declare that they have no competing financial interests.

Table 1: Overall trends in first year of university

	Beginning Mean (SD)	**End** Mean (SD)	**Change** MD (95% CI)	**P-value***
Body Weight (kg)	60.42 (11.98)	61.97 (12.39)	1.55 (1.24 – 1.86)	**<0.001**
BMI (kg/m^2)	21.52 (3.34)	22.16 (3.45)	0.65 (0.53 – 0.76)	**<0.001**
Waist Circumference (cm)	75.08 (8.69)	76.27 (8.99)	1.14 (0.63 – 1.66)	**<0.001**
Hip Circumference (cm)	97.18 (7.73)	98.11 (7.44)	0.93 (0.55 – 1.31)	**<0.001**
WHR	0.772 (0.050)	0.776 (0.054)	0.004 (-0.001 – 0.009)	0.083

Data are expressed as mean (SD) and mean difference (95% CI); Abbreviations: BMI, body mass index; WHR, Waist to hip ratio; MD, Mean difference. *****Non-parametric pairwise comparison (non-adjusted analysis of change in outcomes from the beginning to the end of the school year). P-values below 0.05 represented in bold font.

Table 2: Baseline differences between male (n= 48) and female (n=197) students at the beginning of first year in university

Anthropometric Trait		**Beginning of the Year** Mean (SD)	**P-value***
Body Weight (kg)	Males	71.37 (12.68)	**<0.001**
	Females	57.76 (10.18)	
BMI (kg/m^2)	Males	22.62 (3.79)	**0.008**
	Females	21.25 (3.18)	
Waist Circumference (cm)	Males	81.38 (9.28)	**<0.001**
	Females	73.55 (7.83)	
Hip Circumference (cm)	Males	100.56 (7.57)	**<0.001**
	Females	96.36 (7.56)	
WHR	Males	0.808 (0.040)	**<0.001**
	Females	0.763 (0.048)	

All data presented as mean (SD); Abbreviations: BMI, body mass index; WHR, Waist to hip ratio. *****Non-parametric comparison (non-adjusted comparison of males vs. females at baseline). P-values below 0.05 represented in bold font.

Table 3: Sex-specific trends from the beginning to the end of first year in male (n=48) and female (n=197) undergraduate students

		Beginning Mean (SD)	**End** Mean (SD)	**Change** MD (95% CI)	**Time*** p and η2	**Sex*** p and η2	**Interaction*** p and η2
Body Weight1 (kg)[1]	Males	71.37 (12.68)	73.27 (13.12)	1.90 (1.13 – 2.68)	**<0.001;** 0.079	**<0.001;** 0.233	0.270; 0.005
	Females	57.76 (10.18)	59.22 (10.53)	1.46 (1.12 – 1.80)			
BMI[2] (kg/m²)	Males	22.62 (3.79)	23.36 (3.90)	0.74 (0.48 – 1.00)	**<0.001;** 0.064	**0.002;** 0.041	0.640; 0.001
	Females	21.25 (3.18)	21.87 (3.28)	0.62 (0.49 – 0.76)			
Waist Circumference[1] (cm)	Males	81.38 (9.28)	83.14 (9.83)	1.76 (0.66 – 2.85)	**0.005;** 0.033	**<0.001**; 0.147	0.638; 0.001
	Females	73.55 (7.83)	74.59 (7.93)	0.99 (0.41 – 1.58)			
Hip Circumference (cm)	Males	100.56 (7.57)	101.64 (7.19)	1.08 (0.29 – 1.88)	**<0.001;** 0.054	**<0.001;** 0.067	0.506; 0.002
	Females	96.36 (7.56)	97.25 (7.26)	0.89 (0.46 – 1.32)			
WHR[1]	Males	0.808 (0.040)	0.816 (0.052)	0.0085 (-0.0027 – 0.0197)	0.373; 0.003	**<0.001;** 0.140	0.645; 0.001
	Females	0.763 (0.048)	0.767 (0.049)	0.0030 (-0.0024 – 0.0084)			

Data are expressed as mean (SD) and mean difference (95% CI), WC data not collected for one female participant. * Significance from RMANOVA (Group: sex; Time: beginning to end); Rank based inverse normal transformation applied to all obesity traits; P-value threshold of 0.05 used for statistical significance; effect size determined by Partial Eta-Squared (η2)

1. Body weight, WC, and WHR with living arrangement as a covariate, data on living arrangement was not collected for one participant
2. BMI with living arrangement and cohort as covariates

Supplementary Table 1: Sex-specific trends in obesity traits from the beginning to the end of first year by male (n=48) and female (n=197) subgroups

		Beginning Mean (SD)	**End** Mean (SD)	**Change** MD (95% CI)	**Time***
Body Weight (kg)	Males	71.37 (12.68)	73.27 (13.12)	1.90 (1.13 – 2.68)	**<0.001**
	Females	57.76 (10.18)	59.22 (10.53)	1.46 (1.12 – 1.80)	**<0.001**
BMI (kg/m^2)	Males	22.62 (3.79)	23.36 (3.90)	0.74 (0.48 – 1.00)	**<0.001**
	Females	21.25 (3.18)	21.87 (3.28)	0.62 (0.49 – 0.76)	**<0.001**
Waist Circumference (cm)	Males	81.38 (9.28)	83.14 (9.83)	1.76 (0.66 – 2.85)	**0.006**
	Females	73.55 (7.83)	74.59 (7.93)	0.99 (0.41 – 1.58)	**<0.001**
Hip Circumference (cm)	Males	100.56 (7.57)	101.64 (7.19)	1.08 (0.29 – 1.88)	**0.006**
	Females	96.36 (7.56)	97.25 (7.26)	0.89 (0.46 – 1.32)	**<0.001**
WHR	Males	0.808 (0.040)	0.816 (0.052)	0.0085 (-0.0027 – 0.0197)	0.173
	Females	0.763 (0.048)	0.767 (0.049)	0.0030 (-0.0024 – 0.0084)	0.193

Data are expressed as mean (SD) and mean difference (95% CI); WC data not collected for one participant; Abbreviations: BMI, body mass index; WHR, Waist to hip ratio; MD, Mean difference.***Non-parametric pairwise comparison stratified by sex (non-adjusted comparison of change in outcomes from beginning to end of school year in male and female subgroups). P-values below 0.05 represented in bold font.

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CHAPTER 3: The effect of race/ethnicity on obesity traits in first year university students from Canada: the GENEiUS study

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Abstract

Background: Little is known about the impact of race/ethnicity on weight change at university. The objective of this study is to determine if ethnicity has an impact on obesity traits in a multiethnic cohort of first-year students at McMaster University in Ontario, Canada.

Methods: 183 first year students from the three most represented ethnic groups (South Asian, East Asian, and white-Caucasian) in our sample were followed longitudinally with data collected early in the academic year and towards the end of the year. Obesity parameters including body weight, body mass index (BMI), waist and hip circumference, and waist-to-hip ratio (WHR) were analyzed. The Wilcoxon signed-rank test was used for pairwise comparison of traits from the beginning to the end of the year in the absence of adjustments. Additionally, linear regression was used with covariate adjustments to investigate the effect of ethnicity on obesity traits.

Results: A significant increase in weight by 1.49 kg (95% CI: 1.23 – 1.85) was observed over the academic year in the overall sample. This was accompanied by significant gains in BMI, waist and hip circumferences, and WHR. Ethnicity stratified analysis indicated significant increases in all investigated obesity traits among East Asians and all traits, but WHR, in South Asians. In comparison, white-Caucasians only displayed significant increases in weight and BMI. Body weight and hip circumference were significantly lower in East Asians compared to white-Caucasians at baseline. However, East Asians displayed a significantly larger increase in mean BMI and weight compared to white-Caucasians after first-year. South Asians displayed larger waist circumference at baseline compared to East Asians and larger WHR compared to white-Caucasians.

Conclusion: Our findings demonstrate that ethnicity has an impact on obesity traits in first-year university students. Universities should take ethnicity into account while implementing effective obesity prevention programs to promote healthy and active lifestyles for students.

Introduction

Obesity is defined by the World Health Organization (WHO) as abnormal or excessive fat accumulation that presents a risk to health. WHO classifies adults with a body mass index (BMI) over 30 kg/m^2 as being obese. Obesity is a major global health concern that affects 650 million adults and is projected to rise to 1.12 billion by 2030 [1,2]. High-income countries such as Canada experience a higher prevalence of obesity [1]. Approximately 63.1% of Canadians were either overweight or obese in 2018, according to the Canadian Community Health Survey (CCHS). A considerable increase from approximately 23.24% to 31.2% was also noted amongst Canadian individuals aged 18-19 between 2010 and 2018. While education status is negatively correlated with BMI in the general population from high-income countries, young adults with higher education gain more body weight (BW) and are more likely to be obese than those without university education in the United States [3-5]. The "Freshman 15" concept suggests that university undergraduate students gain 15 pounds (6.8 kg) during their first year of post-secondary education, although the average weight gain reported in literature is estimated to be 3-5 pounds (1.4-2.3 kg) [6-8]. The shift from adolescence to adulthood is a critical time period for establishing healthy behaviours and is associated with risk of chronic disorders [9]. Particularly, students who pursue post-secondary education are at increased risk of weight gain than those who do not due to environmental stimuli and psychosocial factors [10,11]. Obesity, especially if developed early in life, is associated with the rapid onset of multiple comorbidities (e.g. depression, sleep disorders, osteoarthritis, dyslipidemia, type 2 diabetes, hypertension, cardiovascular disease, cancers), lower quality of life and premature mortality [9,12]. Treatments such as behavioral and lifestyle interventions, therapeutics, and bariatric surgery exist; however, despite the investment of significant resources in developed countries such as Canada, obesity is difficult to reverse and tends to be a chronic disorder [13,14]. In that context, researching the causes of obesity in young adults is a critical step to improve the prediction, prevention and treatment of obesity in future generations [15,16].

