Table 1: Frequencies and relative frequencies of the categorical study variables by fracture status

Variable	Level	Fracture		No Fracture	
		Frequency	Percent	Frequency	Percent
Site	1	18	14.4	89	23.7
	2	26	20.8	64	17.1
	3	17	13.6	48	12.8
	4	6	4.8	30	8.0
	5	36	28.8	84	22.4
	6	22	17.6	60	16.0
	Total	125	100.0	375	100.0
Prior fracture	Yes	52	41.6	74	19.7
	No	73	58.4	301	80.3
	Total	125	100.0	375	100.0
Menopause before age 45	Yes	25	20.0	72	19.2
	No	100	80.0	303	80.8
	Total	125	100.0	375	100.0
Mother had hip fracture	Yes	24	19.2	41	10.9
	No	101	80.8	334	89.1
	Total	125	100.0	375	100.0
Needs arms to stand from chair	Yes	63	50.4	125	33.3
	No	62	49.6	250	66.7
	Total	125	100.0	375	100.0
Former or current smokers	Yes	7	5.6	28	7.5
	No	118	94.4	347	92.5
	Total	125	100.0	375	100.0
Self-reported fracture risk	Greater than others	49	39.2	98	26.1
	Same as others	48	38.4	138	36.8
	Less than others	28	22.4	139	37.1
	Total	125	100.0	375	100.0

Table 1 summary

- Site
  - One sparse cell for site 4
  - Doesn't make sense to combine categories

- Prior fracture
  - No sparse cells
  - Persons with fracture are more likely to have had a prior fracture than persons without fracture

- Menopause before age 45
  - No sparse cells

- Mother had hip fracture
  - No sparse cells
  - Persons with fracture are more likely to have mother with hip fracture than persons without fracture

- Needs arms to stand from chair
  - No sparse cells
  - Persons with fracture are more likely to need arms to stand from chair than persons without fracture

- Former or current smokers
  - One sparse cell
  - Can't combine categories

- Self-reported fracture risk
  - No sparse cells
  - Persons with fracture are more likely to report high fracture risk and less likely to report low fracture risk than persons without fracture

	Age		Weight (kg)		Height (cm)		BMI		Fracture Risk Score	
	Fracture	No Fracture	Fracture	No Fracture	Fracture	No Fracture	Fracture	No Fracture	Fracture	No Fracture
Mean	71.8	67.5	70.8	72.2	159.9	161.9	27.7	27.5	4.8	3.3
Std	9.1	8.7	15.6	16.7	6.8	6.1	5.9	6.0	2.5	2.4
Min	56	55	45.8	39.9	134	142	17.0	14.9	0	0
1st quartile	65	60	59.9	60.3	155	158	23.0	23.3	3	1
Median	72	66	68.0	68.0	160	162	26.4	26.4	5	3
3rd quartile	79	74	79.4	81.6	164	166	31.1	30.7	7	5
Maximum	89	90	124.7	127.0	178	199	44.0	49.1	9	11
Lowest values	56,56,56, 56,57	55,55,55, 55,55	45.8,46.3,47.6, 48.1,48.1	39.9,40.8,43.1, 43.5,44.9	134,142,143, 147,148	142,148,149, 150,150	17.0,18.4,18.5, 20.0,20.1	14.9,15.0,17.1, 17.4,17.8	0,0,0,0,0	0,0,0,0,0
Highest values	88,88,89, 89,89	88,89,90, 90,90	111.1,111.6,113.4, 117.0,124.7	116.6,117.9,119.7, 120.2,127.0	173,173,173, 175,178	175,176,176, 178,199	41.7,41.7,43.4, 43.6,44.0	44.2,44.6,45.0, 46.1,49.1	9,9,9,9,9	10,10,11, 11,11

Table 2 summary

- Age
  - No obvious outliers
  - Persons with fracture are older, on average, than persons without fracture

- Weight
  - ÿs outliers

- Height
  - No obvious outliers except possibly 199 cm among those with no fracture
  - Keep for now

- BMI
  - No obvious outliers
    - Fracture risk score
- Fracture risk score
  - No obvious outliers
  - There quite a few zeros; could try dichotomous and continuous variable
  - Persons with fracture have a higher risk score, on average, than persons without fracture
  - Highest risk scores seen among persons with no fracture

