Final Project - BIOS 6643

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Introduction

Sarcoidosis is a potentially lethal disease with ~ 25,000 new cases diagnosed in the United States each year. The disease is characterized by granulomas, and the vast majority (90%) of cases primarily affect the lung. Currently, the standard in care for assessing sarcoidosis are lung images utilizing computed tomography (CT). While this method provides better characterizing of abnormalities compared to chest x-rays there are two primary problems; 1.) CT is primarily based on visual assessment, resulting in high inter- and intra-rater variation, and 2.) these visual assessments are not strongly predictive of disease course. Recently, a new method to better quantify measures of lung CT has been developed utilizing variograms. Variograms are a standard geostatistical too for measuring and modelling spatial covariance within an image, as well as spatial process as a function of distance between points.

Variogram data is typically represented by three parameters: 1.) the sill, 2.) the range, and 3.) the nugget. The sill is the overall variation present in an image, the range represents the spatial scale of correlation, and the nugget is the variation due to measurement error. For sufficiently high resolution images the nugget is 0, which will be assumed for this analysis. The location of each individual scan is represented by the normalized slice variable spanning 0 to 1, corresponding to the bottom and top of the lung respectively.

The purpose of this analysis is to answer two primary questions of interest:

Should race be included as a demographic feature that is adjusted for?

How do clinical measures of disease associate with the lungs after adjusting for demographics?

There are six total clinical measures of disease. Three of these are PFT measurements: FEV1 (Forced Expiratory Volume in 1 second), FVC (Forced Vital Capacity), and FEV1/FVC ratio (provided as a fraction). The other three are VAS (Visual Assessment Scores): fibrosis, mediastinal lymphadenopathy, and traction

bronchiectasis. Demographics other than race are BMI, age, sex, and height. Analysis will involve comparing models with and without race to determine the impact of including this as a demographic feature, and plots will be presented to illustrated trends in clinical features for both sill and range. Additionally, further research on the ethical and clinical/scientific justification for inclusion of race as a predictor in sarcoidosis was performed.

Methods

Data

The data for this analysis was compiled from two main sources, clinical measurements and variogram measurements. The clinical measurements provided the demographic data and the PFT and VAS measurements, and included 368 subjects. Cleaning the clinical data involved several steps. For simplicity in modeling VAS measurements were considered a binary indicating presence of the condition or no presence of the condition. Both traction bronchiectasis and mediastinal lymphadenopathy had four potential levels, which were then collapsed into binary indicators. Fibrosis was already a binary variable, meaning this step was not necessary for this variable. The construction of the race variable involved combining the provided race and ethnicity variables. The race categories initially had 6 possible options, Black or African American, American Indian or Alaskan Native, white, multi-racial or no primary race, Asian, and unknown. The ethnicity variable denoted whether a subject was Hispanic or not Hispanic. The race variable used in this analysis first involved separating white subjects into Hispanic white and non-Hispanic white. After this race was collapsed into three categories: 1.) non-Hispanic white, 2.) Black or African American, 3.) and other, which incorporated American Indian or Alaskan Native, multi-racial or no primary race, Asian, unknown, and Hispanic white. Two important features are that subjects who were missing race/ethnicity data were considered "NA", which is distinct from the "unknown" category, and the majority of subjects were non-Hispanic white, followed by Black or African American. The composite category of "other" had the smallest amount of subjects.

Variogram data included information regarding the subject ID for each measurement, as well as which lung each measurement came from. Variogram measurements had three components, the range, the psill, and the slice normalized variable, which indicated location in the lung. Values closer to 0 correspond to the bottom of the lung, and values closer to 1 correspond to the top of the lung. For this analysis normalized slice values between 0.1 and 0.9 were used to avoid measurement variations of the top and bottom-most portion of scans. In general each subject had 50 slices per lung, meaning a total of 100 scans per subject. Two subjetc were

dropped during initial data cleaning, one due to an outlier in the range measurement (> 300), and another due to missing data on the left lung. Out of the original 342 subject 340 were kept after dropping these two. Lastly, psill and range were log transformed due to prominant right-skew in the distribution of each.

After initial cleaning both data sets were combined. As there were more subject with clinical data than variogram data the subject IDs for variogram data were used for the combining, resulting in a composite data frame of 342 subjects. A complete case analysis was performed, meaning subjects missing any of relevant demographic data were dropped from the analysis. After dropping there were 320 subjects total.

Analysis

Analysis utilized cubic penalized splines with 4 degrees of freedom to model the relationship between location in the lung and each of the two variogram predictors (psill and range). This approach allowed for non-linear associations between the clinical predictors and location in the lung. Outcomes for both psill and range were considered Gaussian-distributed. Models for each clinical predictor were made separately, with each outcome being having its own model, and each lung having its own model. Additionally, models including race and excluding race were compared. In total, each clinical predictor had 4 models for each outcome (right lung psill and range, left lung psill and range) including race and 4 models for each outcome excluding race. Between the six predictors this results in a total of 48 models.

Models including and excluding race were compared with AIC, where lower scores mean better model fitting.