The modern obesity epidemic is explained by major environmental changes such as an unhealthy diet and physical inactivity among many other factors [17]. However, not everybody exposed to an 'obesogenic' environment becomes obese because of inter-individual biological differences (i.e. *in utero* programming, age, sex, gut microbiome, epigenetics and genetics) [16]. Race/ethnicity (hereafter referred to as ethnicity) is a determinant of obesity at the interface of biology and environment [18]. It is defined as a group of people with similar cultural and biological characteristics [18]. Ethnicity has been associated with a differential risk of obesity in diverse multiethnic countries, including Canada [19]. Few studies have focused on the impact of ethnicity on obesity traits in undergraduate students during their freshman year [20-22]. As no data on this topic are available in young adults from Canada, we investigated the impact of ethnicity on the change in obesity traits during the freshman year in a multiethnic prospective cohort of 183 undergraduate students at McMaster University.

Subjects and methods

Participants

Genetic and EnviroNmental Effects on weight in University Students (GENEiUS) is a prospective observational study which investigates the environmental and biological determinants of obesity trait changes in Canadian undergraduate students [15]. As part of this study, undergraduate students from McMaster University (Hamilton, Ontario) were followed every six months over four years, beginning in September of their first year of study. First year undergraduate students enrolled at McMaster University, between the ages of 17 and 25, were eligible to participate in the study. Students were primarily recruited via in-class advertising on main university campus and through social media promotion. Individuals who were pregnant, had previously given birth, or had a medical condition that could have impacted BMI for a long period of time (e.g. bariatric surgery, immobilization from injury) were excluded from the study. Additional details regarding the GENEiUS study have been described previously [15]. Written informed consent was obtained directly from the participants. All methods and procedures for this study were in accordance with the Declaration of Helsinki principles and were reviewed and approved by the Hamilton Integrated Research Ethics Board (REB#0524).

Data collection

Four cohorts of participants (2015–2016, 2016-2017, 2017-2018, 2018-2019) were followed longitudinally with data collected at two study visits: the beginning of their first-year (September/October) and the end of their first-year (March/April). A total of 361 participants were enrolled in the study, of which 245 (68%) completed one year of follow-up. Only 183 participants were analyzed in this investigation (i.e. participants of non-admixed East Asian (N=76), South Asian (N=46), and white-Caucasian (N=61) ethnicities only). A rule of thumb in statistics is that a sample size of at least 30 is sufficiently large to make inferences about the population from the sample [23,24]. Therefore, participants with African, Latin American, Pacific Islander, and Middle-Eastern ethnicities were excluded from the study, because their sample sizes were insufficient. Data analyzed in this study included anthropometrics (body weight (BW), BMI, waist circumference (WC), hip circumference (HC), waist hip ratio (WHR), and demographics (sex, age, ethnicity, living status, type of undergraduate program).

Phenotypes

The obesity trait outcomes including BW, BMI, WC, HC, and WHR were examined. Trained research personnel performed all anthropometric measurements in duplicate to reduce intra-rater variability. Participants wore light clothing and removed shoes before being weighed. BW was measured to the nearest 0.1 kg using a digital scale (Seca, Hamburg, Germany). Height was measured to the nearest 0.1 cm using a portable stadiometer (Seca 225, Hamburg, Germany). WC was measured after a normal exhalation at the midpoint of the last palpable rib and the superior portion of the iliac crest to the nearest 0.1 cm and HC was measured at the widest part of the buttocks to the nearest 0.1 cm using a stretch-resistant tape measure, as previously described by the World Health Organization (WHO) [25]. WHR was calculated as WC divided by HC. BMI (kg/m^2) was calculated by dividing weight by squared height. Demographic information (sex, age, ethnicity, living status, and type of undergraduate program) was collected through online, self-reported questionnaires.

Statistical Methods

All statistical analyses were performed using IBM SPSS Version 25 statistical package. Descriptive analysis was carried out to assess the baseline distribution of traits within the study sample. Data for continuous variables have been reported using means and standard deviations while categorical data have been reported by counts and percentages. Anthropometric data at each time point were screened for potential outliers. Any identified outlying data points were individually cross-checked to determine if they were true outliers, representing participants who truly fell outside the general distribution of our data, or if the outliers were a result of inaccuracies in measurement or data transcription. Data inaccuracies were corrected while all other outliers were left in the dataset. All data were assessed graphically and statistically for normality of distribution prior to analysis. In cases where normality was violated, non-parametric tests were used for pairwise comparisons of obesity traits (i.e. BW, BMI, WC, HC, WHR) at baseline and after 6 months (i.e. beginning and end of the 1st year). The effect of ethnicity on obesity traits at baseline and on the change of parameters by the end of first year were tested using linear regression models with adjustment for covariates including sex, cohort of recruitment (i.e. 2015–2016, 2016-2017, 2017-2018, 2018-2019), and baseline trait values. A rank-based inverse normal transformation was applied in cases where the assumption of normality was violated. Based on the fact that i) the present study is hypothesis-driven; ii) the research questions have been previously tested in literature; iii) tested obesity outcomes are not independent, a Bonferroni correction was not applied in this case as even though it reduces the chance of making type I errors, it can increase the chance of making type II errors [26,27]. Therefore, the level of statistical significance was set at $p < 0.05$ for all tests.

Results

Participant characteristics

Of the 361 participants enrolled in the study, 245 (68%) completed one year of follow up. Only 183 participants were analyzed in this investigation (i.e. participants of East Asian, South Asian, and white-Caucasian ethnicities only). East Asians represented 41.5% of the sample (n = 76), white-Caucasian represented 33.3% (n = 61), and South Asians represented 25.1% (n = 46).

Participants with African, Latin American, Pacific Islander, and Middle-Eastern ethnicities were excluded from the study because their sample sizes were insufficient (n ≤ 20 for all). Participants displayed an average age of 17.84 (SD = 0.49) years at baseline. Male and female participants represented 18.6% (n = 34) and 81.4% (n = 149) of the sample, respectively. 74.3% of the analyzed sample lived in residence on campus (n = 136), 14.8% lived at home with family (n = 27), 10.4% lived in a student house off campus (n = 19) and 0.5% did not report living arrangement status (n=1). Among those who reported their program of study, 89.1% (n=155) reported being enrolled in a science based academic program (e.g. Health Science, Life Science, Kinesiology, Engineering) while 10.9% (n=19) reported being in enrolled a non-science academic program (e.g. Humanities, Business, Arts). At the beginning of the year, 79.2% (n = 145) of the participants had a normal BMI, 12.6% were underweight (n = 23), 7.1% were overweight (n = 13), and 1.1% (n = 2) were obese.

Overall changes in obesity traits in first year of university

Table 1 summarizes the changes in obesity traits during the first year of university in 183 participants. A statistically significant increase across the five investigated obesity parameters was noted between the two time points. The average body weight increased from 59.44 ± 10.04 kg to 60.93 ± 10.31 kg over the year, corresponding to a gain of 1.49 kg (3.28 pounds). An increase in average BMI from 21.32 ± 2.71 kg/m^2 to 21.91 ± 2.77 kg/m^2 was also observed, corresponding to a change of 0.59 ± 0.93 kg/m^2. It is important to note that the average BMI at both time points was below 25 kg/m^2. It signifies that a majority of participants remained within the 'normal weight' category from the beginning to the end of the year. Increases in WC and HC, by 1.34 ± 4.17 cm and 0.88 ± 3.12 cm respectively, were also observed. An increase in WHR from 0.772 ± 0.049 to 0.779 ± 0.054 was also noted between the two time points.

Impact of ethnicity on obesity traits in first year of university

Table 2 summarizes the changes in anthropometric traits during the first year of University in the three ethnic groups. A statistically significant increase across a majority of the obesity parameters was noted between the two time points in the East Asian, white-Caucasian, and South Asian ethnic groups. A notable exception was the absence of a significant increase in the WC and HC of white-Caucasians. Similarly, while East Asians displayed a significant increase in WHR from 0.769 ± 0.045 to 0.781 ± 0.048, no such trends were observed in South Asians and white-Caucasians.

Table 3 compares obesity traits at baseline and change over first year of university between the three analyzed ethnic groups. Body weight was significantly lower in East Asians (57.37 ± 9.85 kg) and South Asians (60.19 ± 11.37 kg) than in white-Caucasians (61.47 ± 8.81 kg) at baseline after adjustment for sex and cohort of recruitment ($p < 0.05$ for both comparisons). Similarly, hip circumference was significantly lower in East Asians (94.97 ± 5.95 cm) compared to white-Caucasians (97.93 ± 5.49 cm) at baseline ($p = 0.007$). On the contrary, East Asians displayed significantly larger increases in BW (1.82 ± 2.08 kg versus 0.94 ± 2.12 kg, $P = 0.026$) and BMI (0.79 ± 0.84 kg/m^2 versus 0.40 ± 0.78 kg/m^2, $P = 0.012$) than white-Caucasians over the academic year. At baseline, waist circumference was significantly higher in South Asians (77.01 ± 9.50) compared to East Asians (73.05 ± 6.80, $p = 0.039$), and WHR was significantly higher in South Asians (0.790 ± 0.052) than white-Caucasians (0.762 ± 0.049, $p = 0.020$).

