Introduction

One of the major causes of death globally is non-communicable diseases, also known as chronic diseases, such as heart disease, type 2 diabetes, and stroke (World Health Organization 2022). These diseases are generally caused by the combination of genetic, lifestyle, physiological, and environmental factors (World Health Organization 2021). To reduce the risk of having chronic diseases, changing the lifestyle factors, including unhealthy diet and physical inactivity that may lead to obesity, is essential (Willett, Koplan, Nugent & et al. 2006).

Body Mass Index (BMI) is a method to examine whether a person has a healthy weight for their height. It is computed by dividing an adult's weight (in kg) by their height (in m^2) (Weir & Jan 2022). Even though BMI is not the best indicator for body fat percentage (Nuttall 2015), it has a moderate correlation with a more direct measure of body fat (Akindele, Phillips & Igumbor 2016), affordable and easy to analyse (Hu 2008). Systemic inflammation is a significant predictor for type 2 diabetes and cardiovascular disease, and it can be assessed by high sensitivity reactive C-reactive protein (hs-CRP) (Ridker, Hennekens, Buring & Rifai 2000; Freeman et al. 2002). Although the association between hs-CRP and waist circumference is established (Brooks, Blaha & Blumenthal 2010), it is interesting to know whether there is a relationship between hs-CRP and BMI. A higher level of high-density lipoprotein (HDL) cholesterol is known to be associated with a lower risk of type 2 diabetes (Hwang et al. 2015) and cardiovascular events (Mahdy Ali, Wonnerth, Huber & Wojta 2012). Due to its positive effect, increasing HDL cholesterol levels through changing lifestyle habits, including being more physically active, is recommended. Another factor that has been found to be related to a variety of chronic diseases is sleeping duration (Knutson, Ryden, Mander & van Cauter 2006; Taheri 2006). The recommended sleeping duration for adults between 18–60 years old is seven or more hours per night (Watson et al. 2015). However, it is unspecified whether there should be different sleeping duration recommendations for men and women.

Different prevalence of obesity due to demographic characteristics have been reported in several studies. In a study from the United States, a higher rate of obesity can be seen in rural compared to urban areas (Befort, Nazir & Perri 2012). Another report from a study in two cities–Seattle and Paris–has shown that socioeconomic status is related to obesity (Drewnowski et al. 2014). Socioeconomic status is often associated with education level; hence, the relationship between obesity and education level is investigated in this report.

Four research questions are addressed in this report: (1) Is there a relationship between BMI and hs-CRP?(2) Is there a significant difference in sleeping duration between male and female participants? (3) Is there a significant difference in HDL cholesterol levels among different race/ethnic backgrounds? (4) Is there a significant association between education level and BMI?

Methods

This study used the data from National Health and Nutrition Examination Survey (NHANES) 2017-2018 (CDC/NCHS 2018). The survey was aimed to assess the health and nutritional status of adults and children in the United States by using the combination of interviews and physical examinations. Several NHANES 2017-2018 files (demographic, body measures, hs-CRP, HDL cholesterol, sleeping habit and education level data) were merged with total observations of 5828. Only participants aged 21-64 years old were included in this project, and data with missing values and outliers of hs-CRP were deleted. Thus, 3214 observations were left for analysis.

1. Methods: Correlation

For the correlation analysis, the BMI and hs-CRP data (both continuous data) from NHANES 2017-2018 were selected. Several assessments (histograms, Shapiro-Wilk tests, and Q-Q plots) were conducted to see if the data is normally distributed. Since both variables were not normally distributed, Spearman's Rank-Order correlation test was used. A scatterplot was created to visualise the association between BMI and hs-CRP.

2. Methods: Wilcoxon Rank-Sum test / Mann-Whitney U test (non-parametric equivalent to independent samples t-test)

This analysis utilised data of sleeping duration on the weekdays of male and female participants in the NHANES 2017-2018. Summary statistics for sleeping duration data by gender (male and female) was conducted. Since the mean difference in sleeping duration was of interest, an independent t-test might be suitable. However, the assumptions of the independent t-test need to be fulfilled.

Histograms and Shapiro-Wilk tests for the sleeping duration of male and female participants were produced to check the assumption of normality. Further, Levene's test was conducted to examine the assumption of homogeneity of variance. Since the normality could not be assumed for this data set, a non-parametric test (Wilcoxon Rank-Sum test / Mann-Whitney U test) was used. Boxplots of sleeping duration data were created for both groups (male and female).

3. Methods: Kruskal-Wallis test (non-parametric equivalent to ANOVA)

The data on HDL cholesterol level and race of the participants in NHANES 2017-2018 were used in this analysis. The race of the study participants was categorised into six groups: Mexican American, Other Hispanic, Non-Hispanic White, Non-Hispanic Black, Non-Hispanic Asian, and other race (including multi-racial). The HDL cholesterol data was a continuous variable.

Several basic diagnostic tools (histogram, Q-Q plot, and Shapiro-Wilk test) were used to examine whether the assumptions of normally distributed residuals were fulfilled. Further, homogeneity of variance was also examined using the Residuals vs Fitted plot and Levene's test. Since the residuals were skewed, a non-parametric test equivalent to one-way ANOVA (Kruskal-Wallis test) was used to analyse the difference in HDL cholesterol levels among several races. Pairwise comparisons with Bonferroni adjustment (to keep the overall type 1 error low, an adjustment to the p-value is needed) was conducted, and visualisation of the significant result was created.

4. Methods: Chi-squared test

The data on education level consisted of five categories - Less than 9th grade, 9-11th grade (including 12th grade with no diploma), High school graduate/GED or equivalent, Some college or AA degree, and College graduate or above. The BMI data (continuous data) was transformed into a categorical variable based on the Centers for Disease Control and Prevention (CDC) definition by using as.factor() and ifelse() functions. It was classified into four categories: Underweight (BMI under 18.5 kg/m^2), Healthy weight (BMI above than or equal to 18.5 to 24.9 kg/m^2), Overweight (BMI higher than or equal to 25 to 29.9 kg/m^2), and Obese (BMI greater than or equal to 30 kg/m^2).

The contingency table with observed frequencies was obtained using the table() command, and the column percentages were derived using the prop.table() command. Pearson's Chi-squared test was used to analyse whether there was a significant association between BMI and education level among the participants of NHANES 2017-2018. Additionally, a bar plot and a balloon plot were made to give graphical visualisations.

Result

Table 1 shows the first ten rows of the NHANES 2017-2018 dataset

Table 1: First ten rows of the NHANES 2017-2018 data

ID	Gender	Age	Weight (kg)	Height (cm)	BMI (kg/m²)	Sleep duration (hours)	hs-CRP (mg/L)	HDL cholesterol (mg/dL)	Race	Education level
93711	Male	56	62.1	170.6	21.3	7	0.82	72	Non-Hispanic Asian	College graduate or above
93714	Female	54	87.1	147.8	39.9	7	5.71	42	Non-Hispanic Black	Some college or AA degree
93716	Male	61	77.7	159.2	30.7	7	1.75	39	Non-Hispanic Asian	College graduate or above
93717	Male	22	74.4	174.1	24.5	8	0.80	53	Non-Hispanic White	High school graduate/GED or equivalent
93718	Male	45	54.4	157.3	22.0	8	0.69	63	Non-Hispanic Black	High school graduate/GED or equivalent
93721	Female	60	85.1	154.0	35.9	9	3.04	45	Mexican American	Less than 9th grade
93722	Female	60	56.8	154.6	23.8	6	0.41	78	Non-Hispanic White	Some college or AA degree
93723	Male	64	64.9	170.1	22.4	6	1.02	54	Non-Hispanic White	College graduate or above
93729	Male	42	82.8	173.2	27.6	9	1.63	49	Non-Hispanic Black	9-11th grade (incl. 12th grade with no diploma)
93730	Male	57	80.2	167.6	28.6	7	2.86	49	Other Hispanic	9-11th grade (incl. 12th grade with no diploma)

1. Result of Correlation Analysis

The table below shows the measures of central tendency of BMI and hs-CRP of the study participants