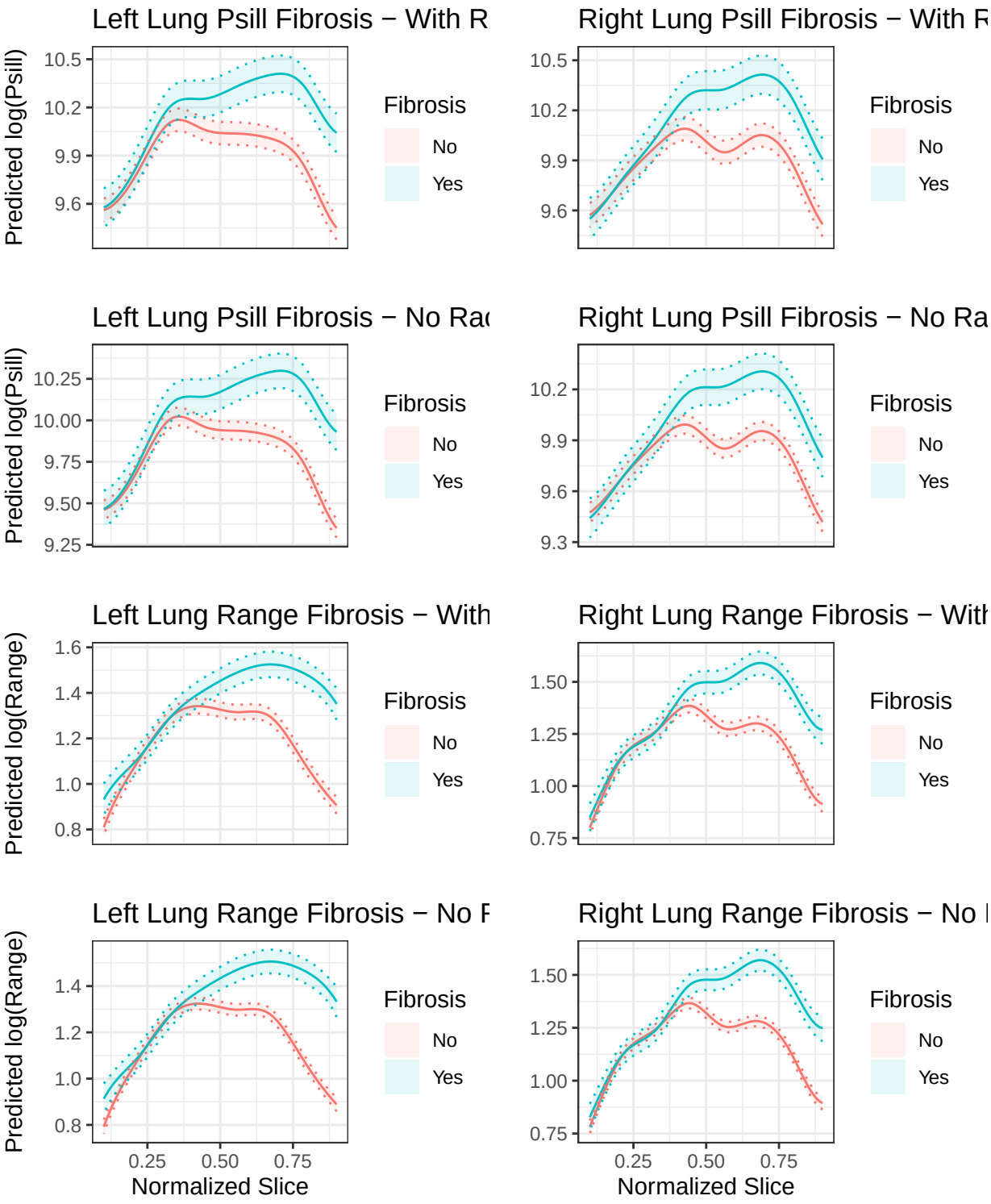
Fibrosis

Table 1: Summary of Models for Fibrosis

	Left Lung					Right Lung				
Term	**Estimate**	**SE**	**P-Value**	**EDF**	**Ref. DF**	**Estimate**	**SE**	**P-Value**	**EDF**	**Ref. DF**
Outcome: Psill | With Race										
Intercept	10.2597	0.3977	<2e-16	NA	NA	10.0292	0.3965	<2e-16	NA	NA
BMI	0.0031	0.0025	0.2	NA	NA	0.0034	0.0025	0.18	NA	NA
Age	0.0017	0.0017	0.3	NA	NA	0.0031	0.0017	0.06	NA	NA
Male	0.0271	0.0434	0.5	NA	NA	0.0480	0.0433	0.27	NA	NA
Height	-0.0081	0.0054	0.1	NA	NA	-0.0060	0.0054	0.27	NA	NA
Other Races	-0.1084	0.0675	0.1	NA	NA	-0.1027	0.0673	0.13	NA	NA
Non-Hispanic White	-0.1616	0.0380	2e-05	NA	NA	-0.1574	0.0379	3e-05	NA	NA
s(Slice)	NA	NA	<2e-16	8.5137	8.8983	NA	NA	<2e-16	8.4116	8.8505
s(ID)	NA	NA	<2e-16	307.5549	312.0000	NA	NA	<2e-16	307.1460	312.0000
s(Slice):Fibrosis	NA	NA	<2e-16	4.2561	4.9289	NA	NA	<2e-16	6.7540	7.5551
Outcome: Psill | Without Race										
Intercept	9.9869	0.4022	<2e-16	NA	NA	9.7647	0.4005	<2e-16	NA	NA
BMI	0.0044	0.0026	0.09	NA	NA	0.0046	0.0026	0.07	NA	NA
Age	0.0015	0.0017	0.39	NA	NA	0.0029	0.0017	0.09	NA	NA
Male	-0.0094	0.0435	0.83	NA	NA	0.0126	0.0433	0.77	NA	NA
Height	-0.0059	0.0055	0.28	NA	NA	-0.0039	0.0055	0.48	NA	NA
s(Slice)	NA	NA	<2e-16	8.5136	8.8983	NA	NA	<2e-16	8.4117	8.8505

Table 1: Summary of Models for Fibrosis *(continued)*

Term	Estimate	SE	P-Value	EDF	Ref. DF	Estimate	SE	P-Value	EDF	Ref. DF
s(ID)	NA	NA	<2e-16	309.7666	314.0000	NA	NA	<2e-16	309.3663	314.0000
s(Slice):Fibrosis	NA	NA	<2e-16	4.2565	4.9294	NA	NA	<2e-16	6.7551	7.5561
Outcome: Range | With Race										
Intercept	1.2840	0.1805	1e-12	NA	NA	1.3706	0.1803	3e-14	NA	NA
BMI	-0.0011	0.0011	0.349	NA	NA	-0.0016	0.0011	0.17	NA	NA
Age	0.0008	0.0008	0.279	NA	NA	0.0016	0.0008	0.03	NA	NA
Male	0.0515	0.0197	0.009	NA	NA	0.0406	0.0197	0.04	NA	NA
Height	-0.0016	0.0025	0.504	NA	NA	-0.0032	0.0024	0.20	NA	NA
Other Races	0.0009	0.0306	0.976	NA	NA	-0.0245	0.0306	0.42	NA	NA
Non-Hispanic White	-0.0293	0.0172	0.090	NA	NA	-0.0299	0.0172	0.08	NA	NA
s(Slice)	NA	NA	<2e-16	7.7680	8.3997	NA	NA	<2e-16	8.5513	8.9123
s(ID)	NA	NA	<2e-16	294.8383	312.0000	NA	NA	<2e-16	294.9661	312.0000
s(Slice):Fibrosis	NA	NA	<2e-16	7.2006	7.9544	NA	NA	<2e-16	5.9516	6.7765
Outcome: Range | Without Race										
Intercept	1.2441	0.1786	3e-12	NA	NA	1.3181	0.1782	1e-13	NA	NA
BMI	-0.0008	0.0011	0.48	NA	NA	-0.0013	0.0011	0.25	NA	NA
Age	0.0008	0.0008	0.32	NA	NA	0.0016	0.0008	0.04	NA	NA
Male	0.0463	0.0193	0.02	NA	NA	0.0336	0.0193	0.08	NA	NA
Height	-0.0014	0.0024	0.58	NA	NA	-0.0027	0.0024	0.26	NA	NA
s(Slice)	NA	NA	<2e-16	7.7681	8.3998	NA	NA	<2e-16	8.5513	8.9123
s(ID)	NA	NA	<2e-16	296.9197	314.0000	NA	NA	<2e-16	297.0172	314.0000
s(Slice):Fibrosis	NA	NA	<2e-16	7.2024	7.9561	NA	NA	<2e-16	5.9519	6.7767



