

Multiple linear regression 2

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Categorical variables in regression models.

The changing reference level

Interaction/effect modification

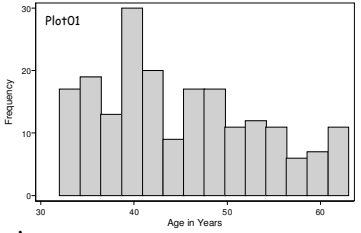
Interaction between a categorical and continuous variable

Interaction between two categorical variables

Morten FrydenbergLinear and Logistic regression - Note 2.21

Categorical variable in regression models

The age distribution:



Let us divide *age* into three agegroups ,

0: $age \leq 40$, 1: $40 < age \leq 50$, 2: $50 < age$

and consider the new model

$$\ln(sbp) = \alpha_0 + \alpha_1 \cdot age1 + \alpha_2 \cdot age2 + \alpha_3 \cdot woman + \alpha_4 \cdot \ln\left(\frac{bmi}{25}\right) + E$$

Morten FrydenbergLinear and Logistic regression - Note 2.22

Categorical variable : age group 0 reference

$$\ln(sbp) = \alpha_0 + \alpha_1 \cdot age1 + \alpha_2 \cdot age2 + \alpha_3 \cdot woman + \alpha_4 \cdot \ln\left(\frac{bmi}{25}\right) + E$$

age1 is one if a person is in age group 1 and zero otherwise

age2 is one if a person is in age group 2 and zero otherwise

The expected $\ln(sbp)$ in the three age groups will be:

$age < 40$: $\ln(sbp) = \alpha_0 + \alpha_3 \cdot woman + \alpha_4 \cdot \ln(bmi/25)$

$40 \leq age < 50$: $\ln(sbp) = \alpha_0 + \alpha_1 + \alpha_3 \cdot woman + \alpha_4 \cdot \ln(bmi/25)$

$50 \leq age$: $\ln(sbp) = \alpha_0 + \alpha_2 + \alpha_3 \cdot woman + \alpha_4 \cdot \ln(bmi/25)$

We see that α_1 is the adjusted difference in $\ln(sbp)$ when comparing a person in the **second group** with one in the **first group**.

And α_2 is the adjusted difference in $\ln(sbp)$ when comparing a person in the **third group** with one in the **first group**.

Morten FrydenbergLinear and Logistic regression - Note 2.23

Categorical variable : age group 0 reference

$$\ln(sbp) = \alpha_0 + \alpha_1 \cdot age1 + \alpha_2 \cdot age2 + \alpha_3 \cdot woman + \alpha_4 \cdot \ln\left(\frac{bmi}{25}\right) + E$$

Finally we see that α_0 is the expected $\ln(sbp)$ for a man in the **first** (reference) age group, with $bmi=25$.

In most programs the model is fitted by first generating the grouping variable and then making the regression telling the program which variables are categorical.

In STATA this done like this:

```
egen agegrp3=cut(age), at(0,40,50,120) label  
xi: regress lnSBP woman i.agegrp3 lnBMI25
```

Categorical variables included

This is categorical

Morten FrydenbergLinear and Logistic regression - Note 2.24

Categorical variable : age group 0 reference

$$\ln(sbp) = \alpha_0 + \alpha_1 \cdot age1 + \alpha_2 \cdot age2 + \alpha_3 \cdot woman + \alpha_4 \cdot \ln\left(\frac{bmi}{25}\right) + E$$

agegrp3 is treated as categorical

The value 0 is chosen as reference

OUTPUT: (naturally coded; _Iagegrp3_0 omitted)

