Factors Associated with Higher Systolic Blood Pressure in Nurses

CHL5222 Report-Final Group C

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Introduction

Systolic blood pressure quantifies the pressure exerted by your blood against your artery walls when your heart beats. High systolic blood pressure has been linked to an increased risk of strokes, heart disease, and chronic kidney disease (Fai et al., 2019). The UCLA Nurse Blood Pressure Study collected data from 203 nurses aged 24-50 working in Los Angeles. For each subject, there was initial baseline documentation of age, family history of hypertension, menstrual phase (F:follicular-beginning with the end of menstruation and ending with ovulation, L: Luteal-beginning with ovulation and ending with pregnancy or menstruation), and whether it was a workday or non-workday. Researchers also collected longitudinal data collected throughout the day. Blood pressure (Systolic and Diastolic in mmHg) and heart rate (beats per minute) were also recorded for each subject 30 minutes before the subject's normal start of work. Subsequent measures of blood pressure (BP) were recorded every 20 minutes for the rest of the day. At each BP measurement (roughly 50 for each nurse), nurses also reported their position during BP measurement(sitting, standing, or reclining), as well as self-ratings of happiness (HAP), stress (STR) and tiredness (TIR) on a 5 point Likert scale (with 1 being the lowest level and 5 being the highest). Activity levels during the 10 minutes before each reading were also measured. Using this data, our research question aims to identify the factors associated with higher systolic blood pressure.

Exploratory Data Analysis

We have explored many main effect graphs to evaluate the effects of different variables' relationship with SYS and we see these two plots show meaningful relationships between variables of interesting our outcome, systolic blood pressure. Table 1 below shows the descriptive statistics for the data.

Table 1: Subject Characteristics at Baseline Blood Pressure Reading

Measure	**N = 203**
Systolic Blood Pressure	118(14), [78, 168]
Age	38(7), [24, 50]
Family History of Hypertension	
1 Hypertensive parent	77 (38%)
Both parents hypertensive	14 (6.9%)
No family history	112 (55%)
Activity Level	186(47), [31, 281]
No Response	121
Day	

Measure	**N = 203**
Non-workday	90 (44%)
Workday	113 (56%)

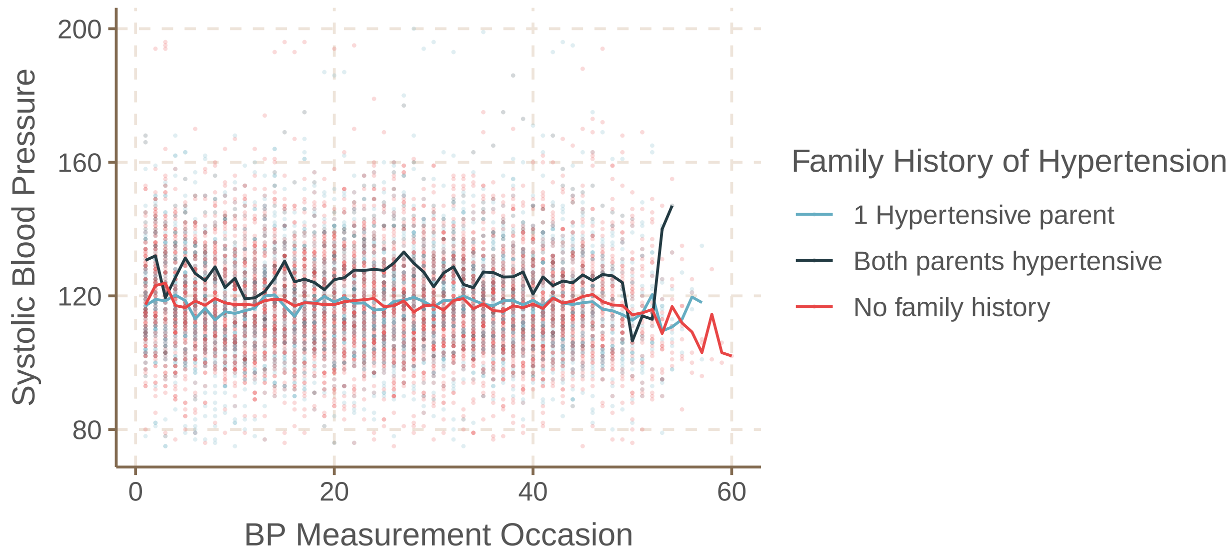

Figure 1: Mean Trajectory of Systolic Blood Pressure given Family History of Hypertension