Mediastinal Lymphadenopathy (ML)

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## resized.
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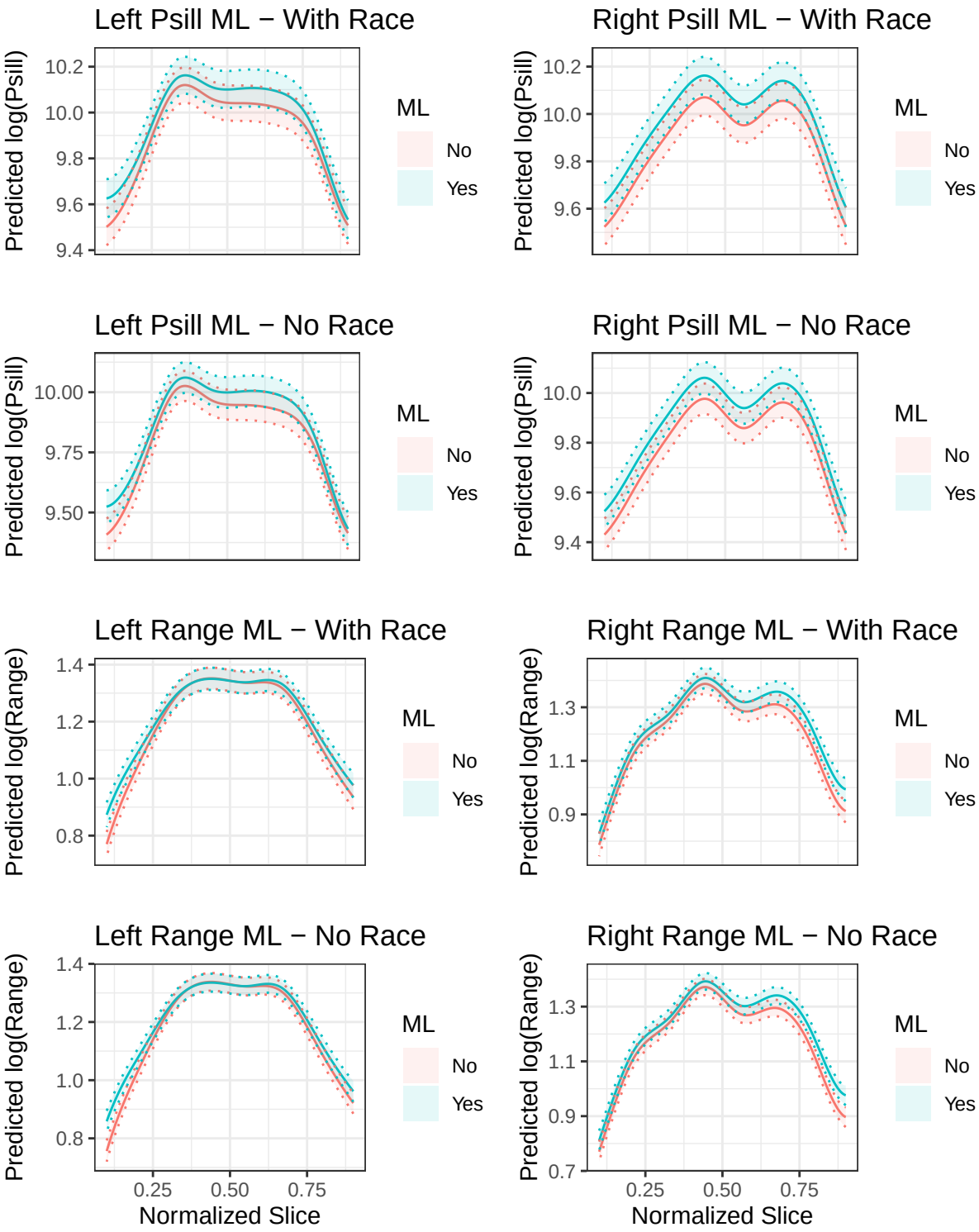
Table 2: Summary of Models for Mediastinal Lymphadenopathy (ML)