Discussion

The cohort under investigation is multi-ethnic, consisting of 7 ethnic groups, and reflects the general population of Ontario. However, the over-representation of South Asians and East Asians in the sample may not reflect the percentages currently observed in the general population of Ontario. According to the 2016 Canadian Census by Statistics Canada, 8.9% and 10.7% of Ontario's population are South Asians and East Asians respectively. In comparison, the proportion of South Asians and East Asians in our study sample was 25.1% and 41.5% respectively. The overrepresentation of students from these two ethnic groups can be explained by family structure, household income and parental education among other factors. Krahn & Taylor (2005) noted that first and second generation Canadian students that make up 52.4% of Ontario's population are more likely to pursue post-secondary education due to the "immigrant drive" that suggests higher parental expectations. Educational attainment is also higher in children whose parents have higher education [28]. Additionally, a national survey in Canada of prospective students and their parents show that students representing the visible minority also have higher educational aspirations [29].

At baseline, the sample had an average weight of 59.44 kg and an average BMI of 21.32, which is within the normal range of 18.50-24.99 according to the WHO guidelines [30]. By the end of the year, participants displayed significant weight gain of 1.49 kg or 3.28 pounds. This is consistent with previous meta-analyses that have found that freshman gain 3-5 pounds (1.4-2.3kg) on average. Beaudry et al (2019) also found that males and females gained 3.8 kg and 1.8 kg respectively at Brock University in Ontario [31]. This confirms that university environment may be "obesogenic" for young adults across Ontario as well as in other provinces across Canada. The Freshman 15 phenomenon, better known as the Freshman 5 phenomenon, can be explained by increased stress, increased alcohol and fast-food consumption, decreased physical activity and lack of sleep [7,10,32].

South Asians displayed a significantly higher WHR at baseline compared to white-Caucasians. This is consistent with previous studies that have established that South Asian adults have a higher propensity to gain abdominal and visceral fat than their white-Caucasian counterparts [33-35]. This is particularly concerning because accumulation of fat in the abdominal area is associated with an increased risk for cardio-metabolic diseases such as type 2 diabetes and coronary heart disease [36]. Our findings are also compatible with the observation that South Asians have increased abdominal visceral fat despite having a healthy BMI, and demonstrate that abdominal fat deposition in South Asians starts early in life likely due to biological factors (e.g. *in utero* environment, genetics, epigenetics). In comparison, East Asians in our sample displayed lower BW, WC and HC at inclusion. These lower values observed at baseline can be attributed to biological (e.g. *in utero* environment, genetics, epigenetics, microbiome) and environmental factors. Particularly, East Asian diet patterns have been found to be associated with a lower risk of abdominal obesity. Their diets are characterized by a high intake of whole grains and vegetables, thus a higher intake of fibre, and a decreased risk of obesity [37]. It should be noted that although East Asians have a lower BMI, they have a higher percentage of body fat compared to white-Caucasians, similar to South Asians [38]. Interestingly, when examining change over the academic year, East Asians displayed larger increases in most traits compared to the other ethnic groups. This suggests that they are particularly at risk of weight gain and unhealthy fat deposition during the transition to university. The significant weight gain observed may be attributed to the change in diet, increased sedentary behaviours, increased stress, and living away from home accompanied by less parental supervision. Their traditional diet does not necessarily continue on campus.

Instead, a Westernized diet characterized by high intake of fat and low intake of fibre is undertaken as a result of the campus environment [37].

One of the strengths of this study is that there are not very many studies on this particular topic as the effect of ethnicity on obesity traits has never been investigated in this population group in Ontario. The study is also longitudinal in nature allowing for stronger inferences regarding predictors of incident weight change in first year of university. Moreover, we further investigated additional obesity parameters such as WHR, WC and HC to assess adiposity. Finally, the study was conducted in Ontario, a highly diverse population, which is ideal for investigating the effect of different ethnicities on obesity traits.

There are some limitations of the GENEiUS Study that should be noted. The study has a modest sample size and hence particular ethnic groups were not accounted for. Our study also exhibits gender bias as more than three fourths of the sample consists of women; however, this trend is commonly seen in epidemiological studies. Apart from that, participant attrition in this case may have also potentially biased our results. Lastly, it is important to note that ethnicity was self-reported.

In conclusion, all three ethnic groups experienced significant weight gain. A significant increase in all five obesity traits was only observed in East Asians despite their low baseline values relative to the other ethnic groups. This indicates an increased risk for unhealthy fat deposition in response to an obesity-prone environment. At baseline, South Asians started with a relatively high BMI and ended with a relatively high BMI, however, the increase was less compared to East Asians. White-Caucasians maintained a BMI higher than East Asians and lower than South Asians, and experienced the least change in all five obesity traits at the end of the first year of university.

Our research can help design effective interventions with ethnic-specific guidelines, especially as individuals of different ethnicities may appear to be healthy with normal BMI levels, but have a higher than normal percentage of body fat. Understanding how ethnicity impacts body weight changes in young adults is critical to combat the rise of adult obesity.

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Author's contribution

D.M. designed the study; D.M, B.M., T.S., R.E.M., and C.L. conducted research; D.M. and T.S. analyzed the data; B.M., T.S., and D.M. wrote the manuscript; R.E.M., and C.L. critically reviewed the manuscript for important intellectual content; D.M. has primary responsibility for final content. All authors read and approved the final manuscript.

Conflict of Interest statement

The authors declare that they have no competing financial interests.

Table 1: Overall Trends in First Year of University

	Beginning Mean (SD)	**End** Mean (SD)	**Change** MD (95% CI)	**P-value***
Body Weight (kg)	59.44 (10.04)	60.93 (10.31)	1.49 (1.23 – 1.85)	**<0.001**
BMI (kg/m^2)	21.32 (2.71)	21.91 (2.77)	0.59 (0.46 – 0.73)	**<0.001**
Waist Circumference (cm)	74.59 (7.62)	75.93 (8.01)	1.34 (0.73 – 1.95)	**<0.001**
Hip Circumference (cm)	96.54 (6.42)	97.42 (5.99)	0.88 (0.42 – 1.33)	**<0.001**
WHR	0.772 (0.049)	0.779 (0.054)	0.007 (0.001 – 0.012)	**0.017**

Data are expressed as mean (SD) and mean difference (95% CI); Abbreviations: BMI, body mass index; WHR, Waist to hip ratio; MD, Mean difference. ***Non-parametric pairwise comparison (non-adjusted comparison of change in outcomes from beginning to end of school year). P-values below 0.05 represented in bold font.

Table 2: Ethnicity specific Trends by East Asian (n=76), white-Caucasian (n=61), and South Asian (n=46) subgroups

Anthropometric Trait	**Ethnicity**	**Beginning** Mean (SD)	**End** Mean (SD)	**Change** MD (95% CI)	**P-value***
Body Weight (kg)	East Asian	57.37 (9.85)	59.19 (9.67)	1.82 (1.35 – 2.30)	**<0.001**
	Caucasian	61.47 (8.81)	62.41 (9.20)	0.94 (0.39 – 1.48)	**0.002**
	South Asian	60.19 (11.37)	61.85 (12.36)	1.67 (0.69 – 2.64)	**0.001**
BMI (kg/m^2)	East Asian	21.05 (2.45)	21.85 (2.40)	0.79 (0.60 – 0.99)	**<0.001**
	Caucasian	21.34 (2.17)	21.74 (2.29)	0.40 (0.20 – 0.60)	**<0.001**
	South Asian	21.72 (3.62)	22.25 (3.77)	0.53 (0.18 – 0.88)	**0.003**
Waist Circumference (cm)	East Asian	73.05 (6.80)	74.90 (6.82)	1.84 (0.99 – 2.70)	**<0.001**
	Caucasian	74.66 (6.55)	75.32 (6.75)	0.65 (-0.22 – 1.53)	0.233
	South Asian	77.01 (9.50)	78.44 (10.59)	1.43 (-0.21 – 3.07)	**0.050**
Hip Circumference (cm)	East Asian	94.97 (5.95)	95.88 (5.36)	0.91 (0.22 – 1.60)	**0.014**
	Caucasian	97.93 (5.49)	98.60 (4.93)	0.67 (-0.13 – 1.47)	0.135
	South Asian	97.29 (7.75)	98.39 (7.61)	1.10 (0.12 – 2.09)	**0.036**
WHR	East Asian	0.769 (0.045)	0.781 (0.048)	0.012 (0.003 – 0.021)	**0.004**
	Caucasian	0.762 (0.049)	0.763(0.050)	0.001 (-0.008 – 0.011)	0.866
	South Asian	0.790 (0.052)	0.795 (0.062)	0.005(-0.008 – 0.017)	0.481

Data are expressed as mean (SD) and mean difference (95% CI); Abbreviations: BMI, body mass index; WHR, Waist to hip ratio; MD, Mean difference. *Non-parametric pairwise comparison by ethnicity subgroup (non-adjusted comparison of change in outcomes from beginning to end of school year). P-values below 0.05 represented in bold font.