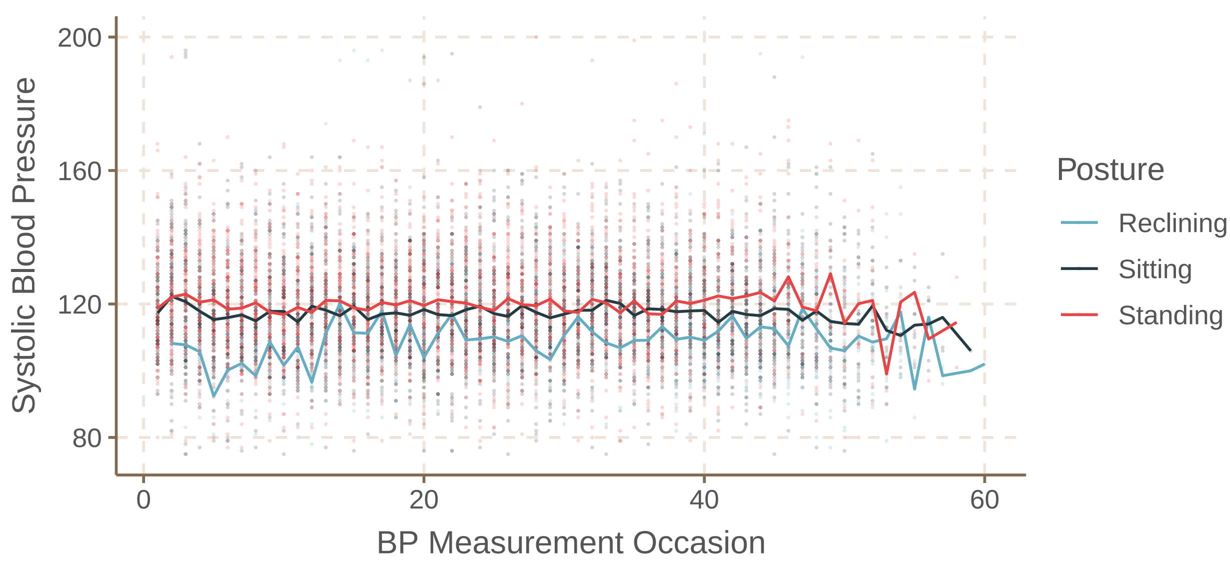

Figure 2: Mean Trajectory of Systolic Blood Pressure given Posture

Exploratory analysis of the data shows that although there doesn't appear to be a time effect, systolic pressure seems to differ based on a family history of hypertension. In particular, from Figure 1, those with both parents having a history of hypertension have a higher mean trajectory of systolic blood pressure compared to those with no family history or with only one hypertensive parent. Similarly, in Figure 2, systolic blood pressure appears to differ based on posture. Those who sat in a reclined position reported lower systolic blood pressure, while those who stood reported the highest systolic blood pressure levels.

Method

In terms of variable selection, variables STR, HAP, and TIR are self-rated data. We decided to exclude them in model variables since 1) we want to keep only clinical effects as predictors 2) these 3 variables have missing values. Another variable MNACT5 (frequency of movements over a 10-minute period) also contains missing values. Eventually, we decided to drop the all the rows which contain missing values. We also noted some blank values in the variable POSTURE, so we also removed the rows containing blank values in POSTURE. Among the remaining variables, we excluded DIA (Diastolic blood pressure) since it is highly correlated to our target variable SYS (Systolic blood pressure). Subject id (SNUM) will be considered as a random intercept later. At last, 8065 observations remained and 10 variables were left to be considered as predictors.

To find out the factors that are associated with higher systolic blood pressure, we tried several model types. Since we have 45 to 50 observations per individual on average, the covariance between later observations will be extremely small if we used a marginal model and set a covariance structure such as first-order autoregressive process (AR1). To avoid this issue, fitting a linear mixed-effect model is a reasonable solution. We will then perform some model assumption checking.