	Source	SS	df	MS	
Model		.980169926	4	.245042482	Number of obs = 200
Residual		4.26524771	195	.021873065	F(4, 195) = 11.20
Total		5.24541764	199	.026358883	Prob > F = 0.0000
					R-squared = 0.1869
					Adj R-squared = 0.1702
					Root MSE = .1479

	lnSBP	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]
woman		.0035403	.0212026	0.17	0.868	-.0382757 .0453562
_Iagegrp3_1		.0715136	.0253373	2.82	0.005	.0215432 .121484
_Iagegrp3_2		.130465	.0280521	4.65	0.000	.0751404 .1857895
lnBMI25		.2898622	.0772432	3.75	0.000	.1375229 .4422015
_cons		4.789641	.0224814	213.05	0.000	4.745303 4.833979

Morten FrydenbergLinear and Logistic regression - Note 2.25

Categorical variable : age group 0 reference

$$\ln(sbp) = \alpha_0 + \alpha_1 \cdot age1 + \alpha_2 \cdot age2 + \alpha_3 \cdot woman + \alpha_4 \cdot \ln\left(\frac{bmi}{25}\right) + E$$

Adjusted difference between for a person in **age group 1** compared to **age group 0**

	lnSBP	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]
woman		.0035403	.0212026	0.17	0.868	-.0382757 .0453562
_Iagegrp3_1		.0715136	.0253373	2.82	0.005	.0215432 .121484
_Iagegrp3_2		.130465	.0280521	4.65	0.000	.0751404 .1857895
lnBMI25		.2898622	.0772432	3.75	0.000	.1375229 .4422015
_cons		4.789641	.0224814	213.05	0.000	4.745303 4.833979

Adjusted difference between for a person in **age group 2** compared to **age group 0**

Expected value for a man in **age group 0** with $bmi=25$.

Morten FrydenbergLinear and Logistic regression - Note 2.26

The expected values:

$age < 40$: $\ln(sbp) = \alpha_0 + \alpha_3 \cdot woman + \alpha_4 \cdot \ln(bmi/25)$

$40 \leq age < 50$: $\ln(sbp) = \alpha_0 + \alpha_1 + \alpha_3 \cdot woman + \alpha_4 \cdot \ln(bmi/25)$

$50 \leq age$: $\ln(sbp) = \alpha_0 + \alpha_2 + \alpha_3 \cdot woman + \alpha_4 \cdot \ln(bmi/25)$

The estimates

	lnSBP	Coef.	
woman	.003540	3	
_Iagegrp3_1	.071514	1	
_Iagegrp3_2	.130465	2	
lnBMI25	.289862	4	
_cons	4.789641	0	

$age < 40$: $\ln(sbp) = 4.789 + 0.004 \cdot woman + 0.290 \cdot \ln(bmi/25)$

$40 \leq age < 50$: $\ln(sbp) = 4.789 + 0.072 + 0.004 \cdot woman + 0.290 \cdot \ln(bmi/25)$

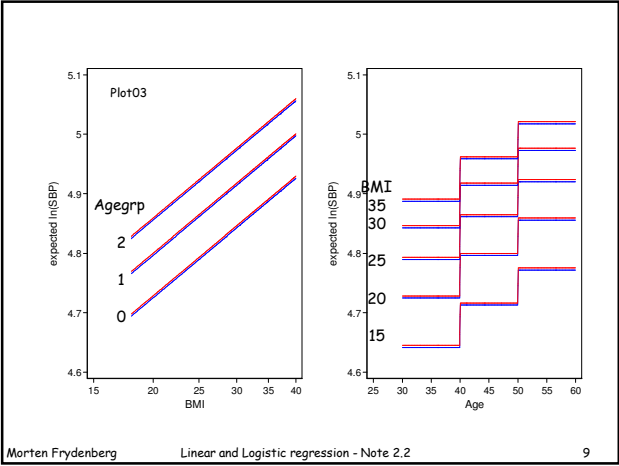
$50 \leq age$: $\ln(sbp) = 4.789 + 0.130 + 0.004 \cdot woman + 0.290 \cdot \ln(bmi/25)$