Table 2: The measures of central tendency of BMI and hs-CRP

	Mean	Median	SD
BMI (kg/m²)	29.53	28.50	6.97
hs-CRP (mg/L)	2.62	1.75	2.30

Several methods were used to test the normality of the data:

a. Histograms

The histograms for BMI and hs-CRP are both skewed to the right (Figure 1 and 2)

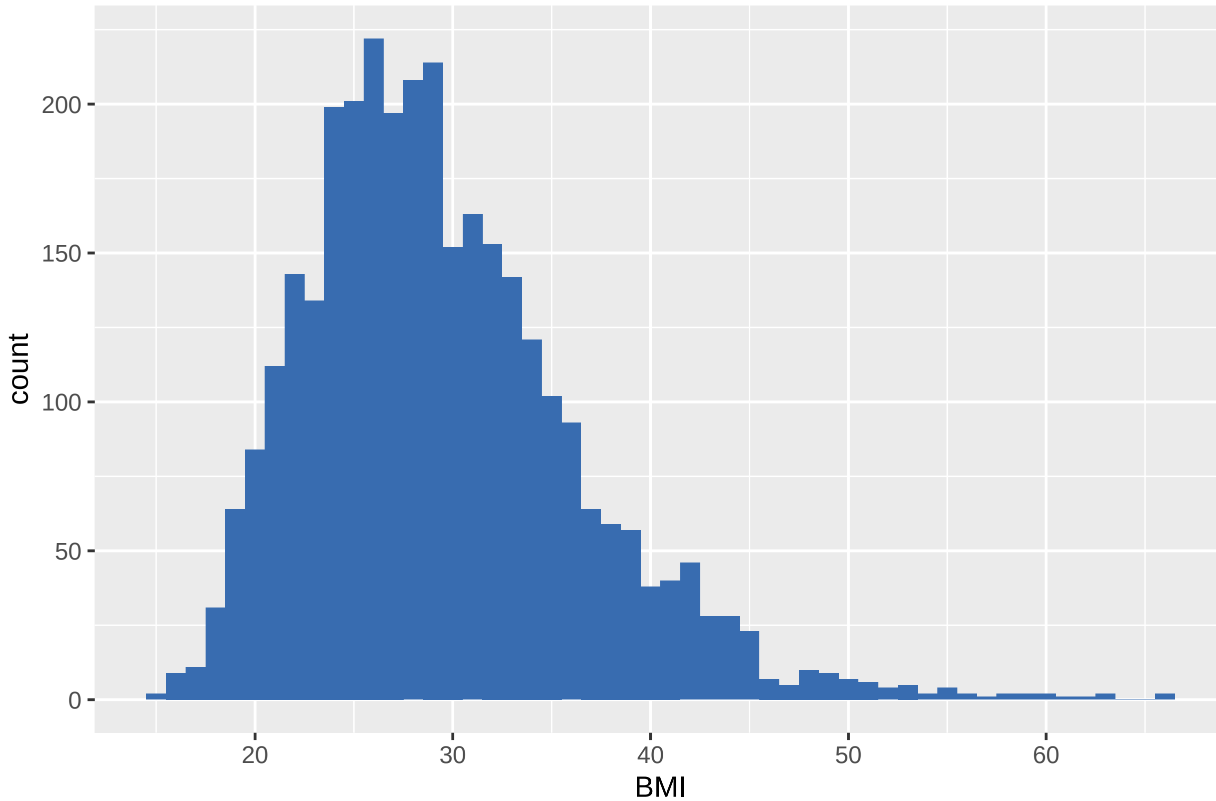

Figure 1. Histogram for BMI

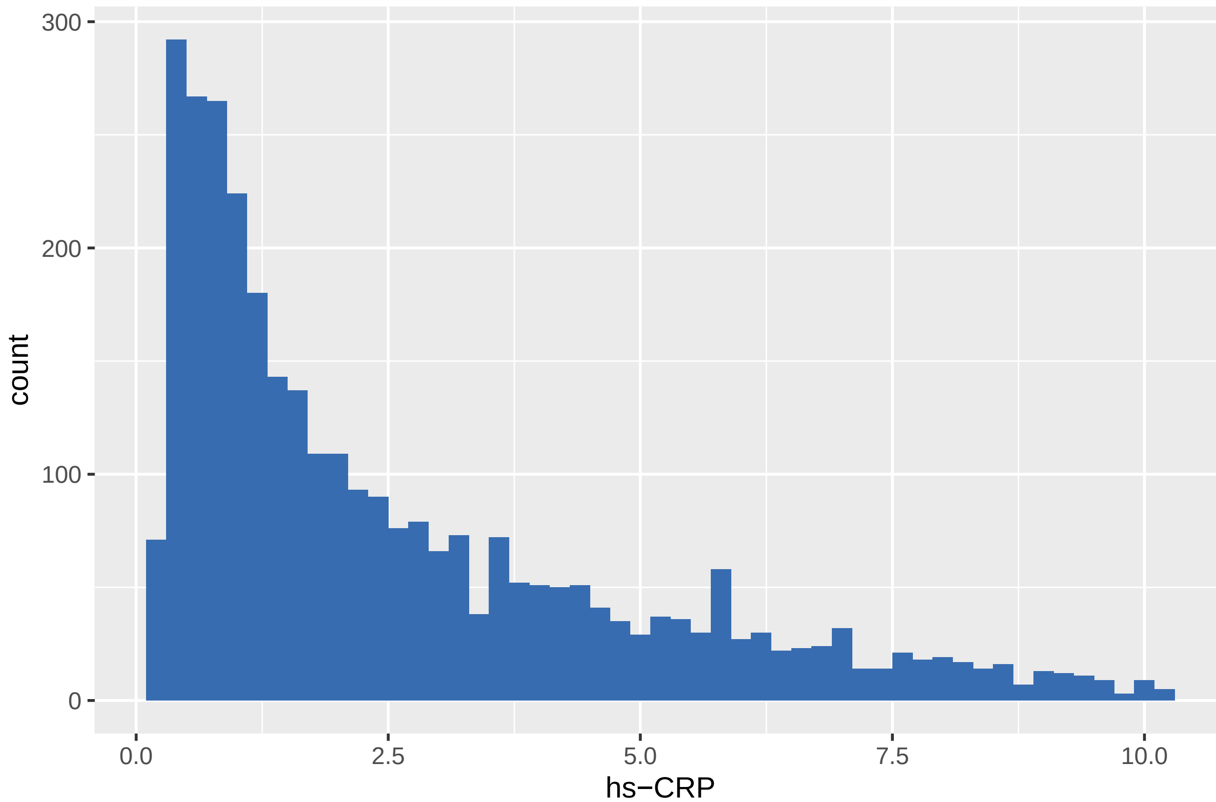

Figure 2. Histogram for hs−CRP

b. Shapiro-Wilk tests

Table 3: Shapiro-Wilk test result for BMI

statistic	p.value	method
0.95	0.00	Shapiro-Wilk normality test

Table 4: Shapiro-Wilk test result for hs-CRP

statistic	p.value	method
0.85	0.00	Shapiro-Wilk normality test

The Shapiro-Wilk tests result for BMI and hs-CRP showed p-values of $< 2.2e\text{-}16$.