Table 3: Association between ethnicity and obesity traits in first year of university

		East Asian vs. Caucasian β (Std. Error) and p-value	**South Asian vs. Caucasian** β (Std. Error) and p-value	**South Asian vs. East Asian** β (Std. Error) and p-value
Body Weight (kg)	Baseline[1]	-0.460 (0.152); **0.003**	-0.404 (0.174); **0.021**	0.056 (0.168); 0.737
	Change[2]	0.399 (0.178); **0.026**	0.300 (0.202); 0.140	-0.100 (0.193); 0.607
BMI (kg/m^2)	Baseline[1]	-0.107 (0.174); 0.541	-0.033 (0.200); 0.870	0.074 (0.193); 0.702
	Change[2]	0.433 (0.170); **0.012**	0.157 (0.195); 0.421	-0.275 (0.188); 0.145
Waist Circumference (cm)	Baseline[1]	-0.278 (0.162); 0.089	0.095 (0.186); 0.610	0.373 (0.180); **0.039**
	Change[2]	0.315 (0.172); 0.069	0.225 (0.196); 0.254	-0.090 (0.192); 0.640
Hip Circumference (cm)	Baseline[1]	-0.460 (0.168); **0.007**	-0.198 (0.192); 0.305	0.262 (0.186); 0.160
	Change[2]	-0.110 (0.164); 0.503	0.019 (0.185); 0.918	0.129 (0.179); 0.470
WHR	Baseline[1]	0.092 (0.160); 0.564	0.429 (0.183); **0.020**	0.337 (0.177); 0.059
	Change[3]	0.291 (0.154); 0.061	0.207 (0.177); 0.244	-0.084 (0.171); 0.625

[1]Linear regression with inverse normal rank transformation, adjusted for sex and cohort; [2]Linear regression with inverse normal rank transformation, adjusted for sex, cohort and baseline values; [3]Linear regression with inverse normal rank transformation, adjusted for sex, cohort, baseline WHR, baseline BMI, and BMI Change; Abbreviations: BMI, body mass index; WHR, Waist to hip ratio.

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CHAPTER 4: The effect of living arrangement on obesity traits in first-year university students from Canada: the GENEiUS study

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ABSTRACT

Background: The transition to university often involves a change in living arrangement for many first-year students. While weight gain during first year of university has been well documented, Canadian literature on the impact of living arrangement within this context is limited. The objective of this investigation was to explore the effect of living arrangement on obesity traits in first-year university students from Ontario, Canada.

Methods: 244 first-year undergraduate students were followed longitudinally with data collected early in the academic year and towards the end of the year. Obesity parameters including weight, waist and hip circumference, body mass index (BMI), and waist-to-hip ratio (WHR) were examined. The Wilcoxon signed-rank test was used for pairwise comparison of traits from the beginning to end the year in the absence of adjustments. Additionally, linear regression models with covariate adjustments were used to investigate effect of the type of living arrangement (i.e. on-campus, off-campus, or family home) on the aforementioned obesity traits.

Results: In the overall sample, a significant weight increase of 1.55kg (95% CI: 1.24 – 1.86) was observed over the school year ($p<0.001$), which was also accompanied by significant gains in BMI, and waist and hip circumferences ($p<0.001$). At baseline, no significant differences were found between people living on-campus, off-campus, and at home with family. Stratified analysis of change by type of living arrangement indicated significant gains across all traits among students living on-campus ($p<0.05$), and significant gains in weight and BMI among students living at home with family. Additionally, a comparison between living arrangements revealed that students living on campus experienced significantly larger gains in weight and BMI compared to students living off-campus ($p<0.05$).

Conclusion: Our findings indicate that living arrangement is associated with different weight gain trajectories in first-year university students.

INTRODUCTION

The rising prevalence of overweight and obesity in the Canadian population is a cause for concern. According to Statistics Canada, 26.8% of the Canadian population was affected by obesity in 2018. In North America, the greatest increase in the number of individuals with obesity has been among those aged 18 to 29, with the transition from adolescence to adulthood being implicated as a sensitive time for dramatic and inappropriate weight gain [1]. Young adults have also experienced the greatest increase in the incidence of overweight and obesity in recent years, compared to adults in other age groups [2,3]. While education status is negatively correlated with body mass index (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 United States [1,4,5]. An American study reported that 69% of university students experienced an increase in BMI between the beginning of their first year at university and the end of their second year [6]. In the university student population, obesity affects 14% of American undergraduate students [7]. 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 [8,9]. 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 [10-15].

The "Freshman 15" is the belief that incoming university student gain 15lb (~6.8kg) during their freshman year, yet the evidence for this is limited [16]. Previous studies have found this to be an exaggeration, estimating an average body weight (BW) increase of 3 to 5 lbs (1.4 to 2.3 kg) [17-19]. These observed BW changes may reflect underlying modifications in environmental factors, lifestyle habits and other health-related behaviours during the transition from secondary school to university[20].

The transition to university often involves a change in living arrangement for many first-year students. While some incoming students can commute to university for classes while still living at home with their families, others who live relatively farther from the university have to relocate and find temporary accommodation closer to the university for the duration of their studies. Generally, most first-year year students who relocate choose between one of two main options: i) applying to live in university residence on campus ii) finding shared rental accommodation near the university campus. In most cases, these arrangements involve living away from family and living with other students. Some previous studies have suggested that living arrangement can have a significant impact on BW and BMI during first year of university [21-23]. However, the number of Canadian studies within this context is relatively limited [21-23]. Furthermore, previous Canadian studies have only examined the broader differences between 'on-campus' and 'off-campus' living arrangements, and have not explored specific differences in weight change between the three most common living arrangement options (on-campus, off-campus, or family home) available to first-year university students[21-23]. This prompted us to study the effect of living arrangement on five obesity traits in a multiethnic sample of 244 undergraduate students from McMaster University in Hamilton, Ontario (Canada).

Subjects and methods

Participants

Genetic and EnviroNmental Effects on weight in University Students (GENEiUS) is a prospective observational study which investigates the environmental and biological determinants of obesity trait changes in Canadian undergraduate students[24]. As of part of this study, undergraduate students from McMaster University (Hamilton, Ontario) are followed every six months over four years, beginning in September of their first year of study. First-year undergraduate students enrolled at McMaster University, between the ages of 17 and 25, were eligible to participate in the study and were primarily recruited via in-class advertising on the main university campus and through social media promotion. Individuals who were pregnant, had previously given birth, or had a medical condition which could have impacted their BMI for a long period of time (e.g. bariatric surgery, immobilization from injury) were excluded from the study. Additional details regarding the GENEiUS study have been described previously [24]. Written informed consent was obtained directly from the participants. All methods and procedures for this study were in accordance with the Declaration of Helsinki principles and were reviewed and approved by the Hamilton Integrated Research Ethics Board (REB#0524).

Data collection

Four cohorts of participants (2015–2016, 2016-2017, 2017-2018, 2018-2019) were followed longitudinally with data collected at two study visits: : one towards the beginning of their first-year (September/October) and one towards the end of their first-year (March/April). A total of 361 participants were enrolled in the study between 2015 and 2018, of which 245 (68%) completed one year of follow-up (i.e. completed the first baseline visit around September/October and a second follow-up visit in March/April) between 2016 and 2019. Only 244 participants were analyzed in this investigation (i.e. only those participants who reported their living/housing arrangement status at baseline). Data analyzed in this study included anthropometric data (i.e. BW, BMI, waist circumference (WC), hip circumference (HC), waist hip ratio (WHR)), and demographic characteristics (i.e. sex, age, ethnicity, living arrangement, type of undergraduate program). Trained research personnel performed all anthropometric measurements in duplicate to reduce intra-rater variability. Participants wore light clothing and removed shoes before being weighed. BW was measured to the nearest 0.1 kg using a digital scale (Seca, Hamburg, Germany). Height was measured to the nearest 0.1 cm using a portable stadiometer (Seca 225, Hamburg, Germany). WC was measured after a normal exhalation at the midpoint of the last palpable rib and the superior portion of the iliac crest to the nearest 0.1 cm, and HC was measured at the widest part of the buttocks to the nearest 0.1 cm using a stretch-resistant tape measure, as recommended by the World Health Organization (WHO) [25]. WHR was calculated as WC divided by HC. BMI (kg/m^2) was calculated by dividing weight by squared height. Demographics information was collected through online, self-reported questionnaires.

Statistical Methods

All statistical analyses were performed using IBM SPSS Version 25 statistical package. Descriptive analysis was carried out to assess the baseline distribution of traits within the study sample. Data for continuous variables have been reported using means and standard deviations while categorical data have been reported by counts and percentages. Anthropometric data at each time point were screened for potential outliers. Any identified outlying data points were individually cross-checked to determine if they were true outliers, representing participants who truly fell outside the general distribution of our data, or if the outliers were a result of inaccuracies in measurement or data transcription. Data inaccuracies were corrected while all other outliers were left in the dataset. All data were assessed graphically and statistically for normality of distribution prior to analysis. Pairwise tests were performed to evaluate change in obesity traits from the beginning to the end of the academic year. In cases where the assumption of normality was violated, the non-parametric alternative (i.e. the Wilcoxon signed-rank test) was used for pairwise comparison of obesity outcomes. The effect of living arrangement on obesity traits at baseline and change by the end of first year were analyzed using linear regression models with adjustment for covariates including sex, cohort of entry (i.e. 2015–2016, 2016-2017, 2017-2018, 2018-2019), and baseline trait values. A rank-based inverse normal transformation was applied to all outcome variables deviating from normality. In our analysis of association, we examined living arrangement in two different ways. Firstly, we examined living arrangement as a ternary variable with three different response categories (i.e. living in university residence, living in student rental housing off-campus, or living at home with family) to evaluate the specific differences between the three main living arrangements options available to most first-year university students. In addition to that, given that a relatively smaller proportion of students in our sample lived in either off-campus rental housing or at home with family, we combined these two categories into one mutual cateogry, in order to increase the relative sample size for comparison, based on the fact that both these categories represent an 'off-campus' living environment. Subsequently, as part a secondary analysis, we examined living arrangement as a binary variable to investigate the differences between 'on-campus' and 'off-campus' living arrangements. Given that i) the present study is hypothesis-driven; ii) the research questions have been previously tested in literature; iii) the tested obesity outcomes are not independent, a Bonferroni correction was not applied, as even though it reduces the chance of making type I errors, it can increase the chance of making type II errors [26,27]. Therefore, the level of statistical significance was set at $p < 0.05$ for all tests.