- There are 125 study participants with fracture and 375 study participants without fracture
- Least frequent outcome divided by 10 = 125/10 ≈ 13
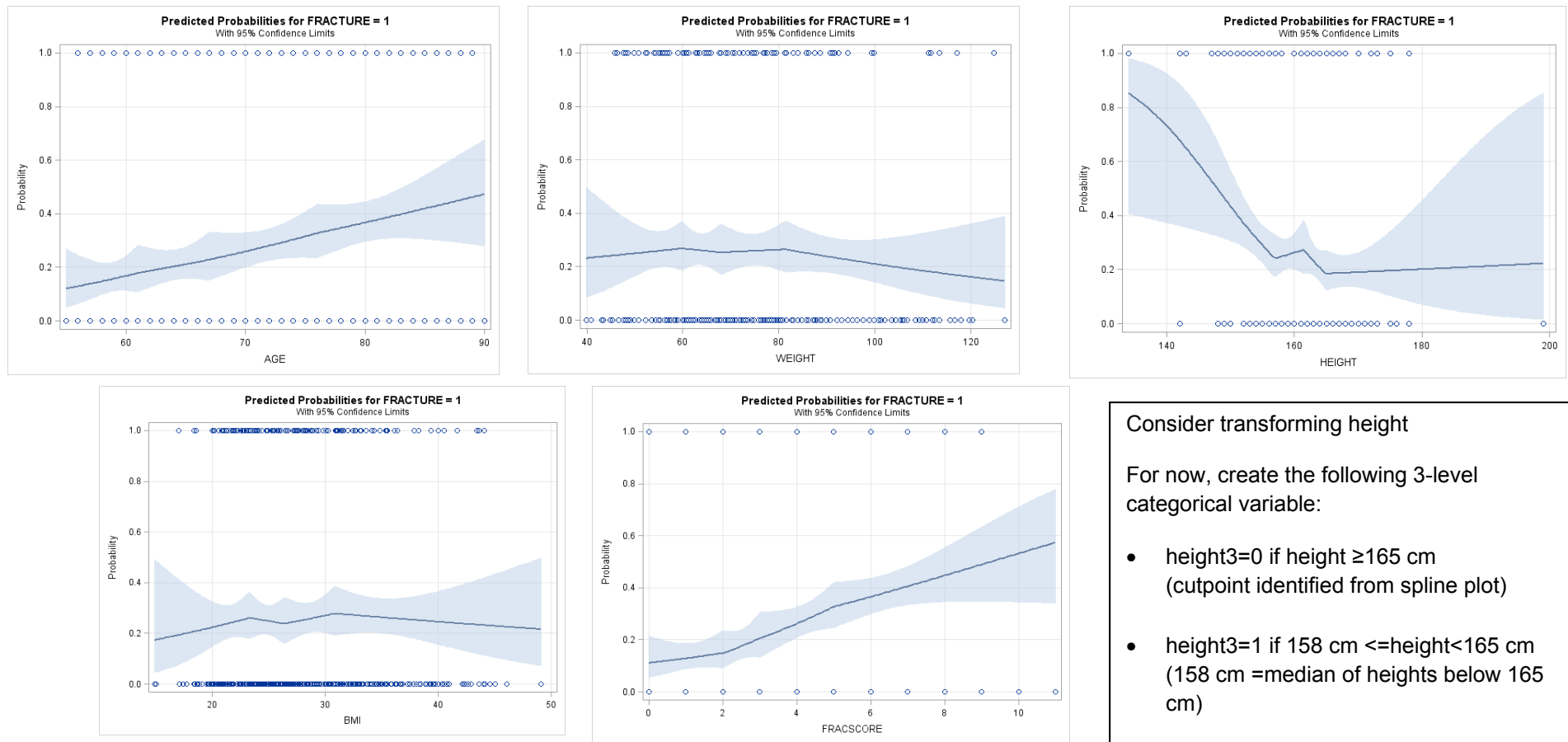- Model should not contain more than about 13 covariates

Figure 1: Spline effect plots; knots=1st quartile, median and 3rd quartile; linear connections

Consider transforming height

For now, create the following 3-level categorical variable:

- height3=0 if height ≥165 cm (cutpoint identified from spline plot)

- height3=1 if 158 cm <=height<165 cm (158 cm =median of heights below 165 cm)

- height3=2 if 134 cm <=height<158 cm (134 cm =minimum height)