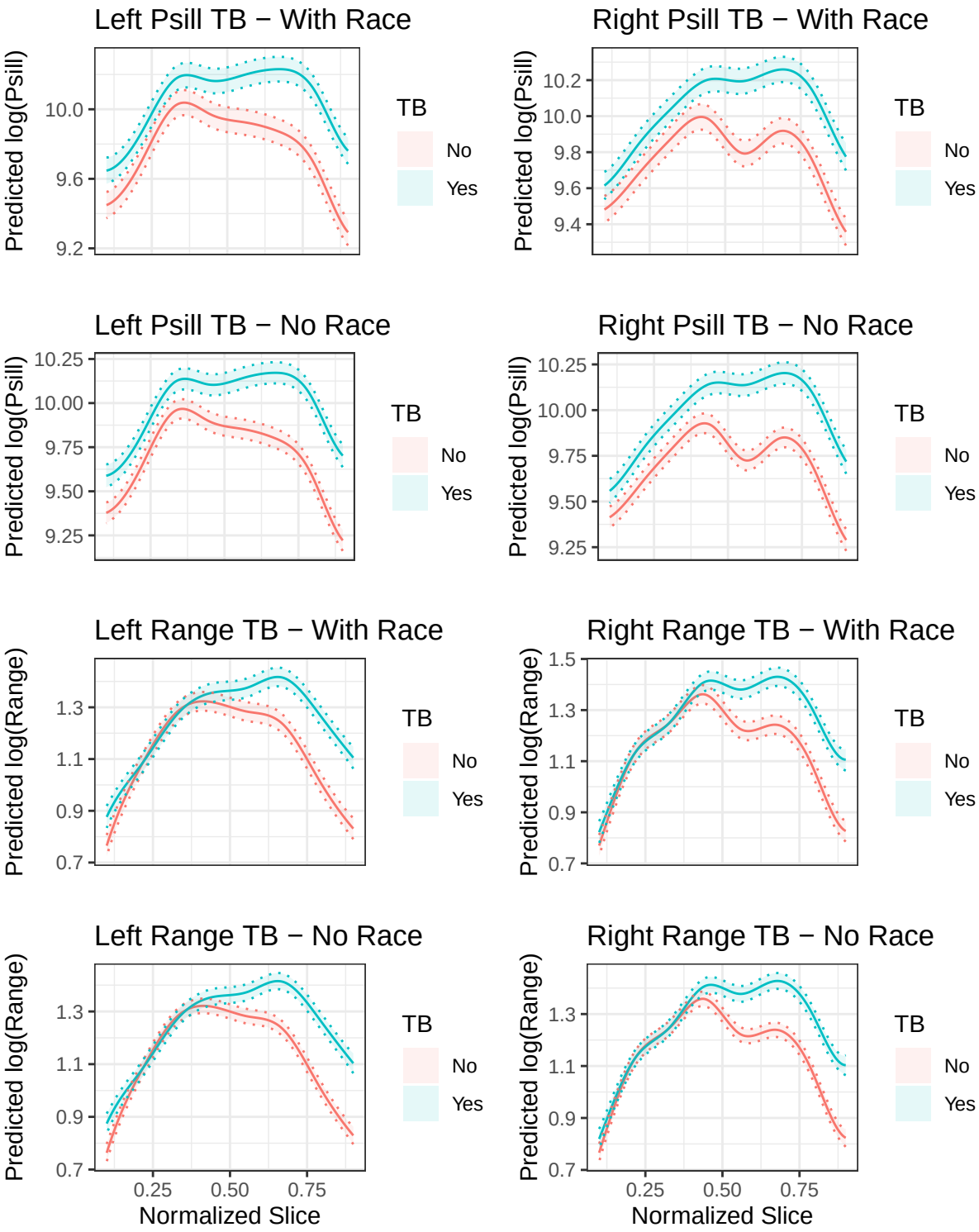
	Left Lung					Right Lung			
Term	**Estimate**	**SE**	**P-Value**	**EDF**	**Ref. DF**	**Estimate**	**SE**	**P-Value**	**EDF**
Outcome: Psill | With Race									
Intercept	10.16950	0.41337	<2e-16	NA	NA	9.90487	0.40554	<2e-16	NA
BMI	0.00117	0.00257	0.6	NA	NA	0.00176	0.00253	0.487	NA
Age	0.00139	0.00173	0.4	NA	NA	0.00263	0.00170	0.121	NA
Male	0.00112	0.04500	1.0	NA	NA	0.02013	0.04415	0.648	NA
Height	-0.00556	0.00560	0.3	NA	NA	-0.00319	0.00550	0.562	NA
Other Races	-0.09654	0.06981	0.2	NA	NA	-0.09626	0.06849	0.160	NA
Non-Hispanic White	-0.15576	0.03932	7e-05	NA	NA	-0.15506	0.03858	6e-05	NA
s(Slice)	NA	NA	<2e-16	8.47249	8.87652	NA	NA	<2e-16	8.36743
s(ID)	NA	NA	<2e-16	307.60405	312.00000	NA	NA	<2e-16	307.10810
s(Slice):ML	NA	NA	2e-05	4.99084	5.75240	NA	NA	0.005	2.00109
Outcome: Psill | Without Race									
Intercept	9.92039	0.41715	<2e-16	NA	NA	9.65681	0.40954	<2e-16	NA
BMI	0.00248	0.00262	0.3	NA	NA	0.00306	0.00257	0.23	NA
Age	0.00121	0.00177	0.5	NA	NA	0.00245	0.00174	0.16	NA
Male	-0.03173	0.04504	0.5	NA	NA	-0.01258	0.04421	0.78	NA
Height	-0.00370	0.00571	0.5	NA	NA	-0.00133	0.00560	0.81	NA
s(Slice)	NA	NA	<2e-16	8.47244	8.87650	NA	NA	<2e-16	8.36747
s(ID)	NA	NA	<2e-16	309.78427	314.00000	NA	NA	<2e-16	309.31517
s(Slice):ML	NA	NA	2e-05	4.99142	5.75303	NA	NA	0.01	2.00033
Outcome: Range | With Race									
Intercept	1.24432	0.19480	2e-10	NA	NA	1.31210	0.19230	9e-12	NA
BMI	-0.00236	0.00121	0.05	NA	NA	-0.00275	0.00120	0.02	NA
Age	0.00072	0.00081	0.38	NA	NA	0.00142	0.00080	0.08	NA
Male	0.03686	0.02121	0.08	NA	NA	0.02425	0.02094	0.25	NA
Height	-0.00026	0.00264	0.92	NA	NA	-0.00157	0.00261	0.55	NA
Other Races	0.01014	0.03290	0.76	NA	NA	-0.01738	0.03247	0.59	NA
Non-Hispanic White	-0.02442	0.01853	0.19	NA	NA	-0.02648	0.01829	0.15	NA
s(Slice)	NA	NA	<2e-16	7.62598	8.27083	NA	NA	<2e-16	8.53294
s(ID)	NA	NA	<2e-16	296.40718	312.00000	NA	NA	<2e-16	296.28256
s(Slice):ML	NA	NA	<2e-16	4.72761	5.45831	NA	NA	4e-08	3.62355
Outcome: Range | Without Race									
Intercept	1.21648	0.19269	3e-10	NA	NA	1.26931	0.19005	2e-11	NA
BMI	-0.00213	0.00121	0.08	NA	NA	-0.00253	0.00119	0.03	NA
Age	0.00066	0.00082	0.42	NA	NA	0.00139	0.00081	0.08	NA
Male	0.03340	0.02080	0.11	NA	NA	0.01860	0.02052	0.36	NA
Height	-0.00011	0.00264	0.97	NA	NA	-0.00125	0.00260	0.63	NA
s(Slice)	NA	NA	<2e-16	7.62600	8.27085	NA	NA	<2e-16	8.53294
s(ID)	NA	NA	<2e-16	298.43738	314.00000	NA	NA	<2e-16	298.28522
s(Slice):ML	NA	NA	<2e-16	4.72784	5.45857	NA	NA	<2e-16	3.62362



Traction Bronchiectasis (TB)

Table 3: Summary of Models for Traction Bronchiectasis (TB)