Results

Participant characteristics

Three hundred and sixty one participants were enrolled into the study of which 245 (68%) completed one year of follow up. Only 244 participants were analyzed in this investigation (i.e. only those participants who reported their living arrangement at baseline). The average follow up time between the baseline visit, early in the academic year, and the follow up visit, towards the end of the year, was 21.6 (SD = 2.18) weeks. Participants displayed an average age of 17.87 (SD = 0.48) years. Female participants represented 80.7% of the sample (n=197). In terms of living arrangement, at baseline 69.7% of the participants reported living in university residence on campus (n = 170), 19.7% reported living at home with family (n = 48), and 10.7% reported living away from family in off-campus student rental housing (n = 26). Participants of East Asian ethnicity represented 31.1% of the sample (n = 76), white-Caucasian participants represented 25% (n = 61), participants of South Asian ethnicity represented 18.4% (n = 45), participants with mixed ethnic background represented 12.7% (n = 31), participants with Middle Eastern background represented 7% (n=17), and participants belonging to other ethnic groups including African, Latin American, Pacific Islander, and Canadian Indigenous collectively represented 5.7% (n=14) of the sample. Out of the participants who reported their program of study, 86.1% reported being enrolled in a science-based academic program (e.g. Health Science, Life Science, Kinesiology, Engineering), while 13.9% reported being enrolled in a non-science academic program (e.g. Humanities, Business, Arts).

Overall trends in obesity traits in first year of university

At baseline, the mean BW, BMI, WC, HC, and WHR for the overall sample was 60.43kg (SD = 12.00), 21.52 kg/m^2 (SD = 3.35), 75.12cm (SD = 8.69), 97.19cm (SD = 7.75), and 0.772 (SD = 0.049) respectively. In terms of their weight status category at baseline, 78.3% (n=191) of the participants were normal weight, 12.3% were underweight (n=30), 6.6% were overweight (n=16), and 2.9% (n=7) were obese. By the end of the academic year, significant increases in BW (1.55 ± 2.47 kg, p<0.001), BMI (0.65 ± 0.95 kg/m^2, p<0.001), WC (1.14 ± 4.09 cm, p<0.001), and HC (0.93 ± 3.00 cm, p<0.001), but not WHR (0.004 ± 0.039, p=0.086), were noted in the overall sample, when compared to baseline. Table 1 summarizes the aggregated data at each time point for all investigated obesity traits. The average rate of weight change over the academic year was +0.072 kg/week (SD = 0.12). Some previous studies have deemed a 5% change in overall body weight to be clinically meaningful with a weight loss of at least 5% being associated with improvements in blood pressure, HDL cholesterol, depression, and overall quality of life as well as reduction in health care costs [28]. In our sample, 28.7% (n = 70) of the participants experienced clinically meaningful weight gain, based on the 5% weight change threshold, with the average weight gain among these participants being 3.65 ± 3.02 kg. Lastly, in our overall sample, only 2.9% (n = 7) of the participants gained 15 pounds or more, as predicted by the popularized theory of 'Freshman 15'.

Trends in obesity traits based on living arrangement in first year of university

At the beginning of the academic year, there were no significant baseline differences in BW, BMI, WC, HC, and WHR between participants living in university residence on campus, those living away from family in off-campus student rental housing, and those living at home with family (p >

0.05 for all comparisons). When examining change from the beginning to the end of the academic year, significant increases were noted across all investigated traits among students living in university residence ($p < 0.05$ for all traits). In comparison, while students living away from family in off-campus housing displayed modest gains over the year across all parameters, none reached the threshold of statistical significance ($p > 0.05$ for all traits). Among students living at home with family, significant changes were observed in only BW and BMI by the end of the year relative to baseline ($p<0.05$ for both traits). Table 2 presents the trends in the investigated obesity traits from the beginning to the end of the academic year categorized by living arrangement.

Table 3 compares the differences in obesity parameters at baseline and change over first year of university between the different living arrangements. In this case, we analyzed living arrangement as a ternary variable, to evaluate the differences between the three specific types of living arrangements, as well as a binary variable to evaluate overall differences between 'on-campus' and 'off-campus' living arrangements. Given that a relatively lower number of participants in our sample lived in either off-campus student housing (n = 26) or at home with family (n = 48), we combined these two 'off-campus' living arrangements into one mutual category (n = 74) to boost the sample size for comparison, and subsequently evaluated the overall differences between 'on-campus' and 'off-campus' living environments.

When considering the specific type of living arrangement (i.e. university residence, off-campus student housing, family home), living in university residence was found to be significantly associated with larger changes in BW (1.86 ± 2.27 kg) and BMI (0.76 ± 0.87 kg/m^2), after adjustment for sex, cohort, and baseline values, when compared to both living at home with family

(BW: 0.96 ± 2.76 kg, p = 0.019; BMI: 0.45 ± 1.07 kg/m^2, p = 0.015), and living in off-campus student rental housing (BW: 0.61 ± 2.76 kg, p = 0.020; BMI: 0.26 ± 1.07, p = 0.007). Interestingly, in this case, the average weight gain among students living in university residence was almost two times as much as students living at home with family (1.86kg vs. 0.96kg), and almost three times as much as students living in off-campus housing away from family (1.86kg vs. 0.61kg). This trend was also observed with respect to the average change in BMI. In contrast, living in university residence was not significantly associated with increased changes in HC and WHR, when compared to both living at home and living in off-campus student housing. With respect to change in WC, while a significant association was noted when comparing living in university residence to living at-home (p = 0.046), no significant difference was found between the former and off-campus student housing. Lastly, when comparing off-campus student housing to at-home living, no significant differences in change were noted for any of the investigated obesity parameters.

When considering binary living arrangement status (i.e. living on-campus *vs.* off-campus), living on-campus was significantly associated with increased change in BW and BMI, with adjustment for sex, cohort, and baseline values, when compared to living off campus (BW: 1.86 ± 2.27 kg *vs.* 0.83 ± 2.75 kg, p = 0.003; BMI: 0.76 ± 0.87 kg/m^2 *vs.* 0.38 ± 1.06 kg/m^2, p = 0.001). In comparison, there was no significant association found between living on-campus and change in WC, HC, and WHR relative to living off campus. Notably, in this case, students living on-campus gained approximately twice as much weight and BMI as students living off-campus.

Discussion

In this investigation, we examined the effect of living arrangement on obesity traits in first year of university. The investigation brought forth several important results. In terms of overall sample trends, our results suggest that, on average, first-year students experience significant gains in BW, BMI, WC, and HC, but not WHR, by the end of the school year compared to early on in the year. When examining specific trends by living arrangement, we found no significant differences at baseline between the participants living in the three different types of living arrangements for any of the investigated traits. However, when examining the patterns of change within the three separate living arrangement subgroups, we found that only the students living in university residence displayed significant gains across all five investigated traits by the end of the academic year relative to baseline. In comparison, students living at home with family displayed significant gains in only BW and BMI, while students living in off-campus student housing displayed no significant changes over the academic year in any of the investigated traits. Lastly, when comparing the change observed between the different types of living arrangements, we found that living in university residence was associated with an increased change in BW and BMI, when compared to living in either type of off-campus living arrangement, and an increased change in WC when compared to only living at home with family. Notably, our data suggests that first-year students living in university residence gain approximately twice as much weight and BMI as students living at home, and almost thrice as much weight and BMI as students living in off-campus student rental housing. This pattern was consistent when examining living arrangement as a binary factor wherein students living on-campus gained approximately twice as much weight as students living off-campus.

In terms of general trends, an average weight gain of 1.55kg (3.4 pounds) was noted in our overall sample. While the observed overall mean weight change in our sample is modest compared to the popularized estimate of 15-pound (6.8 kg) in the media, our result is comparable to the overall pooled estimates of 1.36 kg and 1.75kg previously reported by Vadeboncoeur *et al.* (2015), and Vella-Zarb and Elgar (2009) respectively.

When examining living arrangement options among first-year university students in Canada, it is important to understand the underlying context in terms of how students choose which universities to apply to, and how that ultimately affects their choice of living arrangement. Generally, for many students in Canada, going to university away from home in another city or sometimes even in another province, is not an uncommon practice. There are different potential reasons for this. One of the contributing factors is the geographic location. Considering the province of Ontario as a case in point, there are a total of 21 recognized universities in the province currently with campuses in only 30 communities. Hence, many students who live far from these locations have to travel or relocate temporarily to pursue post-secondary education. Another important factor that often plays a role is student preferences regarding undergraduate programs or institutions. In some cases, certain programs are only offered by certain universities, or alternatively, students see more value in enrolling at a particular university based on their educational goals and the opportunities available at that institution. This is an important consideration for many students and influences which universities and programs students choose to apply to for their undergraduate studies. Last but not least, the university admission process is a selective one in Canada, so students are not automatically accepted to a university that is closer to their home. While the aforementioned factors play a role in the choices that many students make within this context, it is important note that these decisions can be further influenced by additional factors such as socioeconomic status, accessibility, and family needs. Nevertheless, these reasons partly explain why Canadian students tend to apply to different universities, whether close to home or farther away, and that decision ultimately influences their choice of living arrangement.