Table 3: Univariate logistic regression results

Variable	Comparison/Unit	OR	95% CI		P-value
Site[1]	2 vs. 1	2.009	1.016	3.971	0.0448
	3 vs. 1	1.751	0.827	3.707	0.1432
	4 vs. 1	0.989	0.359	2.722	0.9827
	5 vs. 1	2.119	1.118	4.017	0.0214
	6 vs. 1	1.813	0.897	3.664	0.0975
Prior fracture	yes vs. no	2.897	1.871	4.486	<0.0001
Menopause before age 45	yes vs. no	1.052	0.633	1.749	0.8447
Mother had hip fracture	yes vs. no	1.936	1.116	3.358	0.0187
Needs arms to stand from chair	yes vs. no	2.032	1.347	3.066	0.0007
Former or current smokers	yes vs. no	0.735	0.313	1.727	0.4804
Self-reported fracture risk[2]	Same as others vs. less than others	1.727	1.024	2.911	0.0404
	Greater than others vs. less than others	2.482	1.459	4.223	0.0008
Height[3]	158 cm <=height<165 cm vs. height ≥165 cm	1.363	0.823	2.258	0.2291
	134 cm <=height<158 cm vs. height ≥165 cm	2.089	1.226	3.559	0.0067
Age	10	1.697	1.351	2.131	<0.0001
Weight	20	0.901	0.701	1.159	0.4179
BMI	5	1.029	0.870	1.218	0.7376
Fracture score	1	1.280	1.176	1.393	<0.0001

[1] Likelihood-Ratio test p-value=0.1538

[2] Likelihood-Ratio test p-value=0.0028

[3] Likelihood-Ratio test p-value=0.0230

Summary Table 3

Non-significant variables (p≥0.25):
- Menopause before age 45
- Former or current smokers
- Weight
- BMI
- Agrees with conclusions from tables 1 and 2

Significant variables (p<0.25):
- Site
- Prior fracture
- Mother had hip fracture
- Needs arms to stand from chair
- Self-reported fracture risk
- Height
- Age
- Fracture score

Table 4a: Multivariate logistic regression results – Initial main effects model (contains variables significant at the 0.25 level in univariate analyses)

Variable	Comparison/Unit	OR	95% CI		P-value
Site[1]	2 vs. 1	1.974	0.949	4.104	0.0687
	3 vs. 1	1.347	0.591	3.071	0.4784
	4 vs. 1	0.842	0.286	2.479	0.7556
	5 vs. 1	1.804	0.911	3.570	0.0905
	6 vs. 1	1.628	0.769	3.447	0.2026
Prior fracture	yes vs. no	2.236	1.135	4.408	0.0201
Mother had hip fracture	yes vs. no	2.032	0.956	4.320	0.0654
Needs arms to stand from chair	yes vs. no	1.724	0.700	4.246	0.2365
Self-reported fracture risk	Same as others vs. less than others	1.568	0.903	2.722	0.1099
	Greater than others vs. less than others	2.069	1.153	3.714	0.0148
Height	158 cm <=height<165 cm vs. height ≥165 cm	1.478	0.855	2.557	0.1620
	134 cm <=height<158 cm vs. height ≥165 cm	1.943	1.061	3.556	0.0313
Age	10	1.749	0.738	4.144	0.2040
Fracture score	1	0.901	0.594	1.365	0.6221

[1] Likelihood-Ratio test p-value=0.3037

Site: All p-values >0.05, three p-values > 0.2, Likelihood-Ratio test p-value> 0.3 ➔ Remove site

Table 4b: Multivariate logistic regression results – site variable removed

Variable	Comparison/Unit	OR	95% CI		P-value
Prior fracture	yes vs. no	2.102	1.076	4.106	0.0297
Mother had hip fracture	yes vs. no	2.004	0.949	4.233	0.0685
Needs arms to stand from chair	yes vs. no	1.794	0.731	4.402	0.2016
Self-reported fracture risk	Same as others vs. less than others	1.576	0.913	2.718	0.1022
	Greater than others vs. less than others	2.052	1.151	3.657	0.0148
Height	158 cm <=height<165 cm vs. height ≥165 cm	1.435	0.843	2.442	0.1832
	134 cm <=height<158 cm vs. height ≥165 cm	1.859	1.030	3.355	0.0394
Age	10	1.658	0.702	3.917	0.2490
Fracture score	1	0.924	0.610	1.399	0.7086