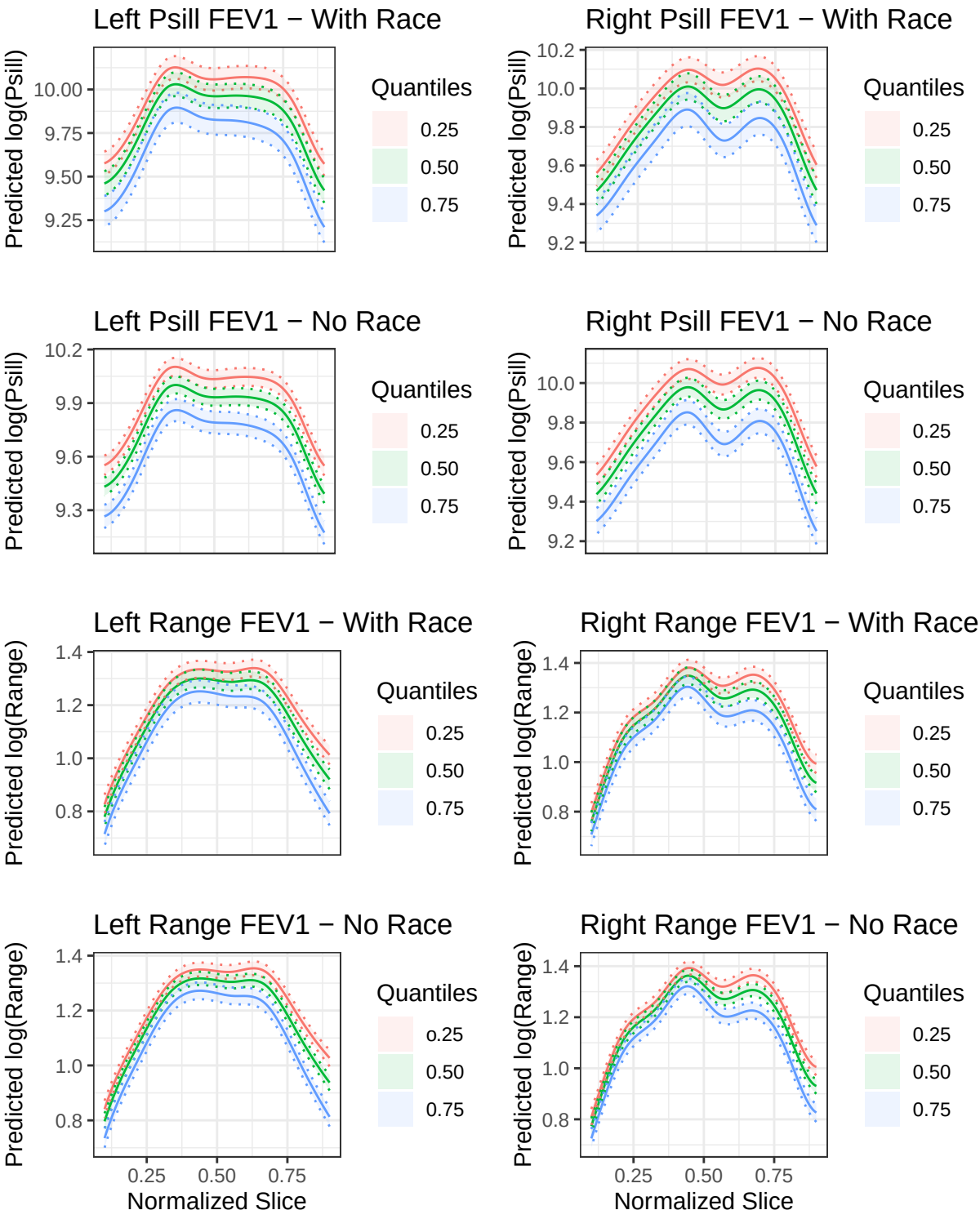
	Left Lung					Right Lung			
Term	**Estimate**	**SE**	**P-Value**	**EDF**	**Ref. DF**	**Estimate**	**SE**	**P-Value**	**EDF**
Outcome: Psill | With Race									
Intercept	10.00629	0.37176	<2e-16	NA	NA	9.77195	0.36387	<2e-16	NA
BMI	0.00440	0.00235	0.061	NA	NA	0.00502	0.00230	0.029	NA
Age	-0.00028	0.00156	0.858	NA	NA	0.00110	0.00153	0.473	NA
Male	0.00961	0.04035	0.812	NA	NA	0.03281	0.03949	0.406	NA
Height	-0.00505	0.00503	0.316	NA	NA	-0.00311	0.00492	0.528	NA
Other Races	-0.03498	0.06315	0.580	NA	NA	-0.03008	0.06181	0.626	NA
Non-Hispanic White	-0.10720	0.03573	0.003	NA	NA	-0.10316	0.03497	0.003	NA
s(Slice)	NA	NA	<2e-16	8.51344	8.89502	NA	NA	<2e-16	8.49022
s(ID)	NA	NA	<2e-16	306.85332	312.00000	NA	NA	<2e-16	306.22110
s(Slice):TB	NA	NA	<2e-16	5.37064	6.16631	NA	NA	<2e-16	8.06327
Outcome: Psill | Without Race									
Intercept	9.83577	0.37065	<2e-16	NA	NA	9.60955	0.36267	<2e-16	NA
BMI	0.00548	0.00236	0.02	NA	NA	0.00606	0.00231	0.009	NA
Age	-0.00056	0.00158	0.72	NA	NA	0.00083	0.00155	0.593	NA
Male	-0.01114	0.03995	0.78	NA	NA	0.01308	0.03909	0.738	NA
Height	-0.00384	0.00507	0.45	NA	NA	-0.00196	0.00496	0.692	NA
s(Slice)	NA	NA	<2e-16	8.51341	8.89500	NA	NA	<2e-16	8.49027
s(ID)	NA	NA	<2e-16	308.97280	314.00000	NA	NA	<2e-16	308.35171
s(Slice):TB	NA	NA	<2e-16	5.37091	6.16659	NA	NA	<2e-16	8.06386
Outcome: Range | With Race									
Intercept	1.17968	0.18123	8e-11	NA	NA	1.26386	0.17901	2e-12	NA
BMI	-0.00109	0.00115	0.34	NA	NA	-0.00147	0.00113	0.2	NA
Age	0.00006	0.00076	0.94	NA	NA	0.00084	0.00075	0.3	NA
Male	0.04017	0.01967	0.04	NA	NA	0.02978	0.01943	0.1	NA
Height	-0.00005	0.00245	0.98	NA	NA	-0.00160	0.00242	0.5	NA
Other Races	0.03434	0.03078	0.26	NA	NA	0.00918	0.03041	0.8	NA
Non-Hispanic White	-0.00533	0.01742	0.76	NA	NA	-0.00568	0.01720	0.7	NA
s(Slice)	NA	NA	<2e-16	7.68792	8.32766	NA	NA	<2e-16	8.57290
s(ID)	NA	NA	<2e-16	294.96882	312.00000	NA	NA	<2e-16	294.79186
s(Slice):TB	NA	NA	<2e-16	6.43847	7.25602	NA	NA	<2e-16	6.65660
Outcome: Range | Without Race									
Intercept	1.18833	0.17857	3e-11	NA	NA	1.26006	0.17592	8e-13	NA
BMI	-0.00101	0.00114	0.38	NA	NA	-0.00141	0.00112	0.2	NA
Age	0.00001	0.00076	0.99	NA	NA	0.00081	0.00075	0.3	NA
Male	0.04158	0.01925	0.03	NA	NA	0.02942	0.01896	0.1	NA
Height	-0.00020	0.00244	0.93	NA	NA	-0.00160	0.00241	0.5	NA
s(Slice)	NA	NA	<2e-16	7.68791	8.32765	NA	NA	<2e-16	8.57291
s(ID)	NA	NA	<2e-16	296.96717	314.00000	NA	NA	<2e-16	296.70074
s(Slice):TB	NA	NA	<2e-16	6.43863	7.25618	NA	NA	<2e-16	6.65665