For students who can attend a post-secondary institution either in their hometown or relatively close to their hometown, living with family and commuting to school from home is an accessible option. However, for students who are originally from places that are farther away from the university, such as international students, out of province students, or even students living in cities far from the institution, relocating to a place that is closer to the university campus is the only viable option. In such cases, many incoming first-year students may prefer living in university residence for a number of potential reasons. Given their lack of familiarity with the university lifestyle, the local surroundings, and in some cases even the local culture (for international students), university residence can be a relatively secured option for incoming first-year students as it entails a large number of resources and supports that may not be easily available or accessible outside the campus environment. Students living in university residence benefit from the convenience of living on campus where they are in close proximity to other first-year students, to their classes, and to a range of additional facilities such as the school cafeterias and other resource centres. Some previous Canadian reports within this context have indicated that living in residence during first year can help students develop new friendships and can also have a positive impact on overall academic outcomes [29,30]. Notably, however, while the cost of living in university residence varies across Canada, it is generally a relatively expensive option.

Among students who relocate for their university education, some choose to live in shared renal accommodation in close proximity to the university campus. However, this is a relatively less common choice among incoming first-year students and/or their families as it does not involve the supports and resources that are usually available in university housing. This trend was also observed in our sample wherein the proportion of students living away from family in off-campus housing was the smallest out of the three living arrangement options. Nevertheless, there are different potential reasons as to why students may choose this living arrangement. Firstly, given that living in residence is relatively expensive, there may be a financial consideration for some of the students who opt for off-campus housing, which can be a relatively cheaper option as rent and other expenses can be shared with roommates to lower cost. Alternatively, in some cases, students who relocate do not necessarily have a choice because of the lack of available spots in university residence, while sometimes it is simply a matter of personal preference. Altogether, these are some of the factors that generally influence the choice of living arrangement in first-year of university, and also potentially explains the disproportionality observed in the distribution of students across the three major living arrangement options.

When examining change in obesity traits by living arrangement, we found that students living on-campus displayed significant gains across all investigated traits over the academic year, and exhibited significantly higher gains in BW and BMI compared to students in either type of off-campus living arrangement. These results have important implications as they indicate that first-year students are not all equally prone to weight gain and that instead susceptibility may vary based on the type of living arrangement.

Our findings are consistent with prior Canadian reports within this context. For instance, in a previous investigation, Vella-Zarb and Elgar (2010) found that students living on campus gain significantly more weight than students living off-campus [23]. Similarly, Pliner and Saunders (2008) found that students living on campus, and particularly those with restrained eating patterns, experience larger gains in BMI than their counterparts living at home, while Provencher et al. (2009) found a significant difference in weight change between male students living in residence and those commuting from home [21,22]. There are several possible explanations for the observed results. Living in university residence has been associated with increased accessibility to food, increased food storage within student dormitory rooms, lack of healthy food options, and overall unhealthy eating patterns [31-34]. Additionally, in several Canadian universities, purchasing a meal plan is compulsory when living in residence. This requirement mandates students to set aside a certain amount of money at the beginning of the year that can be subsequently used for purchasing food on campus during the year. In some cases, this money cannot roll over to the next year or be transferred back to the students. As such, students are sometimes compelled to purchase food excessively in order to use up all their meal plan money by the end of the school year, and hence consume more than they may otherwise. Altogether, we postulate that a combination of these aforementioned factors pertaining to unhealthy food choices on campus and increased food consumption due to mandated meal plans may be critical contributors to the weight gain observed among students living in residence [35]. This may not be surprising as excessive energy intake has been considered to be one of the primary drivers of the current obesity pandemic [36,37]. Interestingly, however, in their investigation, Pliner and Saunders (2008) found that students in university residence with a restrained dietary regime gain the most weight [21]. This finding is paradoxical and ultimately highlights the need to further explore specific eating behaviors within this population to understand how eating patterns in university explain the change in obesity traits during first year of university. Furthermore, it also suggests that the effect of living arrangement on obesity traits may be influenced by additional variables. For instance, when considering other contributing factors within this context, previous studies have also found that having roommates or living with peers can influence different health related behaviors including the choice of meal plan, smoking, alcohol consumption, and overall tendency to lose or maintain weight [38-41]. Ultimately, this collectively highlights some of the factors that potentially make the residence living environment more obesogenic than the off-campus alternatives, and may potentially explain why first-year students living on-campus in university residence gain more weight than their counterparts in living off-campus.

When considering students living off-campus, a significant increase in BW and BMI was observed over the academic year among students living at home with family. There may be a few different explanations for this observed trend. Firstly, students who live at home and commute to university on a daily basis for classes tend to typically spend a large amount of their time on campus, as they do not prefer going back home during breaks between classes due to the extensive commute time. As such, we postulate that while these students spend a large amount of time on campus, many of them purchase food on campus where unhealthier food options are more accessible. When considering cost of purchasing food, it is commonly known that healthier food options are more expensive. A systematic review and meta-analysis by Rao et al. (2013) found that eating healthy can cost up to $1.50 more per person per day than eating unhealthy [42]. Hence, in such cases, some students may be more likely to consume fattening foods as compared to healthier foods, which may partly explain the increase in weight and BMI observed in this group. Notably, however, in comparison to students living on campus, students living at home with family do not solely rely on food from cafeterias on campus and have the opportunity to consume more home-cooked meals, which may partly explain why they do not gain as much weight as students living in residence. Apart from that, increased commuting time may be an additional factor that contributes to the significant weight gain among students living at home. For many students who commute from home, the commute time can be upwards of an hour. This can have a significant impact on their physical and mental health and ultimately influence their weight as commuting time has been linked with decreased levels of life satisfaction, decreased physical activity, decreased sleep quality, and increased overall stress and fatigue [43,44].

Lastly, in our sample, the students living away from family in off-campus housing displayed no significant changes over the academic year in any of the investigated traits. One potential explanation for this may be that students living independently in off-campus accommodation are more likely to cook at home, as supposed to purchasing food from campus regularly. Additionally, many students living in such independent off-campus arrangements have a higher degree of active commute as many of them generally commute to campus by walking or bicycling. This can have a considerable impact as active commuting has been shown to be associated with decreased BMI and decreased odds of being obese or overweight [45,46].

Strengths of this study include a longitudinal study design and investigation of multiple obesity traits. Additionally, to the best of our knowledge, this is the first Canadian study to comprehensively investigate the effect of the three most common types of living arrangements in first-year of university on a wide variety of obesity traits. Our study also has several limitations.

Firstly, we have a modest sample size (N = 244) which is insufficiently powered to detect subtle effects. Additionally, our sample only included 26 participants who lived in off-campus student housing and as such the sample size for this group also may have been insufficient to draw inferences. However, in our investigation, we included comparative analysis of on-campus versus off-campus living environments, which combined the two groups living off-campus, and hence provided a relatively lager sample size for comparison. Lastly, our study was also limited by a relatively high attrition rate which may have potentially biased the results.

In conclusion, our data provides support for the trend of weight gain among first-year university students from Ontario, Canada, and further implicates the type of living arrangement as an important predictor within this context. Ultimately, these results suggest that being in a particular living arrangement influences susceptibility to weight gain in first year of university, and highlight the need of taking living arrangement into consideration for prevention and mitigation efforts. These findings may also be critical in prompting further research in this area to understand the underlying factors that make certain living arrangements more obesogenic than others. Community based interventions in university residence have been previously shown to be effective in promoting physical activity and fruit and vegetable consumption among residents [47]. As such, given that increased BMI during young adulthood has been linked to chronic obesity later in life, understanding the predictors of weight gain in young adults at university may be a critical step forward towards effective prevention of obesity in the next generation. Further large-scale studies should be conducted to confirm these findings.

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Author's contribution

D.M. designed the study; D.M, T.S., R.E.M., and C.L. conducted research; T.S. and D.M. analyzed the data; T.S. and D.M. wrote the manuscript; R.E.M., and C.L. critically reviewed the manuscript for important intellectual content; D.M. has primary responsibility for final content. All authors read and approved the final manuscript.

Conflict of Interest statement

The authors declare that they have no competing financial interests.

Table 1: Overall trends in first year of university

	Beginning Mean (SD)	**End** Mean (SD)	**Change** MD (95% CI)	**P-value***
Body Weight (kg)	60.43 (12.00)	61.98 (12.41)	1.55 (1.24 – 1.86)	**<0.001**
BMI (kg/m^2)	21.52 (3.35)	22.17 (3.46)	0.65 (0.53 – 0.77)	**<0.001**
Waist Circumference (cm)	75.12 (8.69)	76.26 (9.00)	1.14 (0.63 – 1.66)	**<0.001**
Hip Circumference (cm)	97.19 (7.75)	98.12 (7.45)	0.93 (0.55 – 1.31)	**<0.001**
WHR	0.772 (0.049)	0.776 (0.054)	0.004 (-0.001 – 0.009)	0.086

Data are expressed as mean (SD) and mean difference (95% CI); WC data not collected for one participant; Abbreviations: BMI, body mass index; WHR, Waist to hip ratio; MD, Mean difference. *****Non-parametric pairwise comparison (non-adjusted comparison of change in outcomes from beginning to end of school year). P-values below 0.05 represented in bold font.