Remaining ORs hardly changed ➔ No evidence of confounding by site ➔ Do not return site
Fracture score: p>0.7 ➔ Remove fracture score

Table 4c: Multivariate logistic regression results – site and fracture score variables removed

Variable	Comparison/Unit	Estimate	95% CI		P-value
Prior fracture	yes vs. no	1.925	1.185	3.126	0.0081
Mother had hip fracture	yes vs. no	1.841	1.010	3.358	0.0464
Needs arms to stand from chair	yes vs. no	1.549	0.980	2.448	0.0608
Self-reported fracture risk	Same as others vs. less than others	1.573	0.912	2.715	0.1033
	Greater than others vs. less than others	2.031	1.142	3.611	0.0158
Height	158 cm <=height<165 cm vs. height ≥165 cm	1.436	0.844	2.444	0.1821
	134 cm <=height<158 cm vs. height ≥165 cm	1.827	1.020	3.271	0.0426
Age	10	1.418	1.096	1.834	0.0078

Fairly little change in remaining ORs ➔ No strong evidence of confounding by fracture score ➔ Do not return fracture score
Self-reported fracture risk: Consider combining "same as others" and "less than others"

Table 4d: Multivariate logistic regression results – site and fracture score variables removed, "same as others" and "less than others" categories for self-reported fracture risk combined

Variable	Comparison/Unit	OR	95% CI		P-value
Prior fracture	yes vs. no	1.964	1.212	3.184	0.0062
Mother had hip fracture	yes vs. no	1.926	1.059	3.503	0.0318
Needs arms to stand from chair	yes vs. no	1.592	1.010	2.508	0.0450
Self-reported fracture risk	Greater than others vs. same as/less than others	1.553	0.974	2.476	0.0645
Height	158 cm <=height<165 cm vs. height ≥165 cm	1.448	0.852	2.461	0.1713
	134 cm <=height<158 cm vs. height ≥165 cm	1.877	1.052	3.351	0.0331
Age	10	1.401	1.086	1.809	0.0096

Self-reported fracture risk (Greater than others vs. same as/less than others) is borderline non-significant at the 0.05 level. Keep for now.
Height: Consider combining 158 cm <=height<165 cm and height ≥165 cm

Table 4e: Multivariate logistic regression results – site and fracture score variables removed, "same as others" and "less than others" categories for self-reported fracture risk combined, 158 cm <=height<165 cm and height ≥165 cm combined

Variable	Comparison/Unit	OR	95% CI		P-value
Prior fracture	yes vs. no	1.927	1.192	3.117	0.0075
Mother had hip fracture	yes vs. no	1.899	1.049	3.437	0.0342
Needs arms to stand from chair	yes vs. no	1.567	0.996	2.465	0.0521
Self-reported fracture risk	Greater than others vs. same as/less than others	1.548	0.972	2.465	0.0657
Height	158 cm <=height<165 cm vs. height ≥165 cm	1.510	0.933	2.442	0.0931
Age	10	1.419	1.101	1.831	0.0070

Height (158 cm <=height<165 cm vs. height ≥165 cm) is non-significant at the 0.05 level.

The model in Table 4d is the provisional main effects model.

Table 5: Results for variables with univariate p-values≥0.25 when added, one at a time, to the model in Table 4d

Variable	Comparison/Unit	OR	95% CI		P-value
Menopause before age 45	yes vs. no	1.194	0.689	2.070	0.5268
Former or current smokers	yes vs. no	0.705	0.287	1.729	0.4447
Weight	20	1.096	0.803	1.497	0.5634
BMI	5	1.112	0.908	1.361	0.3062

None of the variables are statistically significant at the 0.05 level.
Comparisons of the ORs in Table 4d to the corresponding ORs after inclusion of an additional variable do not suggest evidence of confounding

Table 6: Results of multivariate fp procedure for height and age

Variable	Transformation	Deviance	Comparison	P-value
Height	Linear	509.818		
	Best 1-power ($\frac{1}{x^2}$)	509.137	Best 1-power vs. linear	0.4095
	Best 2-power ($\frac{1}{x^2}$ and $\frac{1}{x^2}\ln(x)$)	507.984	Best 2-power vs. linear	0.6075
			Best 2-power vs. best 1-power	0.5616
Age	Linear	509.818		
	Best 1-power ($\frac{1}{x^2}$)	509.257	Best 1-power vs. linear	0.4540
	Best 2-power (x^3 and $x^3\ln(x)$)	508.953	Best 2-power vs. linear	0.8339
			Best 2-power vs. best 1-power	0.8589