c. Q-Q plots

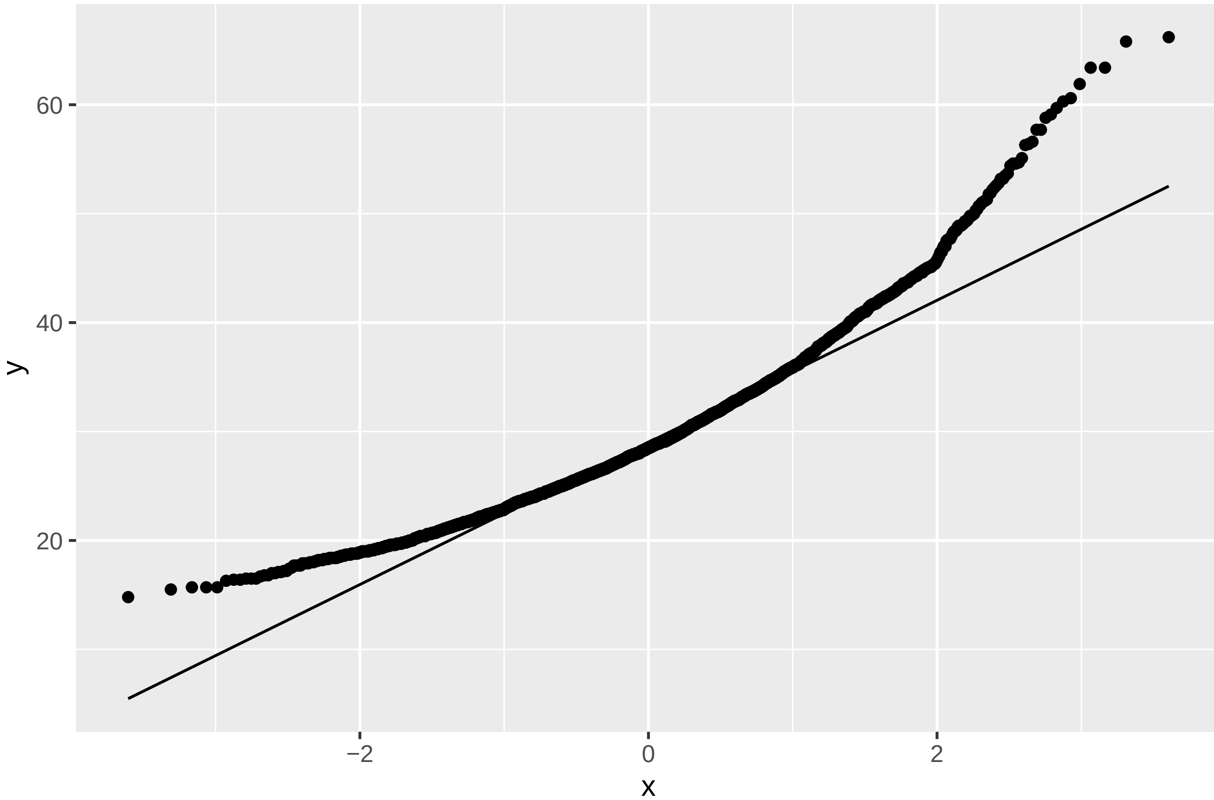

Figure 3. Q−Q plot of BMI

The Q-Q plots of BMI displays deviation from the straight line mostly in the upper end part and the lower left side only slightly deviate. Thus, it shows right-skewed distributions.

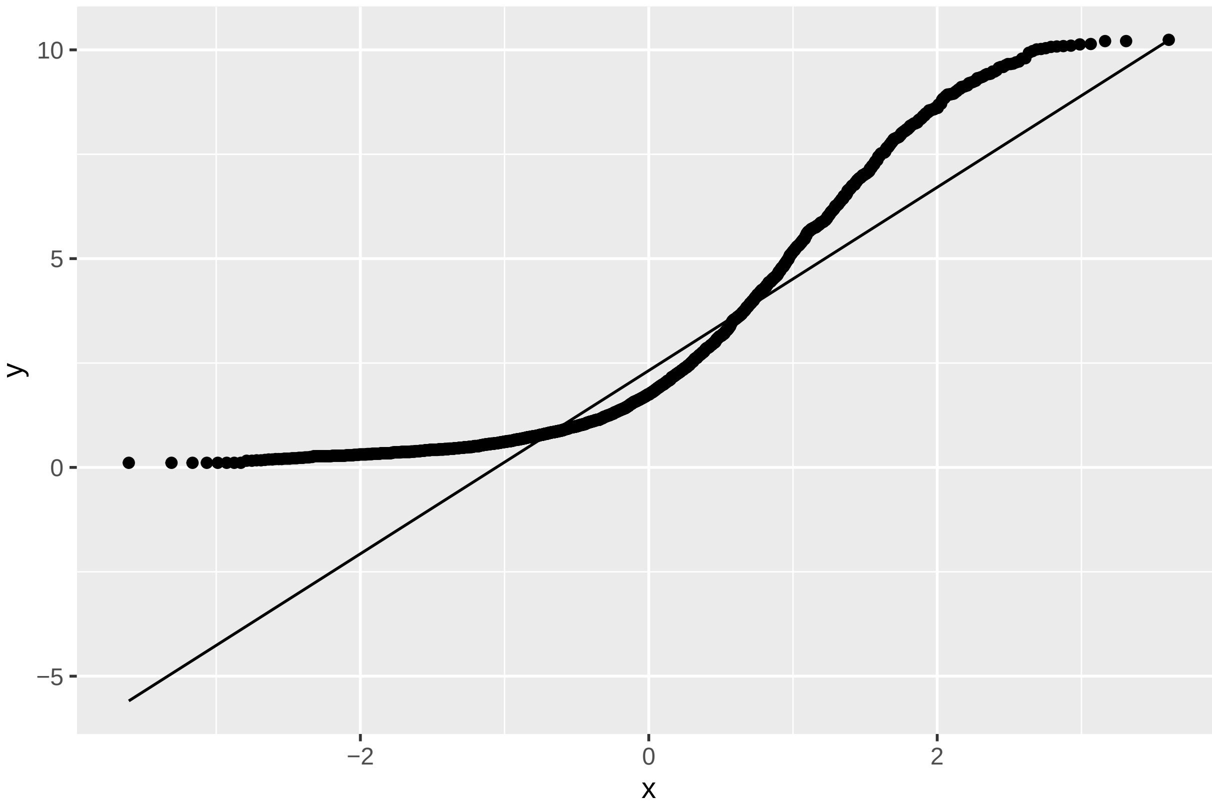

Figure 4. Q−Q plot of hs−CRP

The Q-Q plot for hs-CRP shows that the hs-CRP data do not conform very well to the normal distribution. The deviation between hs-CRP values and the normal distribution line seems to be substantial in the lower left-hand corner of the plot.

Based on the result of the histograms, Shapiro-Wilk tests, and Q-Q plots, it could be concluded that the normality of the data cannot be met. Thus, to assess the correlation between BMI and hs-CRP, Spearman's Rank-Order correlation test was used.

Hypothesis

The null hypothesis: There is no significant correlation between BMI and hs-CRP

The alternative hypothesis: There is a significant correlation between BMI and hs-CRP

Spearman's rank correlation test

Table 5: Result of Spearman's rank correlation test between BMI and hs-CRP

estimate	statistic	p.value	method	alternative
0.51	2689428474.39	0.00	Spearman's rank correlation rho	two.sided

Since the result of Spearman's rank correlation test showed a p-value of less than 0.05 (p-value < 2.2e-16), the null hypothesis is rejected. Hence, we found a significant correlation between BMI and hs-CRP in adults aged 21 to 64 years old; Spearman's rank correlation coefficient was 0.51, indicating a strong positive relationship.