Since systolic blood pressure is a continuous variable, the subjects' blood pressure is recorded several times. A linear-mixed effect model was first fitted using lmer function in R. It takes systolic blood pressure as the response variable, subject id as a random intercept and all 10 variables as predictor variables. Then we performed a Wald chi-square test using the Anova function for the model to test if any covariates can be removed from the model. By removing the insignificant test and performing the test two times, the test result shows that we can keep HRT, MNACT5, FH123, POSTURE and DAY as covariates. It is also reasonable to believe there is a correlation between HRT and POSTURE, since one would higher heart rate when one is standing compared to sitting.

So our final model is:

$$Y_{ij} = \beta_1 + \beta_2 \mathrm{HRT}_{ij} + \beta_3 \mathrm{MNACT5}_{ij} + \beta_4 \mathrm{FH123}_{ij} + \beta_5 \mathrm{POSTURE}_{ij} + \beta_6 \mathrm{DAY} + \beta_7 \mathrm{HRT}_{ij} \times \mathrm{POSTURE}_{ij} + b_{i1} + \epsilon_{ij}$$

Where Y_{ij} is the systolic blood pressure for patients i at j^{th} measurement. β_1 is the intercept term and $\beta_{2\sim7}$ are the coefficients of fixed effect variables. b_{i1} is the random intercept effect for each subject. ϵ_{ij} is the random error.

Results

First, we performed some diagnostics to the final model using the resid_panel() function from package 'redres'. From Figure 3, the residual plot shows no obvious pattern which indicates constant variance assumption holds. However, we observed some tail issues in the Q-Q plot, which indicates the normality assumption of residual was not satisfied well.

Then, by looking at Table 2 below, we can interpret the fixed effects of covariates as the following:

For the main effects, coefficients of MNACT5 suggest the higher frequency of movements has a small positive effect (0.03) on SYS. Nurses' conditional mean systolic blood pressure is 2.51 units (in mmHg) higher than the systolic blood pressure on non-workdays. On average, compared to a nurse with no family history of hypertension, a nurse with both parents hypertensive will result in 7.29 units (in mmHg) higher in systolic blood pressure.

For interpretation of interaction terms, 1 unit (in beats per minute) increase in heart rate will cause systolic blood pressure to increase by 0.11, 0.16, and 0.07 units (in mmHg) for nurses who are reclining, sitting and standing during the BP measurement, respectively. On average, if keeping heart rate constant, comparing