Table 2: Trends from beginning to the end of first year in students living on campus residence (n=170), in off-campus housing (n=26), and at home with family (n=48)

	Living Arrangement	**Beginning** Mean (SD)	**End** Mean (SD)	**Change** MD (95% CI)	**P-value***
Body Weight (kg)	University Residence	60.27 (11.48)	62.13 (11.91)	1.86 (1.52 – 2.20)	**<0.001**
	Off-Campus Student Housing	60.92 (13.42)	61.53 (13.42)	0.61 (-0.51 – 1.72)	0.204
	At home with family	60.71 (13.24)	61.67 (13.78)	0.96 (0.16 – 1.76)	**0.017**
BMI (kg/m^2)	University Residence	21.44 (3.10)	22.20 (3.28)	0.76 (0.63 – 0.89)	**<0.001**
	Off-Campus Student Housing	21.65 (4.03)	21.91 (3.69)	0.26 (-0.17 – 0.70)	0.144
	At home with family	21.72 (3.85)	22.17 (4.00)	0.45 (0.14 – 0.76)	**0.005**
Waist Circumference (cm)	University Residence	74.57 (7.91)	76.07 (8.57)	1.50 (0.95 – 2.06)	**<0.001**
	Off-Campus Student Housing	75.83 (9.82)	77.17 (9.68)	1.34 (-0.44 – 3.13)	0.098
	At home with family	76.69 (10.55)	76.47 (10.25)	-0.23 (-1.70 – 1.24)	0.739
Hip Circumference (cm)	University Residence	96.98 (7.23)	98.02 (7.13)	1.04 (0.59 – 1.50)	**<0.001**
	Off-Campus Student Housing	97.83 (9.14)	98.38 (8.84)	0.55 (-0.32 – 1.42)	0.204
	At home with family	97.59 (8.78)	98.35 (7.93)	0.75 (-0.23 – 1.73)	0.181
WHR	University Residence	0.768 (0.048)	0.775 (0.054)	0.007 (0.001 – 0.013)	**0.014**
	Off-Campus Student Housing	0.775 (0.052)	0.784 (0.053)	0.009 (-0.007 – 0.025)	0.276
	At home with family	0.784 (0.052)	0.775 (0.053)	-0.009 (-0.021 - 004)	0.182

Data are expressed as mean (SD) and mean difference (95% CI); WC data not collected for one participant living in off-campus student housing; Abbreviations: BMI, body mass index; WHR, Waist to hip ratio; MD, Mean difference. ***Non-parametric pairwise comparison by living arrangement subgroups (non-adjusted comparison of change in outcomes from beginning to end of school year). P-values below 0.05 represented in bold font).

Table 3: Association between living arrangement and obesity traits in first year of university

		Living Arrangement Categorical			**Living Arrangement Binary**
		University Residence *vs.* Home with Family[5]	Off-Campus Student Housing *vs.* Home with Family[5]	University Residence *vs.* Off-Campus Student Housing[5]	Living On-Campus *vs.* Living Off-Campus[5]
Body Weight (kg)	Baseline[1]	-0.037 (0.142), 0.793	0.027 (0.212), 0.897	-0.065 (0.184), 0.726	-0.047 (0.121), 0.700
	Change[2]	0.946 (0.399), **0.019**	-0.272 (0.597), 0.649	1.218 (0.518), **0.020**	1.040 (0.341), **0.003**
BMI (kg/m^2)	Baseline[1]	-0.041 (0.159), 0.798	-0.044 (0.238), 0.852	0.004 (0.206), 0.986	-0.025 (0.136), 0.852
	Change[2]	0.367 (0.149), **0.015**	-0.159 (0.223), 0.475	0.526 (0.193), **0.007**	0.422 (0.127), **0.001**
Waist Circumference (cm)	Baseline[1]	-0.163 (0.150), 0.278	-0.128 (0.224), 0.567	-0.035 (0.194), 0.859	-0.118 (0.128), 0.356
	Change[3]	0.328 (0.163), **0.046**	0.354 (0.246), 0.151	-0.027 (0.215), 0.901	0.208 (0.141), 0.141
Hip Circumference (cm)	Baseline[1]	-0.102 (0.156), 0.515	-0.025 (0.233), 0.915	-0.077 (0.202), 0.705	-0.093 (0.133), 0.486
	Change[3]	0.049 (0.159), 0.759	-0.033 (0.237), 0.891	0.081 (0.206), 0.693	0.060 (0.136), 0.658
WHR	Baseline[1]	-0.276 (0.146), 0.060	-0.255 (0.218), 0.244	-0.021 (0.190), 0.913	-0.187 (0.125), 0.136
	Change[4]	0.008 (0.006), 0.149	0.016 (0.009), 0.060	-0.008 (0.008), 0.300	0.003 (0.005), 0.561

[1]Linear regression with rank-based inverse normal transformation, adjusted for sex and cohort; [2]Linear regression adjusted for sex, baseline values, and cohort; [3]Linear regression with rank-based inverse normal transformation, adjusted for sex, baseline values, and cohort; [4]Linear regression adjusted for sex, cohort, baseline WHR, baseline BMI, and BMI Change; [5]β (Std. Error), p-value. Abbreviations: BMI, body mass index; WHR, Waist to hip ratio.

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CHAPTER 5: Discussion and Conclusion

Overview

Young adults pursuing undergraduate studies represent an at-risk group for increased BMI and the development of obesity later in adulthood.[1-3] The transition from high-school to university is a critical period for weight gain with the popular North American notion of 'Freshman 15' suggesting that students gain approximately 15 lbs during their first year in university.[1,4] This thesis compiles a series of investigations focused on identifying the patterns and predictors of change in obesity traits over the academic year among first-year university students from Ontario, Canada. This work is part of a broader longitudinal research study (GENEiUS) geared towards examining the evolution of obesity traits throughout the entire four years of undergraduate studies.[5] This concluding chapter includes a discussion of key findings, methodological limitations, practical lessons learned from study execution and implementation, and future directions.

Summary of Findings

Our investigation yielded several important results. Firstly, our data showed that first-year students on average gain a significant amount of weight by the end of the academic year compared to earlier in the year; however, the amount gained is considerably less than '15 pounds' that is commonly referred to in the 'Freshman 15' theory that is popular among students and in the media. On average, this weight gain is further accompanied by significant gains in BMI, waist circumference, and hip circumference. Our investigation of sex/gender as a predictor, described in Chapter 2, revealed that while males and females differ significantly at baseline, sex/gender does not differentially influence change in obesity traits duing the first year of university. In comparison, our examination of race/ethnicity as a predictor, described in Chapter 3, revealed a significant ethnicity effect wherein students of East-Asian ethnic background were found to experience higher gains in BW and BMI over the academic year compared to white-Caucasians. Lastly, the examination of living arrangement as a predictor, as described in Chapter 4, revealed significant differences in weight and BMI change between students living on campus residence and students living in either type of off-campus living arrangement (i.e. off-campus student rental housing or family home), despite there being no significant differences at baseline.

Methodological Limitations and Sources of Bias

Our investigation had several limitations which may have potentially biased our results. In terms of the design, one of the limitations of our study included the use of a non-probabilistic sampling approach. In this case, participants were enrolled in the study primarily via flyers, in-class announcements, and social media promotion. While this sampling approach was particularly utilized for its convenience and feasibility, the downside is that our sample may not have been entirely representative of the general undergraduate population.[6] One indicator of this is that more than 80% of our sample consisted of students enrolled in science-based undergraduate programs. In addition, our sample further lacked sufficient representation of certain ethnic groups as well with participants from only three ethnic groups (i.e. East Asian, white-Caucasian, and South Asian) representing 74.7% of the sample that completed one year of follow-up. As such, the generalizability of our results to the overall undergraduate student population is relatively limited. In addition to that, there is also a possibility that our study may have been influenced by volunteer bias such that healthier or more health-conscious students may have preferentially enrolled into the study.[6] This may have ultimately skewed our results and led to an underestimation of the average weight gain in this population.

Our investigation also suffered from considerable participant attrition with only 68% of the sample completing 1-year of follow up. This may have potentially skewed our results as the participants who stayed enrolled in the study may have been characteristically different than those who dropped out of the study (e.g. more health-conscious).[6] Additionally, significant participant attrition further led to a reduction in sample size which may have potentially limited our ability to detect small effects due to insufficient statistical power. In this case, we used the complete-case analysis approach and hence excluded participants from our analysis that did not complete 1-year of follow-up. This approach was selected based on a guideline from a previous report which recommends the use of the complete-case analysis framework when a relatively large proportion of data is missing.[7] However, more recently, this recommendation has been challenged by another recent report and hence the validity of this guideline remains uncertain.[8] While the selection of the complete case analysis approach, in this case, was based on contextual factors pertaining to the proportion of missing data, we recognize that this approach still presents critical limitations as it can lead to biased estimates if the missing data are deemed to not be missing at random.[7] We further recognize that an alternative statistical analysis approach using generalized estimating equations may have also been suitable in this case and it may have provided certain benefits given its flexibility. Hence, the findings of our research should be considered in light of these factors.