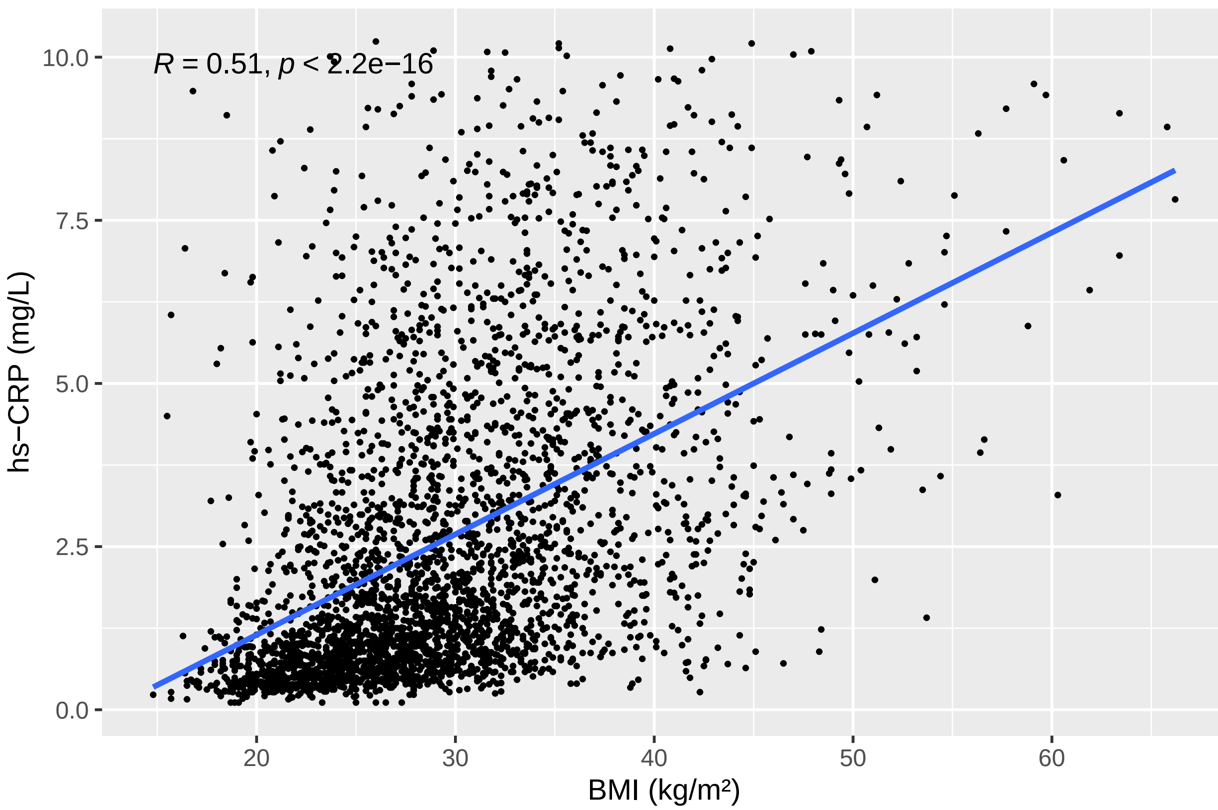

Figure 5. Scatterplot of BMI and hs−CRP in adults aged 21 − 64 years old

The scatterplot implies that as the BMI increases, so does the hs-CRP level.

2. Result of Wilcoxon Rank-Sum test / Mann-Whitney U test (non-parametric equivalent to independent samples t-test)

Several assessments were conducted to see whether the data fit the assumptions for independent t-test:

a. Test the normality of the data

- Histograms

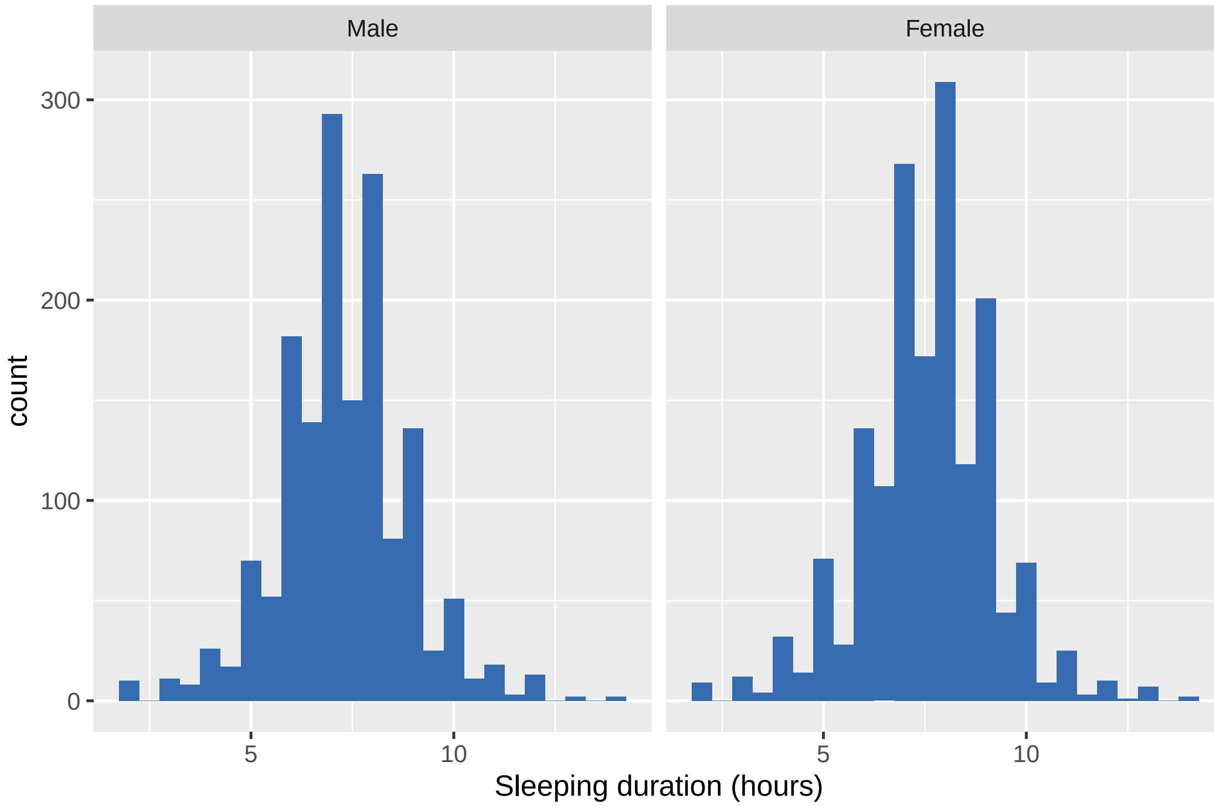

Figure 6. Histograms for sleeping duration of male and female participants in NHANES 2017−2018

The histograms of the sleeping duration of male and female participants display that the data is not normally distributed.

- Shapiro-Wilk tests

Table 6: Shapiro-Wilk Test Result for Male's Sleeping Duration

statistic	p.value	method
0.974	0.00	Shapiro-Wilk normality test

Table 7: Shapiro-Wilk Test Result for Female's Sleeping Duration

statistic	p.value	method
0.973	0.00	Shapiro-Wilk normality test

The result of Shapiro-Wilk tests shows that both of the data is skewed (p-value = 4.578e-16 for the male data and p-value < 2.2e-16 for the female data).

b. Check the homogeneity of variance

Levene's test

Table 8: Levene's Test for Homogeneity of Variance

	df	F value	Pr(>F)
group	1	0.31	0.58
	3,212		

The Levene's test p-value = 0.58 which is greater than 0.05; thus, equality of variances for the two independent samples can be assumed.

Since the normality could not be assumed for this data set, a non-parametric test (Wilcoxon Rank-Sum test / Mann-Whitney U test) was used.

Wilcoxon Rank-Sum test / Mann-Whitney U test

Hypothesis

The null hypothesis: There is no significant difference in sleeping duration between male and female participants in NHANES 2017-2018

The alternative hypothesis: There is a significant difference in sleeping duration between male and female participants in NHANES 2017-2018

Table 9: Wilcoxon Rank-Sum test result for difference of sleeping duration between male and female in NHANES 2017-2018

statistic	p.value	method	alternative
1134864	0.00	Wilcoxon rank sum test with continuity correction	two.sided

The result of Wilcoxon's rank-sum test / Mann-Whitney U test showed that W = 1134864 with p-value = 2.609e-09. Thus, there was a significant difference between the sleeping duration of male and female aged 21-64 years old in this study.