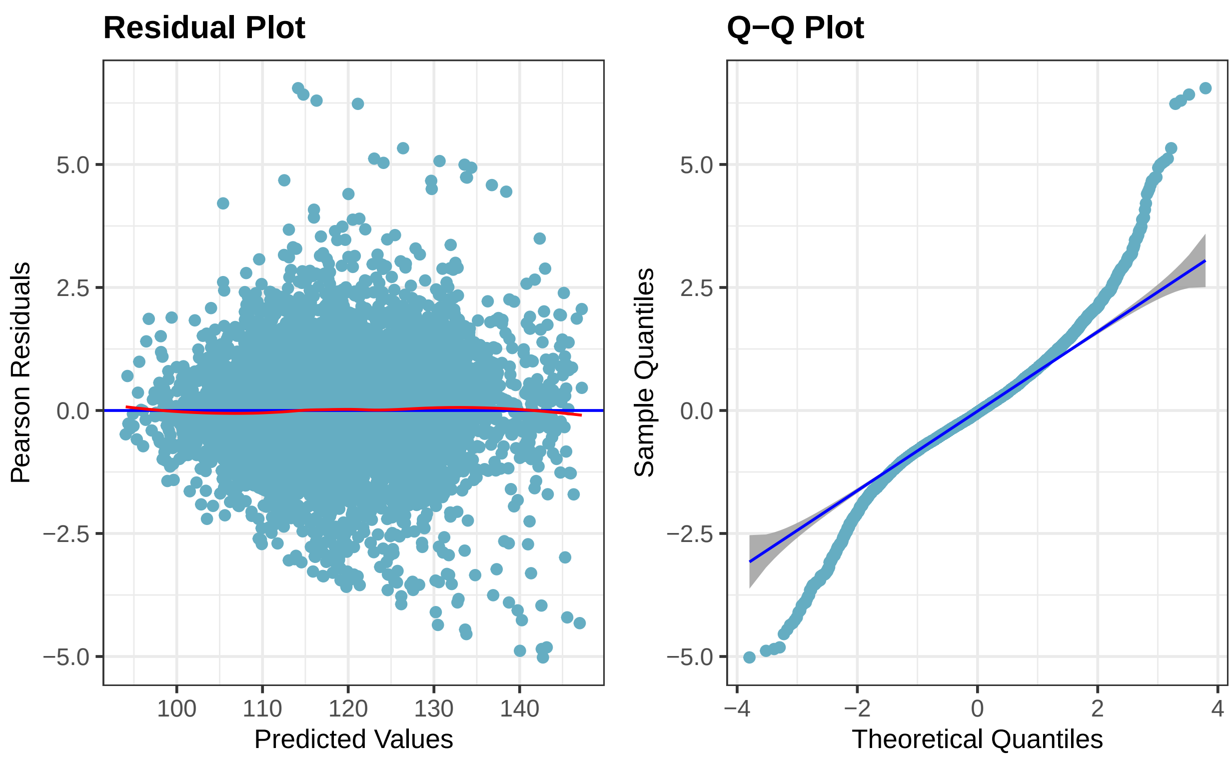

Figure 3: Diagnostic Plots

sitting to reclining while taking the blood pressure measurement, systolic blood pressure will increase by 0.16 units (in mmHg). Similarly, comparing standing to reclining while taking the blood pressure measurement, systolic blood pressure will increase by 7.09 units (in mmHg).

Among all of those fixed effects, standing while taking blood pressure measurements and both parents being hypertensive are the 2 factors that increase systolic blood pressure most significantly.

The estimated intra-cluster correlation (ICC) is $\frac{\hat{\sigma_b}^2}{\hat{\sigma_b}^2+\hat{\sigma}^2} = \frac{59.59}{59.59+156.13}$=27.6%, indicating that there exist considerable effects within clusters.

Table 2: Final Model Estimated Coefficients

	Estimate	Std. Error	t value
Intercept	97.47	3.72	26.18
Heart Rate	0.11	0.05	2.21
Activity Levels	0.03	0.00	12.59
Workdays	2.51	1.18	2.12
One Hypertensive Parent	0.19	1.25	0.15
Two Hypertensive Parents	7.29	2.34	3.12
Sitting	0.11	3.76	0.03
Standing	7.13	3.80	1.88
Heart Rate * Sitting	0.05	0.05	0.95
Heart Rate * Standing	-0.04	0.05	-0.69

Conclusion and Discussion

In this study, we fitted a linear mixed model with the nurse blood pressure data. Results showed that higher systolic blood pressure is associated with higher heart rate, higher frequency of movements, having hypertensive parents, standing during the blood pressure measurements and having blood pressure measurements on weekdays. By comparing the effect sizes, family history of hypertension and posture during blood pressure measurement are the most significant factors. Understanding these factors and their impact on blood pressure is crucial in developing effective strategies for the prevention and management of hypertension.

One limitation we have is regarding how we deal with missing data. In our model, we simply delete the column that contains factors that are self-rated because they are objective. However, there might be values in these factors that have not been revealed yet. If you are not happy and you feel tired all the time, it might be because your body showing symptoms of higher systolic blood pressure. Thus, there might be some form of correlation that is not realized by this final model. Dealing with missing data can be a potential challenge in this study. For instance, the self-rated variables may be missing by random, we can use other imputation methods such as last value carry forwards to deal with this missing mechanism but at the same time, we need to pay attention to the interpretation of the final model. If adding these columns would have a larger standard error than it should be which may cause inaccuracy in systolic blood pressure.

Another limitation is the that normality assumption for our final model does not hold. In addition, we have not checked the residual independence and linearity between the response variable and predictors, which could be further investigated.

References

Fai Wan, E. Y., Tak Yu, E. Y., Chin, W. Y., Tak Fong, D. Y., Hang Choi, E. P., & Kuen Lam, C. L. (2019). Association of Blood Pressure and Risk of Cardiovascular and Chronic Kidney Disease in Hong Kong Hypertensive Patients. Hypertension (Dallas, Tex. : 1979), 74(2), 331-340. https://doi.org/10.1161/HYPERTENSIONAHA.119.13123