Left Psill TB − With Race
Predicted log(Psill)
10.0
9.6
9.2
TB
No
Yes
Right Psill TB − With Race
Predicted log(Psill)
10.2
10.0
9.8
9.6
9.4
TB
No
Yes
Left Psill TB − No Race
Predicted log(Psill)
10.25
10.00
9.75
9.50
9.25
TB
No
Yes
Right Psill TB − No Race
Predicted log(Psill)
10.25
10.00
9.75
9.50
9.25
TB
No
Yes
Left Range TB − With Race
Predicted log(Range)
1.3
1.1
0.9
0.7
TB
No
Yes
Right Range TB − With Race
Predicted log(Range)
1.5
1.3
1.1
0.9
0.7
TB
No
Yes
Left Range TB − No Race
Predicted log(Range)
1.3
1.1
0.9
0.7
0.25
0.50
0.75
Normalized Slice
TB
No
Yes
Right Range TB − No Race
Predicted log(Range)
1.3
1.1
0.9
0.7
0.25
0.50
0.75
Normalized Slice
TB
No
Yes

FEV1

Table 4: Summary of Models for FEV1

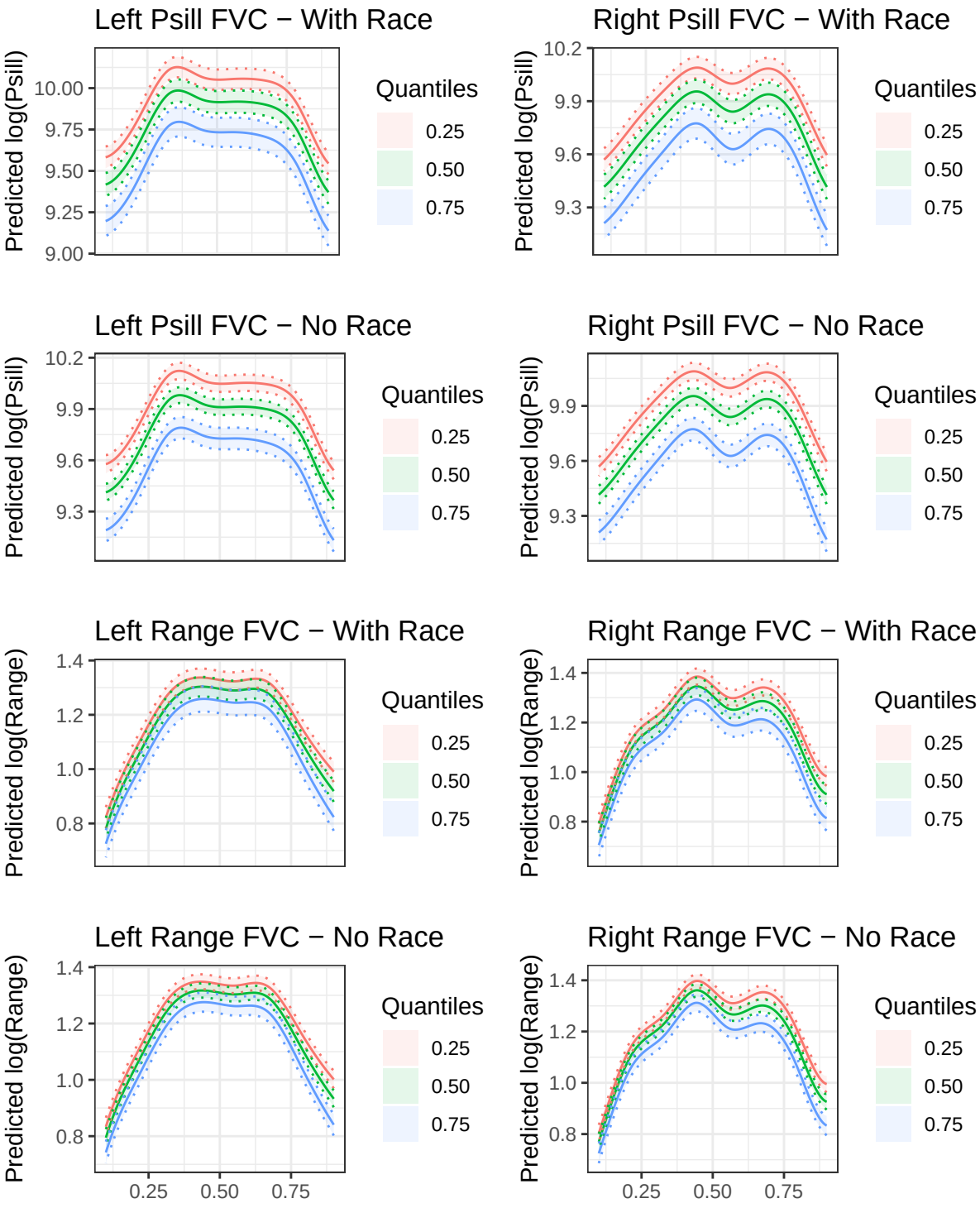
	Left Lung					Right Lung			
Term	**Estimate**	**SE**	**P-Value**	**EDF**	**Ref. DF**	**Estimate**	**SE**	**P-Value**	**EDF**
Outcome: Psill | With Race									
Intercept	10.04239	0.36986	<2e-16	NA	NA	9.82668	0.37014	<2e-16	NA
BMI	0.00028	0.00231	0.903	NA	NA	0.00085	0.00231	0.713	NA
Age	-0.00450	0.00169	0.008	NA	NA	-0.00267	0.00169	0.114	NA
Male	0.11603	0.04187	0.006	NA	NA	0.13256	0.04190	0.002	NA
Height	0.00789	0.00525	0.133	NA	NA	0.00889	0.00526	0.091	NA
Other Races	-0.02708	0.06296	0.667	NA	NA	-0.02761	0.06300	0.661	NA
Non-Hispanic White	-0.04349	0.03719	0.242	NA	NA	-0.04736	0.03722	0.203	NA
s(Slice)	NA	NA	<2e-16	8.30046	8.74502	NA	NA	<2e-16	5.90979
s(ID)	NA	NA	<2e-16	306.59394	312.00000	NA	NA	<2e-16	306.20319
s(Slice):FEV1	NA	NA	<2e-16	5.69606	6.49358	NA	NA	<2e-16	8.93362
Outcome: Psill | Without Race									
Intercept	9.96901	0.36398	<2e-16	NA	NA	9.74764	0.36441	<2e-16	NA
BMI	0.00058	0.00230	0.801	NA	NA	0.00118	0.00230	0.608	NA
Age	-0.00482	0.00167	0.004	NA	NA	-0.00302	0.00167	0.070	NA
Male	0.11196	0.04156	0.007	NA	NA	0.12828	0.04161	0.002	NA
Height	0.00899	0.00517	0.082	NA	NA	0.01008	0.00517	0.051	NA
s(Slice)	NA	NA	<2e-16	8.30036	8.74494	NA	NA	<2e-16	5.90980
s(ID)	NA	NA	<2e-16	308.58259	314.00000	NA	NA	<2e-16	308.19578
s(Slice):FEV1	NA	NA	<2e-16	5.69657	6.49411	NA	NA	<2e-16	8.93368
Outcome: Range | With Race									
Intercept	1.18577	0.17724	2e-11	NA	NA	1.27623	0.17738	7e-13	NA
BMI	-0.00274	0.00111	0.01	NA	NA	-0.00316	0.00111	0.004	NA
Age	-0.00186	0.00081	0.02	NA	NA	-0.00095	0.00081	0.242	NA
Male	0.08645	0.02007	2e-05	NA	NA	0.07425	0.02008	2e-04	NA
Height	0.00563	0.00252	0.03	NA	NA	0.00383	0.00252	0.129	NA
Other Races	0.04005	0.03017	0.18	NA	NA	0.01313	0.03019	0.664	NA
Non-Hispanic White	0.02419	0.01782	0.17	NA	NA	0.02146	0.01784	0.229	NA
s(Slice)	NA	NA	<2e-16	7.40982	8.06188	NA	NA	<2e-16	8.32629
s(ID)	NA	NA	<2e-16	293.50107	312.00000	NA	NA	<2e-16	293.86043
s(Slice):FEV1	NA	NA	<2e-16	4.84094	5.56381	NA	NA	<2e-16	6.10298
Outcome: Range | Without Race									
Intercept	1.23809	0.17473	1e-12	NA	NA	1.31233	0.17459	6e-14	NA
BMI	-0.00289	0.00111	0.009	NA	NA	-0.00330	0.00110	0.003	NA
Age	-0.00172	0.00080	0.032	NA	NA	-0.00079	0.00080	0.324	NA
Male	0.09064	0.01995	6e-06	NA	NA	0.07624	0.01993	1e-04	NA
Height	0.00489	0.00248	0.049	NA	NA	0.00328	0.00248	0.185	NA
s(Slice)	NA	NA	<2e-16	7.40974	8.06180	NA	NA	<2e-16	8.32619
s(ID)	NA	NA	<2e-16	295.52728	314.00000	NA	NA	<2e-16	295.82713
s(Slice):FEV1	NA	NA	<2e-16	4.84119	5.56408	NA	NA	<2e-16	6.10342