Table 10 shows the measures of central tendency of sleeping duration based on the gender

Table 10: The measures of central tendency of the sleeping duration of male and female participants in NHANES 2017-2018

Gender	Count	Mean	Median	SD
Female	1,651	7.57	7.50	1.62
Male	1,563	7.29	7.00	1.59

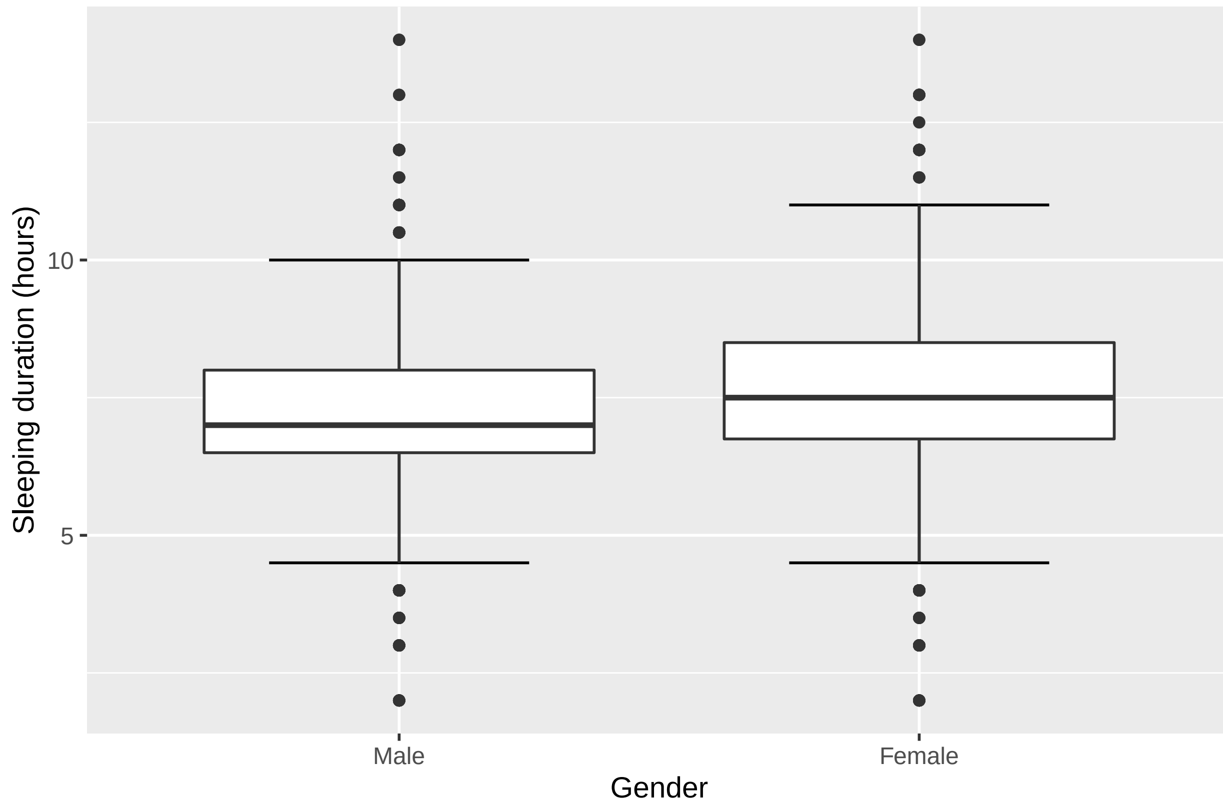

Figure 7. Boxplots of the sleeping duration of male and female participants in NHANES 2017−2018

Figure 7 shows that the median sleeping duration of female participants is slightly higher than male participants. In comparison to the male boxplot, the female boxplot is relatively taller; it suggests that female participants have more varied sleeping durations. There are some outliers in both male and female sleeping duration data.

3. Result of Kruskal-Wallis rank sum test (non-parametric equivalent to ANOVA)

The table below shows the measures of central tendency of HDL cholesterol level based on the participants' race

Table 11: The measures of central tendency of HDL cholesterol level based on the study participants' race

Race	Count	Mean	Median	SD
Mexican American	487	49.24	48.00	12.56
Non-Hispanic Asian	540	53.51	50.00	15.84
Non-Hispanic Black	724	56.89	54.00	17.55
Non-Hispanic White	957	52.97	50.00	16.19
Other Hispanic	337	50.55	48.00	14.19
Other Race - Including Multi-Racial	169	52.09	50.00	17.66

It is necessary to see whether the data fit the assumptions for one way ANOVA:

a. Several basic diagnostic tools were used to examine whether the assumptions of normally distributed residuals were met