Appendix

You can find all the R code we used in this appendix

```
knitr::opts_chunk$set(echo = TRUE)
#devtools::install_github('Mikata-Project/ggthemr')
#devtools::install_github("goodekat/redres")
library(tidyverse)
library(ggplot2)
library(ggthemr)
library(gtsummary)
library(viridis)
library(ggExtra)
library(lme4)
library(car)
library(MASS)
library(MuMIn)
library(lattice)
library(tinytex)
library(PupillometryR)
library(knitr)
library(nlme)
library(contrast)
library(AICcmodavg)
library(foreign)
library(geepack)
library(naniar)
library(here)
library(redres)
library(ggResidpanel)
knitr::opts_chunk$set(warning = FALSE, message = FALSE)
#theme_set(theme_bw()) # Use black/white theme and increase font size for all ggplot figures

ggthemr('fresh')
nurses<-read.table("nursebp.txt",header=T)

###### 5 summary table of continuous variables
nurses <- nurses %>% mutate(`Family History of Hypertension`=case_when(
  FH123=="NO"~"No family history", FH123=="YES"~"1 Hypertensive parent",
  FH123=="YESYES"~"Both parents hypertensive" ),`Activity Level`= MNACT5,
  Day=case_when(DAY=="W"~"Workday",DAY=="NW"~"Non-workday"),
  Posture=case_when(POSTURE=="SIT"~"Sitting",POSTURE=="STAND"~"Standing",
                    POSTURE=="RECLINE"~"Reclining"))
nurses %>% filter(timept==1) %>% dplyr::select(c(`Systolic Blood Pressure`=SYS,Age=AGE,
`Family History of Hypertension`,`Activity Level`,Day)) %>%
tbl_summary(statistic = list(all_continuous()~"{mean}({sd}), [{min}, {max}]"),
missing_text="No Response") %>% bold_labels() %>% modify_caption("
Subject Characteristics at Baseline Blood Pressure Reading") %>%
modify_header(label~"**Measure**")
nurses %>% ggplot(aes(x=timept,y=SYS,color=`Family History of Hypertension`))+
  geom_point(size=0.1,alpha=0.2)+
  stat_summary(fun=mean,geom="line")+
  labs(x="BP Measurement Occasion",y="Systolic Blood Pressure")
# plot for Mean Trajectory of Systolic Blood Pressure given Posture
```

```r
nurses %>% filter(!is.na(Posture)) %>% ggplot(aes(x = timept, y=SYS,color =
Posture)) + geom_point(size=0.01, alpha=0.2) + stat_summary(fun = mean,geom="line")+
  labs(x="BP Measurement Occasion", y="Systolic Blood Pressure")
#how many observations per individual
nurses %>%
#  drop_na() %>%
  group_by(SNUM) %>%
  summarise(nobs = n_distinct(timept)) %>%
  count(nobs)
naniar::vis_miss(nurses, sort_miss = TRUE)
#Drop 3 self rated variables
nurses <- subset(nurses, select = -c(STR, HAP, TIR))
#Remove all rows containing NAs
nurses <- na.omit(nurses)
#Remove all rows with blank POSTURE value
nurses <- nurses %>% filter(POSTURE != "")
#Base model to select variable
model_base <- lmer(SYS~AGE+HRT+MNACT5+PHASE+DAY+POSTURE+FH123+time+timept+timepass+
                 (1|SNUM), data=nurses)
#Anova test to check significance levels
Anova(model_base)
#Another around of Anova test by selecting significant variables
model_improve <- lmer(SYS~HRT+MNACT5+DAY+POSTURE+FH123+(1|SNUM), data=nurses)
Anova(model_improve)
#Final model
model_final <- lmer(SYS ~ HRT + MNACT5 + DAY + FH123 + POSTURE + HRT:POSTURE +
                      (1|SNUM), data = nurses)
#Model diagnostic
resid_panel(model_final, smoother = TRUE, qqbands = TRUE, plots = c("resid", "qq"))
library(kableExtra)
coefs <- as.data.frame(summary(model_final)$coefficient)
rownames(coefs) <- c("Intercept", "Heart Rate", "Activity Levels", "Workdays",
                     "One Hypertensive Parent", "Two Hypertensive Parents",
                     "Sitting", "Standing", "Heart Rate * Sitting",
                     "Heart Rate * Standing")
knitr::kable(coefs, caption = "Final Model Estimated Coefficients", digits = 2,
             booktabs=T) %>%
kable_styling(latex_options = "HOLD_position")
```