Morten FrydenbergLinear and Logistic regression - Note 2.27

Agegroup

	Women	Men
0:	$4.793 + 0.290 \cdot \ln(bmi/25)$	$4.790 + 0.290 \cdot \ln(bmi/25)$
1:	$4.865 + 0.290 \cdot \ln(bmi/25)$	$4.861 + 0.290 \cdot \ln(bmi/25)$
2:	$4.924 + 0.290 \cdot \ln(bmi/25)$	$4.920 + 0.290 \cdot \ln(bmi/25)$

Morten FrydenbergLinear and Logistic regression - Note 2.28



Categorical variable : age group 1 reference

$\ln(sbp) = \gamma_0 + \gamma_1 \cdot age0 + \gamma_2 \cdot age2 + \gamma_3 \cdot woman + \gamma_4 \cdot \ln\left(\frac{bmi}{25}\right) + E$

$age0$ is one if a person is in age group 0 and zero otherwise

$age2$ is one if a person is in age group 2 and zero otherwise

The expected $\ln(sbp)$ in the three age groups will be:

$age < 40$: $\ln(sbp) = \gamma_0 + \gamma_1 + \gamma_3 \cdot woman + \gamma_4 \cdot \ln(bmi/25)$

$40 \leq age < 50$: $\ln(sbp) = \gamma_0 + \gamma_3 \cdot woman + \gamma_4 \cdot \ln(bmi/25)$

$50 \leq age$: $\ln(sbp) = \gamma_0 + \gamma_2 + \gamma_3 \cdot woman + \gamma_4 \cdot \ln(bmi/25)$

We see that γ_1 is the adjusted difference in $\ln(sbp)$ when comparing a person in the **first group** with one in the **second group**.

And γ_2 is the adjusted difference in $\ln(sbp)$ when comparing a person in the **third group** with one in the **second group**.

Morten FrydenbergLinear and Logistic regression - Note 2.210

Categorical variable : age group 1 reference

$\ln(sbp) = \gamma_0 + \gamma_1 \cdot age0 + \gamma_2 \cdot age2 + \gamma_3 \cdot woman + \gamma_4 \cdot \ln\left(\frac{bmi}{25}\right) + E$

Finally we see that γ_0 is the expected $\ln(sbp)$ for a man in the **second** (reference) age group, with $bmi=25$.

Many programs (but regression in SPSS) let you chose the reference group

In STATA this done like this:

```
char agegrp3[omit]1
```

The group label 1 is reference

```
xi: regress lnSBP woman i.agegrp3 lnBMI25
```

Categorical variables included

This is categorical

Morten FrydenbergLinear and Logistic regression - Note 2.211

Categorical variable : age group 1 reference

$\ln(sbp) = \gamma_0 + \gamma_1 \cdot age0 + \gamma_2 \cdot age2 + \gamma_3 \cdot woman + \gamma_4 \cdot \ln\left(\frac{bmi}{25}\right) + E$

agegrp3 is treated as categorical

The value 1 is chosen as reference

i. agegrp3 _Iagegrp3_0-2 (naturally coded; _Iagegrp3_1 omitted)

Source	SS	df	MS	Number of obs = 200
Model	.980169926	4	.245042482	F(4, 195) = 11.20
Residual	4.26524771	195	.021873065	Prob > F = 0.0000
Total	5.24541764	199	.026358883	R-squared = 0.1869
				Adj R-squared = 0.1702
				Root MSE = .1479

	lnSBP	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]
woman	.0035403	.0212026	0.17	0.868	-.0382757	.0453562
_Iagegrp3_0	-.0715136	.0253373	-2.82	0.005	-.121484	-.0215432
_Iagegrp3_2	.0589513	.0263496	2.24	0.026	.0069846	.1109181
lnBMI25	.2898622	.0772432	3.75	0.000	.1375229	.4422015
_cons	4.861154	.0207406	234.4	0.000	4.82025	4.902059

Morten FrydenbergLinear and Logistic regression - Note 2.212

Categorical variable : age group 1 reference

$$\ln(sbp) = \alpha_0 + \alpha_1 \cdot age1 + \alpha_2 \cdot age2 + \alpha_3 \cdot woman + \alpha_4 \cdot \ln\left(\frac{bmi}{25}\right) + E$$