Apart from that, our results may have also been impacted to a degree by random and systematic errors in the measurement of anthropometric parameters. While there are several comprehensive methods and technologies available for measuring body mass and adiposity, such as dual-energy X-ray absorptiometry or bioelectric impedance analysis, we decided to use anthropometric indices in our investigation primarily based on considerations for cost and feasibility. Several steps were taken in order to minimize the degree of measurement error in the anthropometric data. We conducted physical measurement appointments wherein all participants were objectively measured by trained research assistants using standardized tools and in accordance with a standardized protocol. Multiple measurements were taken for each trait which were subsequently averaged to further improve precision. In this case, an objective measurement approach was chosen for the collection of anthropometric data over a self-reporting framework as the latter generally tends to be skewed.[9-13] For example, some previous studies have identified systematic tendencies among participants to under-report their weight and over-report their height.[11-13] Additionally, implementing a self-reporting format within this context presents a practical challenge for participants with regards to self-measurement of traits such as the waist and hip circumference, and can also further selectively screen out participants who may not have access to the appropriate measurement tools, hence increasing the risk of selection bias in the study. However, despite the implementation of the aforementioned precautionary measures, our data for certain anthropometric parameters, such as height or waist and hip circumference, may have been still been affected by measurement error due to various contributing factors. Firstly, given that these set of anthropometric measurements entailed some judgment on the part of the administrator during the measurement process, they were susceptible to a degree observer bias as well as a degree of inter-rater and intra-rater variability. Secondly, these parameters may have been further affected by factors such as posture or standing position, time of day, post-prandial status, depth of inspiration, and site of measurement.[14-16] Lastly, in this case, we measured WC and HC over clothing in the majority of our participants, depending on what participants were comfortable with and consented to. This may have further contributed to measurement error in our WC and HC data, as even lighter forms of clothing have been shown to significantly impact the measurement of these traits.[17]

When comparing the use of self-reported versus observed anthropometric measurements, several strengths and limitations can be identified for each option. As discussed above, the use of self-reported anthropometric measurements presents a threat to validity due to the tendency among participants to sometimes over-report or under-report certain measurements.[12] Nevertheless, some studies have found a high correlation between self-reported and directly measured estimates for parameters such as weight and height, indicating that self-reported estimates may be sufficiently accurate in most cases with minimal impact on epidemiological measures of association.[11,13,18] Notably, however, the correlation has been shown to vary across different population groups.[13] Similar patterns have been reported with respect to the measurement of waist circumference, hip circumference, and WHR.[10,18,19] Apart from concerns regarding validly, implementing a self-reported strategy can further present practical challenges for participants and induce selection bias as discussed above. However, one of the benefits of the self-report system may be increased convenience for participants. In our experience, many study participants found it challenging to find the time for a scheduled in-person visit for physical measurement in the middle of a busy semester, which may have consequently contributed to participant drop out. As such, we postulate that using a self-report system to record anthropometric data, in this case, could have been advantageous in regards to minimizing participant burden and consequently minimizing participant attrition. Furthermore, in light of the current COVID-19 pandemic which has severely impacted several ongoing research studies, including ours, due to distancing and isolation measures, the self-reported data collection method may be considered to a more lucrative option. Ultimately, we recognize that each option presents certain strengths and limitations and that it is critical to consider such factors when designing a study.

Lastly, our study results may have been influenced by potential confounding factors. While we accounted for certain established covariates at the analysis stage, such as sex and baseline trait values, as they are known to be associated with change in obesity traits, as well as the cohort of entry, to account for the clustering of data, there are several other factors that are known to impact obesity traits, such as diet and physical activity, which we did not account for. Over the five years that the GENEiUS study was conducted, several major modifications were made based on insights gained from a 2-year pilot phase. Many of these changes pertained to the types of variables measured and the methods/tools used to measure them. As such, the amount and type of data collected between the two groups of participants (i.e. participants enrolled before and after study modifications were made) was considerably different for many of the variables. The investigations in this thesis only examined variables that were common between the two phases of the study as that allowed us to incorporate data from a larger set participants and hence maximize the available sample size for investigation. Furthermore, due to the potential risk of confounding from the aforementioned discrepancies in measurement, we did not examine any additional variables or include them as covariates in our investigations. Finally, it is important to identify that observational studies are inherently prone to influence from potential residual confounding and that can further influence the validity of the results.

Ultimately, we recognize that the results of this thesis are limited by the factors discussed above and as such, our results may be considered hypothesis generating. All in all, the results should be interpreted with caution and further studies should be conducted in this area to confirm these findings.

Recruitment and Retention of University Students as Participants – Challenges, Practical Considerations & Lessons Learned

As discussed above, two major limitations of our investigation included a modest sample size and high participant attrition. These limitations can be directly linked to two practical components of implementing a research study – recruitment and retention of study participants. Challenges in recruitment and retention of participants often impact the validity of the results and lead to an underpowered study.[20] Yet, despite their foundational role in influencing study outcomes, discussion of methods and challenges pertaining to these practical aspects are often limited in research papers. In the field, there are often several miscalculated or unanticipated logistical, organizational, and system challenges that are faced which make recruiting and retention of participants more challenging than predicted. Hence, it is critical that the methods, opportunities and challenges within this context are discussed so future studies can benefit from it. Given that a core aspect of the investigations in this thesis involved participant recruitment, data collection, and participant follow up, in this section we present a brief overview of the lessons learned from working with university students as research participants.

While recruiting university students as in a research study presents certain benefits, including access to a relatively large and diverse group of eligible participants to sample from, it also entails particular challenges. According to previous literature, the motivation behind student participation can depend on a variety of different factors.[21] When considering student motivations from a psychosocial perspective, it has been suggested that students choose to enroll in research studies based on a subjective cost-benefit analysis, and hence most students only participate if the benefits gained from participating outweigh the costs.[22] Alternatively, another theory of motivation within this context suggests that while some students are motivated by intrinsic factors, such as a genuine interest in the research topic, others are motivated by extrinsic factors, such as the possibility of obtaining a tangible reward (e.g. monetary compensation, course credits).[23,24] Hence, it is ultimately critical to focus on promoting the benefits of participation to motivate students when recruiting.

For our research investigation, we primarily used flyers/poser advertisements, information kiosks at large student events, in-class announcements/presentations, and social media promotions to spread awareness about the study and recruit participants who voluntary sign-up. These methods are consistent with some of the most frequently documented strategies in research studies within this context.[25,26] In our experience, social media advertising and in-class announcements were relatively higher yield options.

With respect to participant retention, while we followed up with participants diligently and sent regular reminders through email and phone, we still observed significant participant drop-out. There may be different potential reasons for this. Firstly, our follow up period in March and April coincided with the time when final exams and assessments are scheduled. The end of a semester is usually considered a peak time for students in terms of academic workload as most final projects and exams are conducted at this time. As such, despite offering flexible appointment options and having wide availability, from a logistical standpoint this time period may not have been optimal for student participation. Logistical aspects such as conflicting schedules and lack of time have been previously shown to be important factors that influence participation in a research study.[20,26] While we recognize that the timing of our follow-up period could have potentially been an important logistical limitation, we feel that this was still the most optimal option in this case. Given the objective of our study to measure anthropometric change over an entire academic year, conducting follow up appointments earlier in the year would not have supported the study objective. Alternatively, given that most students leave campus immediately after their final exams to go back to their hometowns for the summer, scheduling the follow-up study period after April may not have been a suitable option either.

Secondly, we postulate that having a multi-step appointment process may have also potentially contributed to increased attrition of participants. In this case, our overall appointment process included an in-person study visit for anthropometric measurements as well as the completion of two online questionnaires. While we opted for an online questionnaire system as a user friendly and accessible option so students could complete it at a convenient time after their physical appointment, we hypothesize that having a multi-step process may have unintentionally increased participant burden. In our experience with this process, we found that in many cases students failed to complete the online questionnaires after their physical appointments despite being given ample time and multiple reminders. This could potentially be attributed to a variety of different reasons. In this case, requiring participants to complete multiple aspects puts the onus of remembering and completing all parts of the process on the participant, which increases workload and burden. Additionally, despite having reminders, ultimately the ability of participants to successfully complete all aspects depends on factors such as their schedules, their interest in the research study, and ultimately the benefit they see in completing this process. Hence, ultimately in order to optimize participant retention, it may be valuable for investigators to consider some of the practical factors mentioned above and strive to achieve an optimal balance between having sufficient study components to capture all relevant participant information and minimizing the amount of burden on participants.

Finally, we also believe that the remuneration we offered may have been limited to sufficiently motivate participants to join and remain enrolled in the study. In this case, we offered students a

$10 gift card for completion of their first appointment, and $5 gift cards for completion of subsequent follow-up appointments. For a multi-step appointment process, this may have been an insufficient incentive for students. Previous literature has indicated that while some students participate due to intrinsic motivation such as an inherent understanding or interest in the area of research, others are more likely to be motivated when there is a high extrinsic incentive that offsets the cost or burden of participating. In this case, a majority of our sample consisted of students in science related academic programs, who may have chosen to participate due to interest in the field, compared to students from non-science related programs. As such, in order to have a representative sample, investigators may consider creating incentives that appeal to a wider range of participants and sufficiently motivate potential participants. Furthermore, it is also important to recognize that students may not be as interested in the research topic as the investigators, and hence it is critical to set targets and timelines accordingly to successively achieve goals of the study.

In conclusion, based on our experience of working with undergraduate students as research participants, we postulate that promoting benefits of participation, creating incentives, minimizing logistical hurdles, and minimizing participation burden may be critical factors in optimizing recruitment and retention of student participants. Our observations are consistent with some of the observations reported previously within this context and may help inform future work in this area.[20-23,27]

Future Directions

Our investigations confirm the trend of weight gain during first year of university and implicate ethnicity and type of living arrangement, but not sex, as potential predictors within this context. These results may be used to promote further research in this area which may ultimately help us have a better understanding of the risk factors that make students susceptible to weight gain during first of university. In addition, these results may also be used to develop and optimize prediction and prevention strategies within this context.

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