- Histogram

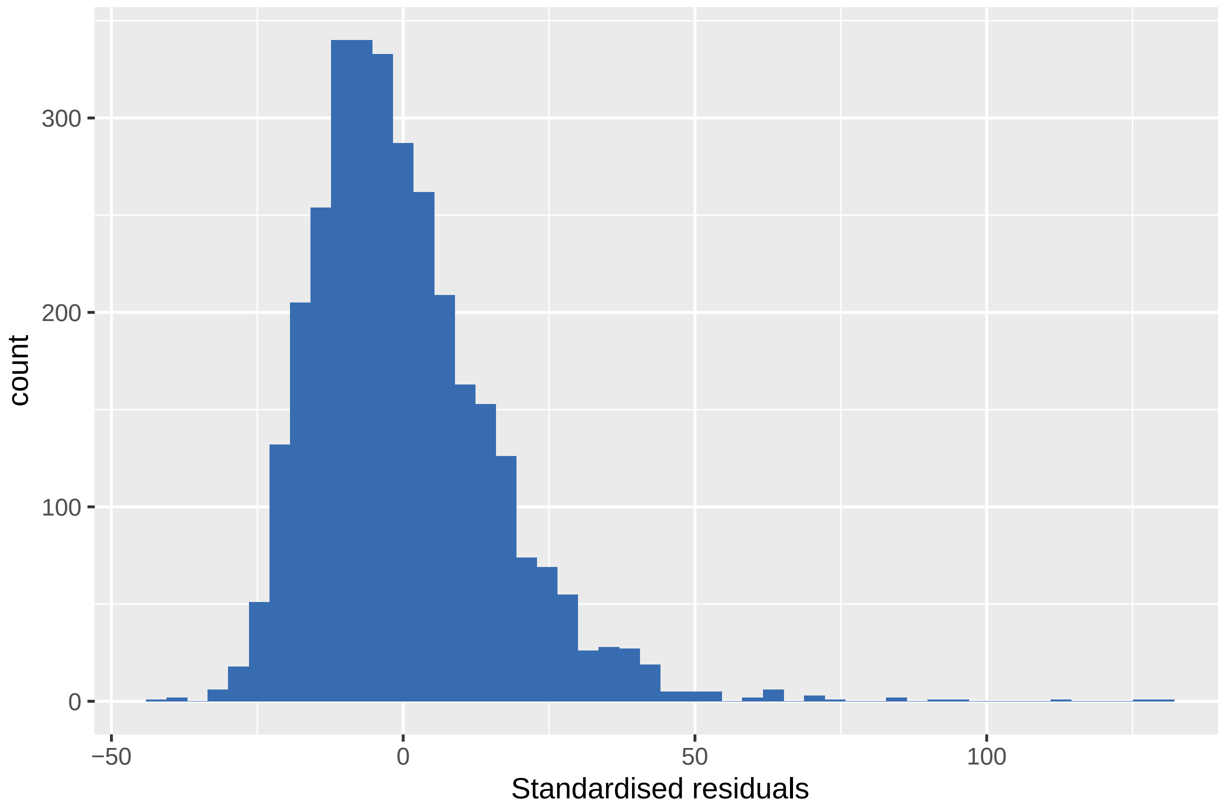

Figure 8. Histogram of the standardised residuals

- Q-Q plot

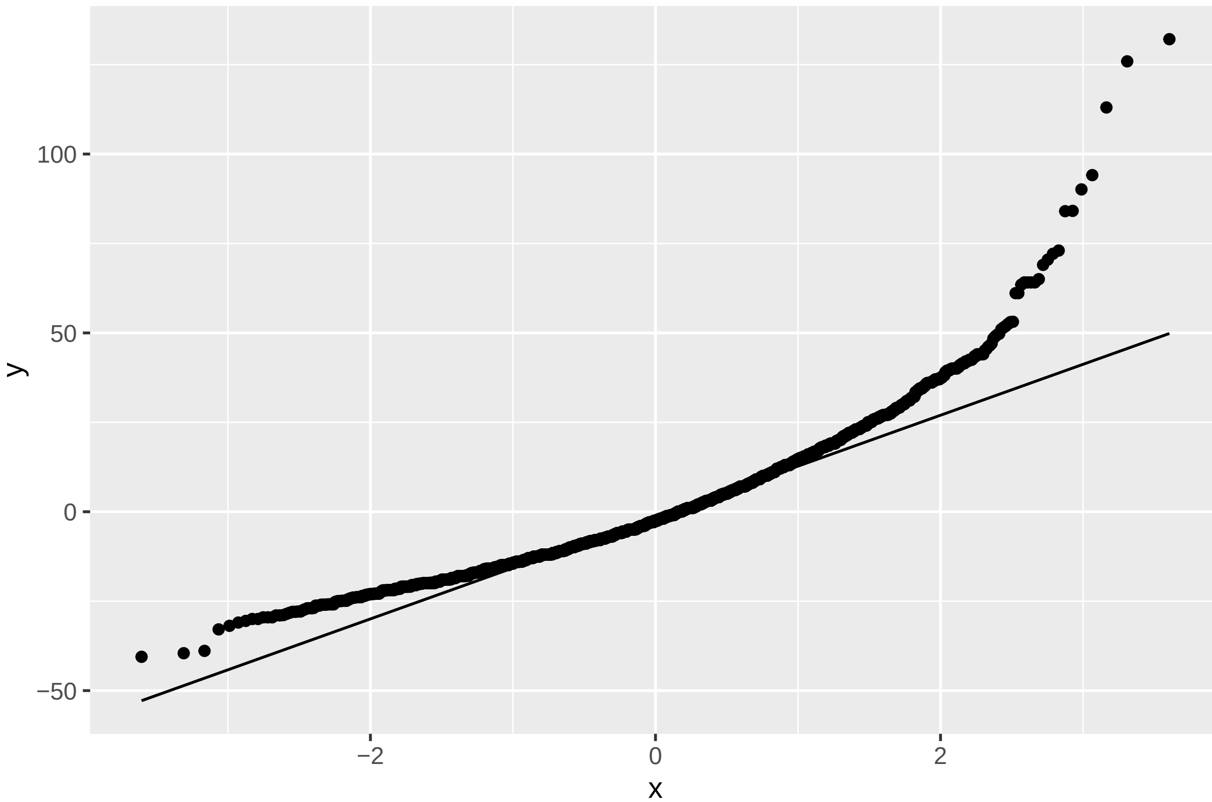

Figure 9. Q−Q plot of the standardised residuals

- Shapiro-Wilk test

Table 12: Shapiro-Wilk normality test result of the standardised residuals

statistic	p.value	method
0.93	0.00	Shapiro-Wilk normality test

The histogram and Q-Q plot displays that the residuals skewed to the right. In addition, the Shapiro-Wilk test shows that the p-value is significant (p-value < 2.2e-16). Hence, we cannot assume normality of the residuals.

b. Homogeneity of variance

The variances should be similar for all groups

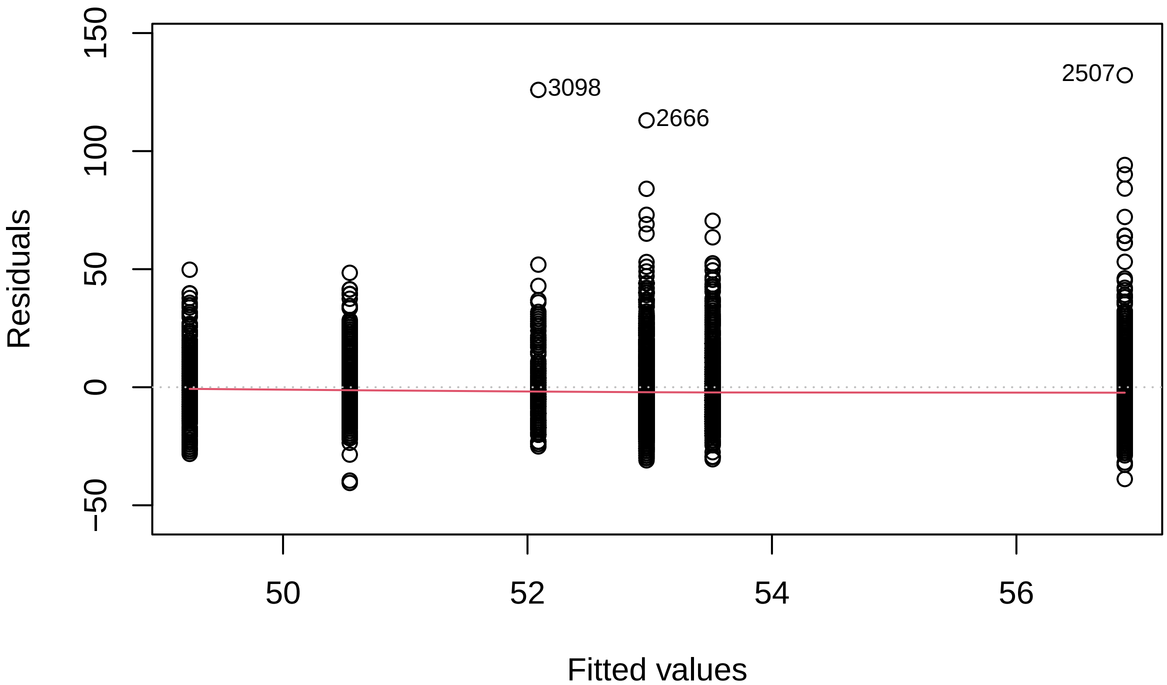

Figure 10. Residuals vs Fitted values plot

The result of Residuals vs Fitted plot shows that the spread of the residuals in some of the group are almost more than three times the spread in the group with the smallest spread.

Levene's test

Table 13: Levene's Test for Homogeneity of Variance (center = median)

	df	F value	Pr(>F)
group	5	4.86	0.00
	3,208		

The result of Levene's test shows a significant result ($p < 0.001$); there is evidence to suggest that the variance across groups is statistically significantly different. Therefore, we cannot assume the homogeneity of variances in the six different race groups.

Since the ANOVA assumptions were not met, a non-parametric alternative to one-way ANOVA; Kruskal-Wallis test was used.

Kruskal-Wallis test

Hypothesis

The null hypothesis: There is no significant difference in HDL cholesterol level among different races

The alternative hypothesis: There is a significant difference in HDL cholesterol level among different races

Table 14 shows the result of Kruskal-Wallis rank sum test between HDL cholesterol level and race

Table 14: Result of Kruskal-Wallis test

statistic	p.value	parameter	method
73.19	0.00	5	Kruskal-Wallis rank sum test

As the p-value = 2.216e-14, there was strong evidence to suggest a difference between at least one pair of the groups. In order to discover which pairs, we conducted the pairwise Wilcoxon signed-rank comparisons for each pair of groups.

Pairwise Comparisons

Since multiple comparisons were being done, the Bonferroni adjustment was used to keep the overall type 1 error low.

Table 15: Pairwise comparisons using Wilcoxon rank sum test with continuity correction

	Mexican American	Other Hispanic	Non-Hispanic White	Non-Hispanic Black	Non-Hispanic Asian
Other Hispanic	1.0000	-	-	-	-
Non-Hispanic White	0.0076	0.7189	-	-	-
Non-Hispanic Black	2.8e-14	7.8e-08	4.8e-06	-	-
Non-Hispanic Asian	0.0038	0.311	1.0000	0.0013	-
Other Race - Including Multi-Racial	1.0000	1.0000	1.0000	0.0014	1.00000

P value adjustment method: Bonferroni

Table 15 shows the results of the Wilcoxon tests on each pair of groups. The adjusted p-values are shown for each pair in the output. There were significant differences between: (1) Non-Hispanic White and Mexican American (p-value = 0.0076), (2) Non-Hispanic Black and Mexican American (p-value = 2.8e-14), (3) Non-Hispanic Asian and Mexican American (p-value = 0.0038), (4) Non-Hispanic Black and Other Hispanic (p-value = 7.8e-08), (5) Non-Hispanic Black and Non-Hispanic White (p-value = 4.8e-06), (6) Non-Hispanic Asian and Non-Hispanic Black (p-value = 0.0013), (7) Other Race - Including Multi-Racial and Non-Hispanic Black (p-value = 0.0014).