Adjusted difference between for a person in age group 0 compared to age group 1

	lnSBP	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]
woman		.0035403	.0212026	0.17	0.868	-.0382757 .0453562
_Iagegrp3_0		-.0715136	.0253373	-2.82	0.005	-.121484 -.0215432
_Iagegrp3_2		.0589513	.0263496	2.24	0.026	.0069846 .1109181
lnBMI25		.2898622	.0772432	3.75	0.000	.1375229 .4422015
_cons		4.861154	.0207406	234.4	0.000	4.82025 4.902059

Adjusted difference between for a person in age group 2 compared to age group 1

Expected value for a man in age group 1 with bmi=25.

Morten FrydenbergLinear and Logistic regression - Note 2.213

Categorical variable: Comparing to parameterizations

$$\ln(sbp) = \alpha_0 + \alpha_1 \cdot age1 + \alpha_2 \cdot age2 + \alpha_3 \cdot woman + \alpha_4 \cdot \ln\left(\frac{bmi}{25}\right) + E$$

$$\ln(sbp) = \gamma_0 + \gamma_1 \cdot age0 + \gamma_2 \cdot age2 + \gamma_3 \cdot woman + \gamma_4 \cdot \ln\left(\frac{bmi}{25}\right) + E$$

age group 0: $\alpha_0 = \gamma_0 + \gamma_1$

age group 1: $\alpha_0 + \alpha_1 = \gamma_0$

age group 2: $\alpha_0 + \alpha_2 = \gamma_0 + \gamma_2$

$$\begin{aligned} \alpha_0 &= \gamma_0 + \gamma_1 & \gamma_0 &= \alpha_0 + \alpha_1 \\ \alpha_1 &= -\gamma_1 & \gamma_1 &= -\alpha_1 \\ \alpha_2 &= \gamma_2 - \gamma_1 & \gamma_2 &= \alpha_2 - \alpha_1 \\ \alpha_3 &= \gamma_3 & \gamma_3 &= \alpha_3 \\ \alpha_4 &= \gamma_4 & \gamma_4 &= \alpha_4 \end{aligned}$$

Morten FrydenbergLinear and Logistic regression - Note 2.214

Categorical variable: Comparing two parameterizations

The estimates:

age group 0 reference

age group 1 reference

Root MSE	=	.1479
lnSBP	Coef.	[95% CI]
woman	.0035	-.0382 .0453
_Iagegrp3_1	.0715	.0215 .1214
_Iagegrp3_2	.1304	.0751 .1857
lnBMI25	.2898	.1375 .4422
_cons	4.7896	4.745 4.833

Root MSE	=	.1479
lnSBP	Coef.	[95% CI]
woman	.0035	-.0382 .0453
_Iagegrp3_0	-.0715	-.1214 -.0215
_Iagegrp3_2	.0589	.0069 .1109
lnBMI25	.2898	.1375 .4422
_cons	4.8611	4.820 4.902

Note, the estimates fulfil the same equations.

The interpretation of the "_Iagegrp3_2" line" and "_cons" line" are altered!!!!!!

Always remember: what is the reference group!

Morten FrydenbergLinear and Logistic regression - Note 2.215

Categorical variable : age group 1 reference

lnSBP	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]
woman	.0035403	.0212026	0.17	0.868	-.0382757 .0453562
_Iagegrp3_0	-.0715136	.0253373	-2.82	0.005	-.121484 -.0215432
_Iagegrp3_2	.0589513	.0263496	2.24	0.026	.0069846 .1109181
lnBMI25	.2898622	.0772432	3.75	0.000	.1375229 .4422015
_cons	4.861154	.0207406	234.4	0.000	4.82025 4.902059

Two test:

One testing no difference between age group 0 and 1.

One testing no difference between age group 2 and 1.

Can we get one test testing no difference between age groups?