Left Psill FEV1 − With Race
Right Psill FEV1 − With Race
Left Psill FEV1 − No Race
Right Psill FEV1 − No Race
Left Range FEV1 − With Race
Right Range FEV1 − With Race
Left Range FEV1 − No Race
Right Range FEV1 − No Race
Predicted log(Psill)
Predicted log(Range)
Quantiles
0.25
0.50
0.75
Normalized Slice

FVC

Table 5: Summary of Models for FVC

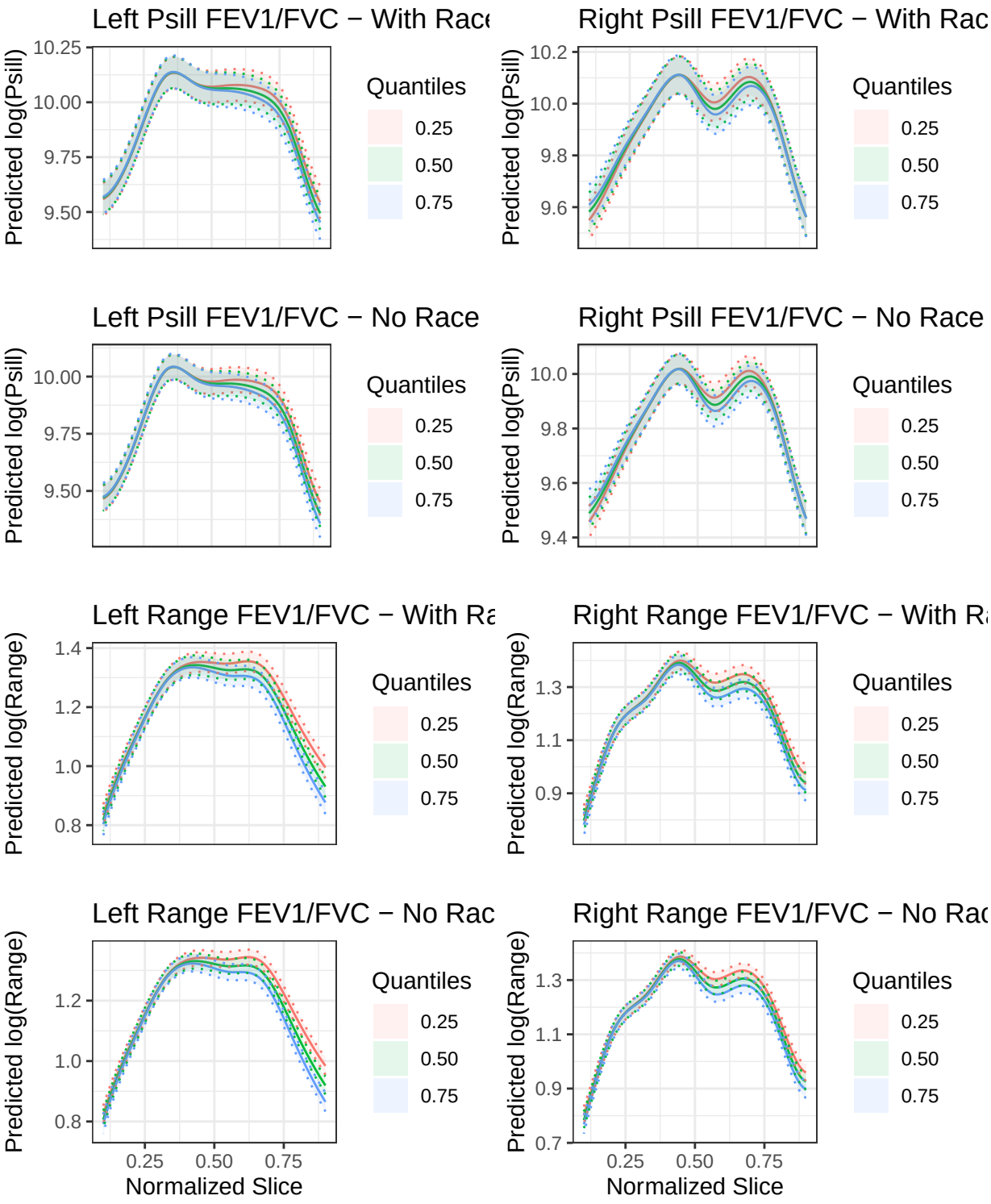
	Left Lung					Right Lung			
Term	**Estimate**	**SE**	**P-Value**	**EDF**	**Ref. DF**	**Estimate**	**SE**	**P-Value**	**EDF**
Outcome: Psill | With Race									
Intercept	9.66089	0.35733	<2e-16	NA	NA	9.42400	0.34952	<2e-16	NA
BMI	-0.00114	0.00222	0.607	NA	NA	-0.00065	0.00217	0.76	NA
Age	-0.00488	0.00159	0.002	NA	NA	-0.00354	0.00156	0.02	NA
Male	0.16951	0.04117	4e-05	NA	NA	0.19513	0.04027	1e-06	NA
Height	0.01748	0.00527	9e-04	NA	NA	0.01974	0.00516	1e-04	NA
Other Races	0.02586	0.06082	0.671	NA	NA	0.03104	0.05949	0.60	NA
Non-Hispanic White	-0.00873	0.03617	0.809	NA	NA	-0.00369	0.03538	0.92	NA
s(Slice)	NA	NA	<2e-16	8.40892	8.82473	NA	NA	<2e-16	5.86866
s(ID)	NA	NA	<2e-16	306.06383	312.00000	NA	NA	<2e-16	305.35883
s(Slice):FVC	NA	NA	<2e-16	4.75602	5.48317	NA	NA	<2e-16	8.68093
Outcome: Psill | Without Race									
Intercept	9.65835	0.34899	<2e-16	NA	NA	9.43234	0.34133	<2e-16	NA
BMI	-0.00106	0.00221	0.631	NA	NA	-0.00060	0.00216	0.78	NA
Age	-0.00497	0.00157	0.002	NA	NA	-0.00360	0.00154	0.02	NA
Male	0.17118	0.04100	3e-05	NA	NA	0.19715	0.04010	9e-07	NA
Height	0.01757	0.00512	6e-04	NA	NA	0.01965	0.00501	9e-05	NA
s(Slice)	NA	NA	<2e-16	8.31987	8.73880	NA	NA	<2e-16	5.86866
s(ID)	NA	NA	<2e-16	308.03504	314.00000	NA	NA	<2e-16	307.32504
s(Slice):FVC	NA	NA	<2e-16	5.11245	5.98174	NA	NA	<2e-16	8.68095
Outcome: Range | With Race									
Intercept	1.10584	0.18673	3e-09	NA	NA	1.17425	0.18289	1e-10	NA
BMI	-0.00303	0.00116	0.009	NA	NA	-0.00353	0.00114	0.002	NA
Age	-0.00104	0.00083	0.212	NA	NA	-0.00045	0.00082	0.583	NA
Male	0.08600	0.02151	6e-05	NA	NA	0.08075	0.02107	1e-04	NA
Height	0.00625	0.00276	0.023	NA	NA	0.00546	0.00270	0.043	NA
Other Races	0.04587	0.03178	0.149	NA	NA	0.02376	0.03113	0.445	NA
Non-Hispanic White	0.01817	0.01890	0.336	NA	NA	0.02187	0.01851	0.237	NA