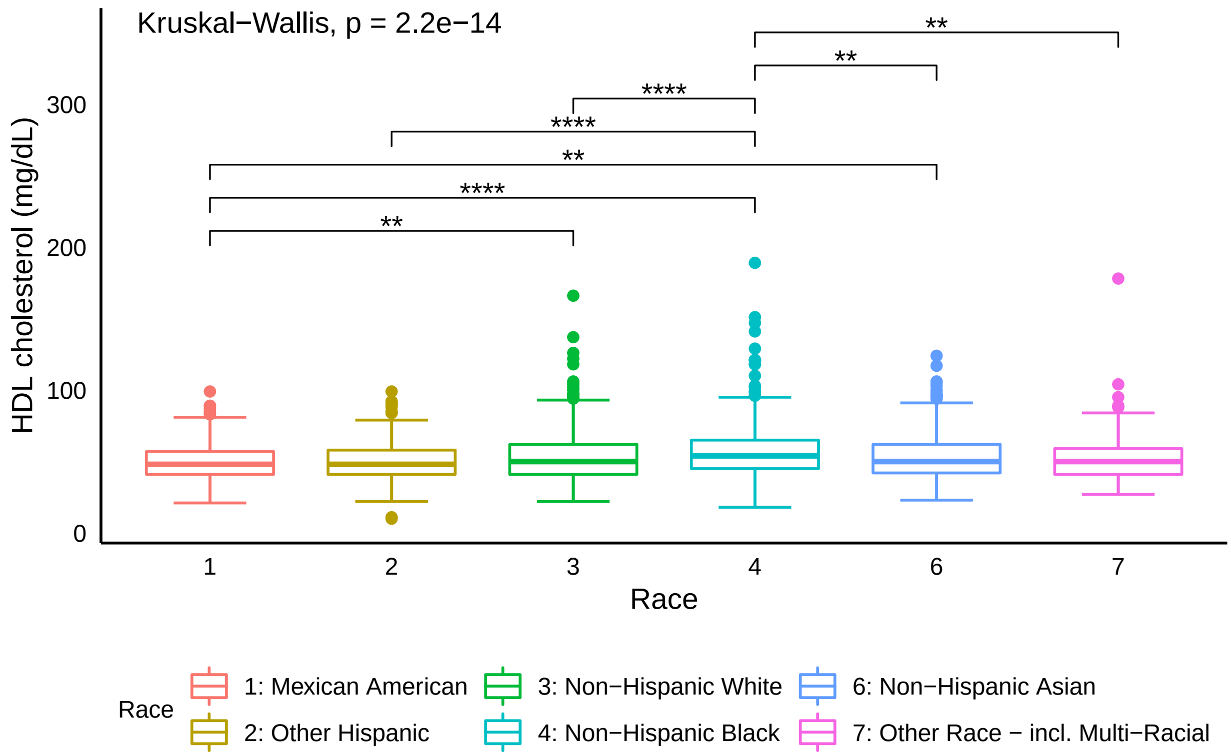

Figure 11. Visualisation of the significant result of Pairwise comparisons
**: p =< 0.01, ***: p =< 0.001, ****: p =< 0.0001

4. Result of Chi-squared test

Table 16: Contingency table containing the observed frequencies

	Less than 9th grade	9-11th grade (incl. 12th grade with no diploma)	High school graduate/GED or equivalent	Some college or AA degree	College graduate or above	Sum
Underweight	2	8	14	13	13	50
Healthy weight	36	90	190	234	263	813
Overweight	105	102	222	313	297	1,039
Obese	102	142	312	499	257	1,312
Sum	245	342	738	1,059	830	3,214

Table 16 shows the contingency table of observed frequencies. Almost half of the participants were obese (1,312 people). Participants with some college or AA degree had the highest number of overweight (313) and obese (499) people. Most of the college graduates or above were overweight (297 people); However, this group also had the highest number of people with healthy weights (263 people) compared to the other groups with lower education levels.

Table 17: Contingency table of percentages

	Less than 9th grade	9-11th grade (incl. 12th grade with no diploma)	High school graduate/GED or equivalent	Some college or AA degree	College graduate or above
Underweight	0.82	2.34	1.90	1.23	1.57
Healthy weight	14.69	26.32	25.75	22.10	31.69
Overweight	42.86	29.82	30.08	29.56	35.78
Obese	41.63	41.52	42.28	47.12	30.96

The contingency table of percentages shows that more college graduates or above have the highest percentage of healthy weight (31.69%). People with less than 9th-grade education level are 42.86% overweight, and 47.12% of participants with some college or AA degree are obese.

Hypothesis

The null hypothesis: Participants' education level is not associated with BMI

The alternative hypothesis: Participants' education level is associated with BMI

Table 18: Result of the Pearson's Chi-squared test

statistic	p.value	parameter	method
78.58	0.00	12	Pearson's Chi-squared test

Pearson's Chi-squared test results are shown in Table 18. The null hypothesis must be rejected because there was a significant outcome ($\chi 2$ = 78.58, df = 12, p = 7.689e-12). According to this finding, BMI was significantly associated with education level of the participants.

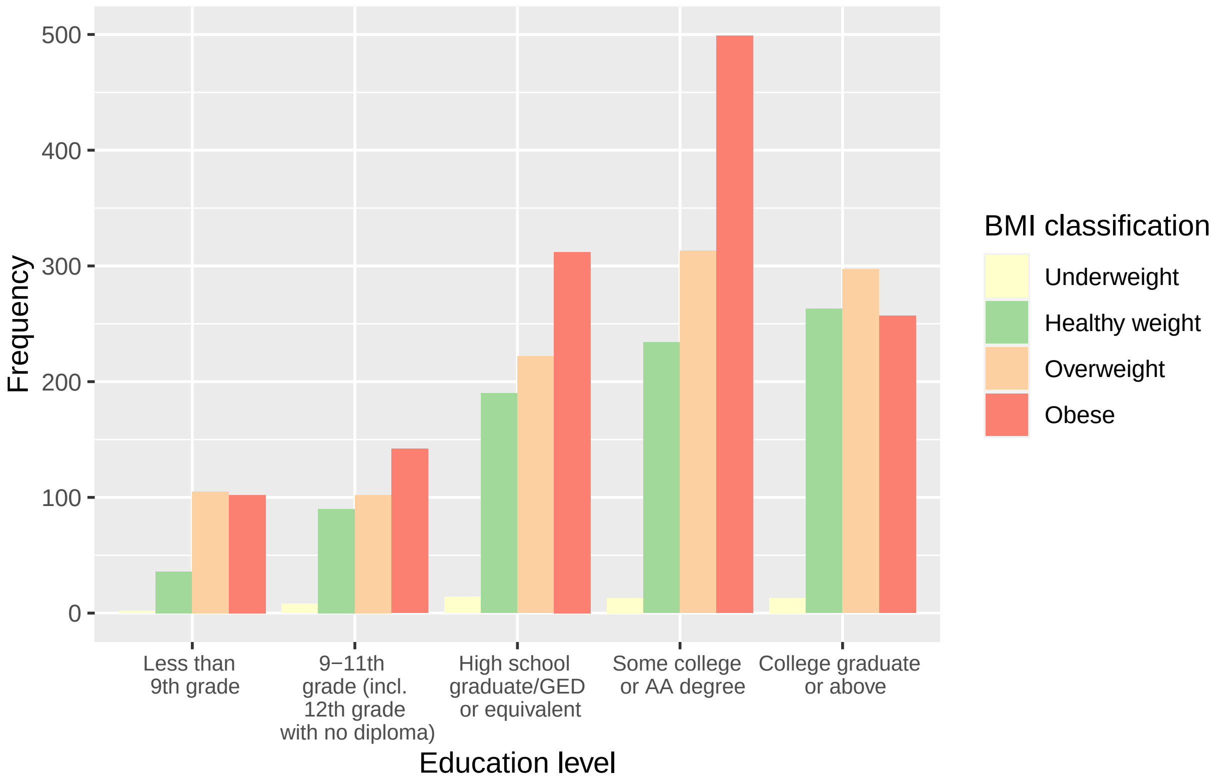

Figure 12. The clustered bar chart shows the frequency of BMI of the NHANES 2017−2018 participants according to their education level

To check on the validity of chi-squared test, we need to examine if one or more of the expected frequencies are less than 5.