A F-test in STATA: `testparm _Iagegrp3*`

1) _Iagegrp3_0 = 0

2) _Iagegrp3_2 = 0

F(2, 195) = 10.93

Prob > F = 0.0000

Highly significant

Morten FrydenbergLinear and Logistic regression - Note 2.216

Interactions/effectmodification

$$\ln(sbp) = \gamma_0 + \gamma_1 \cdot age0 + \gamma_2 \cdot age2 + \gamma_3 \cdot woman + \gamma_4 \cdot \ln\left(\frac{bmi}{25}\right) + E$$

One of the central assumptions was "no effect modification".

E.g. in model above the "effect" of age, sex and bmi did not depend on the value of each other.

One can introduce effect modification between a categorical variable and another variable.

Here we first will look at agegrp3 and lnBMI25.

The effect modification will be that the coefficient to lnBMI25 depend on age group.

That is, we will allow different effect of bmi in the different age groups.

Morten FrydenbergLinear and Logistic regression - Note 2.217

Interactions/effectmodification

$$\ln(sbp) = \omega_0 + \omega_1 \cdot age0 + \omega_2 \cdot age2 + \omega_3 \cdot woman + \omega_4 \cdot \ln\left(\frac{bmi}{25}\right) + \omega_5 \cdot age0 \cdot \ln\left(\frac{bmi}{25}\right) + \omega_6 \cdot age2 \cdot \ln\left(\frac{bmi}{25}\right) + E$$

$$age \leq 40: \ln(sbp) = (\omega_0 + \omega_1) + (\omega_4 + \omega_5) \cdot \ln\left(\frac{bmi}{25}\right) + \omega_3 \cdot woman$$

$$40 < age \leq 50: \ln(sbp) = \omega_0 + \omega_4 \cdot \ln\left(\frac{bmi}{25}\right) + \omega_3 \cdot woman$$

$$50 < age: \ln(sbp) = (\omega_0 + \omega_2) + (\omega_4 + \omega_6) \cdot \ln\left(\frac{bmi}{25}\right) + \omega_3 \cdot woman$$

ω_1 is the difference between the constant for age group 0 and reference group.

ω_5 is the difference between the coefficient to lnBMI25 for age group 0 and reference group.

Morten FrydenbergLinear and Logistic regression - Note 2.218

Interactions/effect modification

xi: regress lnSBP woman i.agegrp3*lnBMI25

i.agegrp3 _Iagegrp3_0-2 (naturally coded; _Iagegrp3_1 omitted)

i.age~3*lnB~25 _IageXlnBMI_# (coded as above)

Source	SS	df	MS	Number of obs = 200	
Model	.994860827	6	.165810138	F(6, 193) = 7.53	
Residual	4.25055681	193	.02202361	Prob > F = 0.0000	
Total	5.24541764	199	.026358883	R-squared = 0.1897	
				Adj R-squared = 0.1645	
				Root MSE = .1484	

lnSBP	Coef.	Std. E.	t	P> t	[95% Conf. Interval]
woman	.0076438	.02191	0.35	0.728	-.03558 .0508772
_Iagegrp3_0	-.0708045	.02611	-2.71	0.007	-.1223213 -.0192877
_Iagegrp3_2	.0631082	.02703	2.33	0.021	.009787 .1164287
lnBMI25	.3155479	.12229	2.58	0.011	.074350 .5567453
_IageXlnBMI-0	.0429736	.19123	0.22	0.822	-.334209 .420157
_IageXlnBMI-2	-.1165375	.18554	-0.63	0.531	-.482499 .2494241
_cons	4.859743	.02141	226.9	0.000	4.81751 4.901975