No transformations suggested

Table 7: Multivariate logistic regression results – site and fracture score variables removed, "same as others" and "less than others" categories for self-reported fracture risk combined, height continuous

Parameter	Comparison/Unit	OR	95% CI		P-value
Intercept					0.2836
Prior fracture	yes vs. no	1.943	1.201	3.142	0.0068
Mother had hip fracture	yes vs. no	1.943	1.067	3.536	0.0298
Needs arms to stand from chair	yes vs. no	1.604	1.020	2.525	0.0410
Self-reported fracture risk	Greater than others vs. same as/less than others	1.581	0.991	2.521	0.0544
Height	10	0.629	0.441	0.898	0.0106
Age	10	1.393	1.081	1.796	0.0104

The continuous linear height variable is highly statistically significant; keep height continuous and linear

Model seems stable (no ridiculously large ORs or 95% CIs).

The model in Table 7 is the final main effects model.

Table 8: Multiplicative interaction terms added to the model in Table 7 one at a time

Interaction	P-value
Prior fracture × Mother had hip fracture	0.0947
Prior fracture × Needs arms to stand from chair	0.6357
Prior fracture × Self-reported fracture risk	0.7265
Prior fracture × Height	0.6442
Prior fracture × Age	0.0248
Mother had hip fracture × Needs arms to stand from chair	0.0302
Mother had hip fracture × Self-reported fracture risk	0.4652
Mother had hip fracture × Height	0.1184
Mother had hip fracture × Age	0.7081
Needs arms to stand from chair × Self-reported fracture risk	0.1354
Needs arms to stand from chair × Height	0.2076
Needs arms to stand from chair × Age	0.7020
Self-reported fracture risk × Height	0.3198
Self-reported fracture risk × Age	0.3055
Height × Age	0.7155

Significant at the 0.1 level:

- Prior fracture × Mother had hip fracture
- Prior fracture × Age
- Mother had hip fracture × Needs arms to stand from chair

Table 9a: Statistically significant multiplicative interaction terms added to the model in Table 7 together

Variable	P-value
Intercept	0.5558
Prior fracture	0.0144
Mother had hip fracture	0.0005
Needs arms to stand from chair	0.0137
Self-reported fracture risk	0.0492
Height	0.0080
Age	0.0005
Prior fracture * Mother had hip fracture	0.1910
Age*Prior fracture	0.0399
Mother had hip fracture * Needs arms to stand from chair	0.0585

Prior fracture × Mother had hip fracture no longer statistically significant at the 0.1 level ➔ remove

Table 9b: Statistically significant multiplicative interaction terms added together without Prior fracture × Mother had hip fracture

Variable	P-value
Intercept	0.6051
Prior fracture	0.0142
Mother had hip fracture	0.0015
Needs arms to stand from chair	0.0106
Self-reported fracture risk	0.0515
Height	0.0108
Age	0.0005
Age*Prior fracture	0.0331
Mother had hip fracture * Needs arms to stand from chair	0.0398

Remaining two interaction terms are statistically significant

At this point you may want to test the significance of interactions between model covariates and selected other study variables. We'll skip this step here.

Table 10: Final model

Variable	Coefficient	Standard Error	Wald Chi-Square	P-value
Intercept	1.7175	3.3217	0.2673	0.6051
Prior fracture	4.6117	1.8802	6.0163	0.0142
Mother had hip fracture	1.2465	0.3930	10.0630	0.0015
Needs arms to stand from chair	0.6441	0.2519	6.5370	0.0106
Self-reported fracture risk	0.4690	0.2408	3.7935	0.0515
Height	-0.0467	0.0183	6.5005	0.0108
Age	0.0573	0.0165	12.0578	0.0005
Age*Prior fracture	-0.0553	0.0259	4.5423	0.0331
Mother had hip fracture * Needs arms to stand from chair	-1.2804	0.6230	4.2243	0.0398

Table 11: Selected odds ratios and 95% confidence intervals based on the final model