Table 19: Result of expected frequencies

	Underweight	Healthy weight	Overweight	Obese
Less than 9th grade	3.81	61.97	79.20	100.01
9-11th grade (incl. 12th grade with no diploma)	5.32	86.51	110.56	139.61
High school graduate/GED or equivalent	11.48	186.68	238.58	301.26
Some college or AA degree	16.47	267.88	342.35	432.30
College graduate or above	12.91	209.95	268.32	338.82

Table 19 shows that only one cell has an expected count of less than five. According to Dan Yates, David Moore & George P. McCabe (1999), the expected counts that are less than five should be 20% or less, and the individual expected counts should all be one or more. Since only one out of twenty cells had an expected count of less than five, the Chi-squared test was valid.

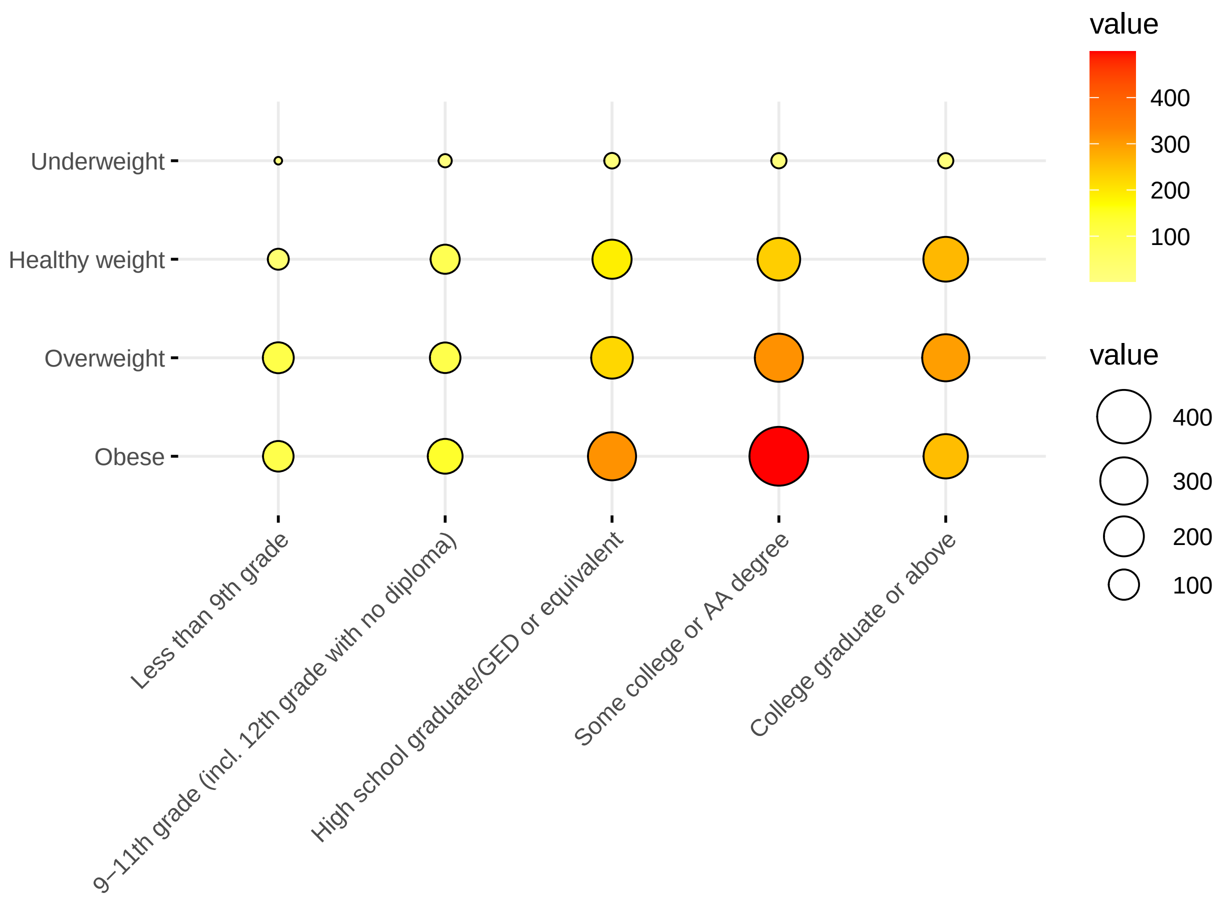

Figure 13. Balloon plot for the visualisation of the contigency table

Figure 13 shows the balloon plot visualising the contingency table formed by two categorical variables (BMI classification and education level). It can be seen that the highest number of obese people has some college or AA degree.

Discussion

Correlation between BMI and the hs-CRP level

The relationship between BMI and the hs-CRP level was investigated using Spearman's rank correlation. There was a significant result (p-value $< 2.2e-16$) to suggest an association between BMI and hs-CRP level in adults aged 21-64 years old in the NHANES 2017-2018. Spearman's rank correlation coefficient was 0.51, demonstrating a strong positive relationship. This finding confirms prior discoveries linking systemic inflammation associated with increased adiposity as measured by BMI (Huffman, Whisner, Zarini & Nath 2010; Nishitani & Sakakibara 2013). In addition, a Korean study found that people with high hs-CRP levels had a significantly increased risk of insulin resistance even after adjusting for other important variables, such as socio-demographic and health-related factors (Kim, Choi, Nam, Jang & Park 2020).

Difference in sleeping duration between male and female participants

The Wilcoxon's rank-sum test showed a significant difference ($W = 1134864$, p-value $= 2.609e-09$) of sleeping duration between male and female participants of NHANES 2017-2018. The median sleeping duration of male participants was 7.00 hours compared to 7.50 hours for female participants. A report from a Finnish study (Polo-Kantola et al. 2016) presented a comparable result – female participants slept 14 minutes longer on working days than male participants. The significance of sleeping duration should not be underestimate since short sleep of less than 6 hours was linked to 30% greater risk to overall chronic disease, particularly stroke and overall cancer, as compared to average sleep duration of 7-8 hours per day. The significance of sleeping duration should not be underestimated since short sleep of less than 6 hours was linked to a 30%

greater risk of overall chronic disease, particularly stroke and overall cancer, as compared to an average sleep duration of 7-8 hours per day (von Ruesten, Weikert, Fietze & Boeing 2012).

Difference in HDL cholesterol levels among different race/ethnic backgrounds

A Kruskal-Wallis test was carried out to compare the HDL cholesterol level among six groups of races in the NHANES 2017-2018. There was robust evidence of difference (p-value = 2.216e-14) among the mean ranks of at least one pair of groups. Wilcoxon signed-rank pairwise tests were conducted for the six pairs of groups. There was strong evidence (p-value < 0.05, adjusted using the Bonferroni correction) of significant differences in seven comparisons among the groups.

The median HDL cholesterol level for the Non-Hispanic Black was 54 mg/dL compared to 50 mg/dL for Non-Hispanic Asian. Further, Non-Hispanic White and Other Race - including Multi-Racial, have the same median HDL cholesterol level of 50 mg/dL. Lastly, Mexican American and Other Hispanic have the lowest median HDL cholesterol level of 48 mg/dL. Similar to the result of this report, a Multi-Ethnic Study of Atherosclerosis found that greater HDL cholesterol levels and a higher amount of big particles are linked to decreased risk of stroke in African Americans (Reina et al. 2015).

Association between education level and BMI

A Pearson's Chi-squared analysis was conducted to analyse whether there was an association between participants' education level and BMI. The result showed a significant relation ($\chi 2 = 78.58$, df = 12, p = 7.689e-12) between NHANES 2017-2018 participants' education level and their BMI. Participants who were college graduates or above had the highest percentage of healthy weight (31.69%) in contrast to other groups with lower education levels. The highest overweight percentage was found in the group of people with an education level of less than 9th grade (42.86%); further, participants with some college or AA degree had the most significant percentage of obese people (47.12%). These findings align with prior studies (A Molarius, J C Seidell, S Sans, J Tuomilehto & K Kuulasmaa 2000; Hajian-Tilaki & Heidari 2010) that education level is related to general obesity.

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