Morten Frydenberg Linear and Logistic regression - Note 2.2 19

Interactions/effect modification

Ref: constant and 'slope' in reference group

0: difference in constant and slope compared to reference

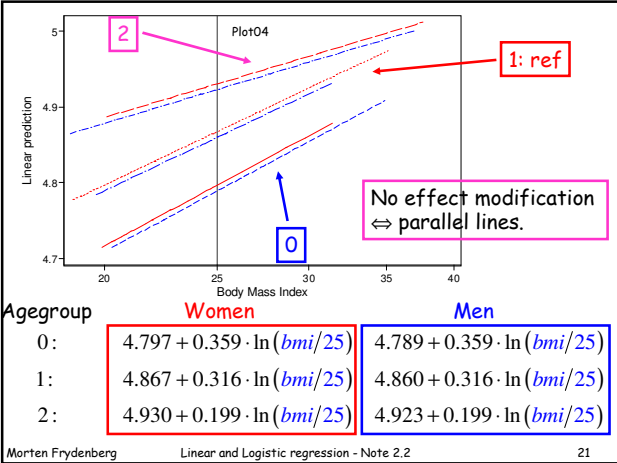
2: difference in constant and slope compared to reference

lnSBP	Coef.	Std. E.	t	P> t	[95% Conf. Interval]
woman	.0076438	.02191	0.35	0.728	-.03558 .0508772
_Iagegrp3_0	-.0708045	.02611	-2.71	0.007	-.1223213 -.0192877
_Iagegrp3_2	.0631082	.02703	2.33	0.021	.009787 .1164287
lnBMI25	.3155479	.12229	2.58	0.011	.074350 .5567453
_IageXlnBMI-0	.0429736	.19123	0.22	0.822	-.334209 .420157
_IageXlnBMI-2	-.1165375	.18554	-0.63	0.531	-.482499 .2494241
_cons	4.859743	.02141	226.9	0.000	4.81751 4.901975

Note the larger standard errors

Based on the estimates one can find the six "dose-response" curves:

Morten Frydenberg Linear and Logistic regression - Note 2.2 20



Interactions/effect modification

lnSBP	Coef.	Std. E.	t	P> t	[95% Conf. Interval]
woman	.0076438	.02191	0.35	0.728	-.03558 .0508772
_Iagegrp3_0	-.0708045	.02611	-2.71	0.007	-.1223213 -.0192877
_Iagegrp3_2	.0631082	.02703	2.33	0.021	.009787 .1164287
lnBMI25	.3155479	.12229	2.58	0.011	.074350 .5567453
_IageXlnBMI-0	.0429736	.19123	0.22	0.822	-.334209 .420157
_IageXlnBMI-2	-.1165375	.18554	-0.63	0.531	-.482499 .2494241
_cons	4.859743	.02141	226.9	0.000	4.81751 4.901975

Two test:

One testing differences between "slope" in age group 0 and 1.

One testing differences between "slope" in age group 2 and 1.

Can we get one test testing no difference between age groups?

A F-test in STATA: testparm _IageX*

(1) _IageXlnBMI_0 = 0

(2) _IageXlnBMI_2 = 0

F(2, 193) = 0.33

Prob > F = 0.7168

Non-significant

Morten Frydenberg Linear and Logistic regression - Note 2.2 22

Interactions/effect modification

The test of no interaction was non-significant.

But look at the confidence interval for the difference in slope for between age group 2 and group 1!

lnSBP	Coef.	Std. E.	t	P> t	[95% Conf. Interval]
woman	.0076438	.02191	0.35	0.728	-.03558 .0508772
_Iagegrp3_0	-.0708045	.02611	-2.71	0.007	-.1223213 -.0192877
_Iagegrp3_2	.0631082	.02703	2.33	0.021	.009787 .1164287
lnBMI25	.3155479	.12229	2.58	0.011	.074350 .5567453
_IageXlnBMI-0	.0429736	.19123	0.22	0.822	-.334209 .420157
_IageXlnBMI-2	-.1165375	.18554	-0.63	0.531	-.482499 .2494241
_cons	4.859743	.02141	226.9	0.000	4.81751 4.901975

It is very wide!!! We know very little about this difference!

The test for no interaction has very low power!!!

The data have very little information on whether there is effect modification.