Variable	Comparison/Unit	OR	95% CI		P-value
Self-reported fracture risk	Greater than others vs. same as/less than others	1.60	1.00	2.56	0.0515
Height	10 cm increase	0.63	0.44	0.90	0.0108
Prior fracture	Yes vs.no at age 55	4.82	1.80	12.86	0.0017
	Yes vs.no at age 60	3.65	1.69	7.89	0.0010
	Yes vs.no at age 65	2.77	1.53	5.01	0.0007
	Yes vs.no at age 70	2.10	1.29	3.42	0.0027
	Yes vs.no at age 75	1.59	0.97	2.63	0.0681
	Yes vs.no at age 80	1.21	0.64	2.27	0.5533
	Yes vs.no at age 85	0.92	0.40	2.08	0.8369
	Yes vs.no at age 90	0.70	0.25	1.96	0.4930
Age	10 year age increase among those with a prior fracture	1.02	0.68	1.53	0.9216
	10 year age increase among those without a prior fracture	1.77	1.28	2.45	0.0005
Mother had hip fracture	Yes vs. no among those who need arms to stand from chair	1.00	0.38	2.49	0.9440
	Yes vs. no among those who don't need arms to stand from chair	3.48	1.61	7.51	0.0015
Needs arms to stand from chair	Needs vs. doesn't need arms to stand from chair among those whose mother had a hip fracture	0.53	0.17	1.64	0.2713
	Needs vs. doesn't need arms to stand from chair among those whose mother didn't have a hip fracture	1.90	1.16	3.12	0.0106

Model seems stable (no ridiculously large coefficients or SEs in Table 10 or ridiculously large ORs or 95% CIs in Table 11).

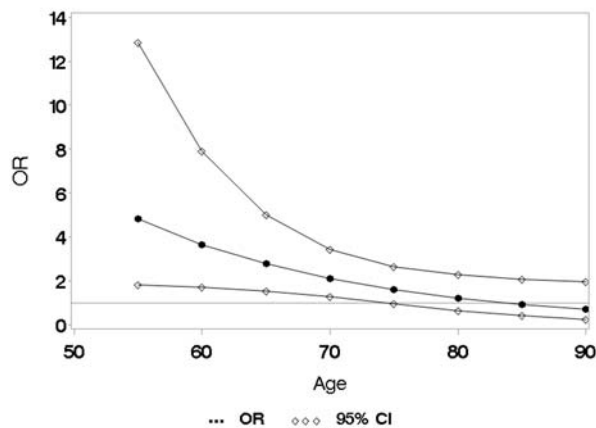The model in Tables 10 and 11 is the final model.

Figure 2: Odds ratios and 95% confidence intervals for prior fracture (yes vs. no) by age

Interpretations

Self-reported fracture risk
- Persons who self-report a greater fracture risk than others of the same age are 1.6 times as likely to have a fracture in the first year as persons who self-report a similar or lower fracture risk than others of the same age. The increased risk is borderline non-significant at the 0.05 level.

Height
- A 10 cm increase in height significantly decreases the risk of a fracture in the first year by almost 40%.

Prior fracture and age
- The effect of a prior fracture decreases with increasing age. Among 55 year olds, having had a prior fracture significantly increases the risk of a fracture in the first year almost 5fold.   Among 75 year olds, having had a prior fracture increases the risk of a fracture in the first year approximately 1.6fold but the increase is not statistically significant. After age 85, no increase in risk is observed.
- Age is only important among persons without a prior fracture. In this subgroup, a 10 year increase in age significantly increases the risk of a fracture in the first year by about 75%.

Mother with hip fracture and needing arms to stand up from chair

- Having a mother who had a hip fracture is a risk factor among persons who don't need their arms to stand from a chair. In this subgroup, persons whose mother had a hip fracture are 3.5 times as likely to have a fracture in the first year as persons whose mother did not have a hip fracture.
- Having a mother who had a hip fracture has no effect among persons who do need their arms to stand from a chair.

- Needing arms to stand from a chair is a risk factor among those whose mother did not have a hip fracture. In this subgroup, persons who need arms to stand from a chair are almost twice as likely to have a fracture in the first year as persons who don't need arms to stand from a chair.
- Needing arms to stand from a chair appears to be beneficial among those whose mother did have a hip fracture. In this subgroup, persons who need arms to stand from a chair are about half as likely to have a fracture in the first year as persons who don't need arms to stand from a chair. However, the decreased risk is not statistically significant.