Morten Frydenberg Linear and Logistic regression - Note 2.2 23

Interaction between age group and sex

xi: regress lnSBP lnBMI25 i.agegrp3*i.sex

i.agegrp3 _Iagegrp3_0-2 (naturally coded; _Iagegrp3_1 omitted)

i.sex _Isex_1-2 (naturally coded; _Isex_1 omitted)

i.age~3*i.sex _IageXsex_# (coded as above)

Source	SS	df	MS	Number of obs = 200	
Model	1.24006476	6	.20667746	F(6, 193) = 9.96	
Residual	4.00535288	193	.020753124	Prob > F = 0.0000	
Total	5.24541764	199	.026358883	R-squared = 0.2364	
				Adj R-squared = 0.2127	
				Root MSE = .14406	

lnSBP	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]
lnBMI25	.2265018	.0774898	2.92	0.004	.0736662 .3793374
_Iagegrp3_0	-.0426734	.0377096	-1.13	0.259	-.1170493 .0317025
_Iagegrp3_2	-.0025412	.0365457	-0.07	0.945	-.0746215 .0695391
_Isex_2	-.0210869	.0322283	-0.65	0.514	-.0846518 .042478
_IageXse-0_2	-.0548967	.0501668	-1.09	0.275	-.1538422 .0440488
_IageXse-2_2	.133379	.0501308	2.66	0.008	.0345043 .2322536
_cons	4.873442	.0251767	193.57	0.000	4.823786 4.923099

testparm _IageX*

(1) _IageXsex_0_2 = 0

(2) _IageXsex_2_2 = 0

F(2, 193) = 6.26

Prob > F = 0.0023

Highly significant

Morten Frydenberg Linear and Logistic regression - Note 2.2 24

Interaction between age group and sex

Differences between age groups among men are small

	lnSBP	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]
lnBMI25		.2265018	.0774898	2.92	0.004	.0736662 .3793374
_Iagegrp3_0		-.0426734	.0377096	-1.13	0.259	-.1170493 .0317025
_Iagegrp3_2		-.0025412	.0365457	-0.07	0.945	-.0746215 .0695391
_Isex_2		-.0210869	.0322283	-0.65	0.514	-.0846518 .042478
_Iagekse-0_2		-.0548967	.0501668	-1.09	0.275	-.1538422 .0440488
_Iagekse-2_2		.133379	.0501308	2.66	0.008	.0345043 .2322536
_cons		4.873442	.0251767	193.57	0.000	4.823786 4.923099

Women age group 1: $4.873 - 0.021 = 4.852$
Women age group 0: $4.873 - 0.021 - 0.042 - 0.055 = 4.755$
Women age group 2: $4.873 - 0.021 - 0.003 + 0.133 = 4.982$

Large differences in the age groups among women.

Morten Frydenberg Linear and Logistic regression - Note 2.2 25

Interaction between age group and sex

Using women as reference: `char sex[omit]2`

Large differences between age groups among women

	lnSBP	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]
lnBMI25		.2265018	.0774898	2.92	0.004	.0736662 .3793374
_Iagegrp3_0		-.0975701	.0328469	-2.97	0.003	-.162355 -.0327852
_Iagegrp3_2		.1308378	.0354804	3.69	0.000	.0608587 .2008168
_Isex_1		.0210869	.0322283	0.65	0.514	-.042478 .0846518
_Iagekse-0_1		.0548967	.0501668	1.09	0.275	-.0440488 .1538422
_Iagekse-2_1		-.133379	.0501308	-2.66	0.008	-.2322536 -.0345043
_cons		4.852355	.0205502	236.12	0.000	4.811824 4.892887

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Plot05

Agegroup Women Men

0: $4.755 + 0.227 \cdot \ln(bmi/25)$ $4.831 + 0.227 \cdot \ln(bmi/25)$

1: $4.852 + 0.227 \cdot \ln(bmi/25)$ $4.873 + 0.227 \cdot \ln(bmi/25)$

2: $4.982 + 0.227 \cdot \ln(bmi/25)$ $4.871 + 0.227 \cdot \ln(bmi/25)$

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