s(Slice)	NA	NA	<2e-16	7.47676	8.12238	NA	NA	<2e-16	8.51501
s(ID)	NA	NA	<2e-16	294.84587	312.00000	NA	NA	<2e-16	294.50475
s(Slice):FVC	NA	NA	<2e-16	4.99693	5.73112	NA	NA	<2e-16	3.99263
Outcome: Range | Without Race									
Intercept	1.15781	0.18286	2e-10	NA	NA	1.22208	0.17889	9e-12	NA
BMI	-0.00310	0.00116	0.008	NA	NA	-0.00364	0.00113	0.001	NA
Age	-0.00094	0.00082	0.255	NA	NA	-0.00030	0.00081	0.714	NA
Male	0.08900	0.02149	3e-05	NA	NA	0.08232	0.02102	9e-05	NA
Height	0.00544	0.00268	0.043	NA	NA	0.00468	0.00263	0.075	NA
s(Slice)	NA	NA	<2e-16	7.47672	8.12234	NA	NA	<2e-16	8.51500
s(ID)	NA	NA	<2e-16	296.85386	314.00000	NA	NA	<2e-16	296.47259
s(Slice):FVC	NA	NA	<2e-16	4.99731	5.73153	NA	NA	<2e-16	3.99292


Left Psill FVC − With Race
Predicted log(Psill)
10.00
9.75
9.50
9.25
9.00
Quantiles
0.25
0.50
0.75
Right Psill FVC − With Race
Predicted log(Psill)
10.2
9.9
9.6
9.3
Quantiles
0.25
0.50
0.75
Left Psill FVC − No Race
Predicted log(Psill)
10.2
9.9
9.6
9.3
Quantiles
0.25
0.50
0.75
Right Psill FVC − No Race
Predicted log(Psill)
9.9
9.6
9.3
Quantiles
0.25
0.50
0.75
Left Range FVC − With Race
Predicted log(Range)
1.4
1.2
1.0
0.8
Quantiles
0.25
0.50
0.75
Right Range FVC − With Race
Predicted log(Range)
1.4
1.2
1.0
0.8
Quantiles
0.25
0.50
0.75
Left Range FVC − No Race
Predicted log(Range)
1.4
1.2
1.0
0.8
0.25
0.50
0.75
Quantiles
0.25
0.50
0.75
Right Range FVC − No Race
Predicted log(Range)
1.4
1.2
1.0
0.8
0.25
0.50
0.75
Quantiles
0.25
0.50
0.75

FEV1/FVC

Table 6: Summary of Models for FEV1/FVC

	Left Lung					Right Lung			
Term	**Estimate**	**SE**	**P-Value**	**EDF**	**Ref. DF**	**Estimate**	**SE**	**P-Value**	**EDF**
Outcome: Psill | With Race									
Intercept	10.46161	0.43697	<2e-16	NA	NA	10.06222	0.43335	<2e-16	NA
BMI	0.00135	0.00259	0.6	NA	NA	0.00164	0.00257	0.52	NA
Age	0.00132	0.00174	0.5	NA	NA	0.00310	0.00173	0.07	NA
Male	0.00854	0.04487	0.8	NA	NA	0.03237	0.04450	0.47	NA
Height	-0.00704	0.00560	0.2	NA	NA	-0.00472	0.00556	0.40	NA
Other Races	-0.09313	0.06990	0.2	NA	NA	-0.08754	0.06932	0.21	NA
Non-Hispanic White	-0.14955	0.03935	1e-04	NA	NA	-0.14818	0.03903	1e-04	NA
s(Slice)	NA	NA	<2e-16	8.28304	8.71098	NA	NA	<2e-16	6.01842
s(ID)	NA	NA	<2e-16	307.70117	312.00000	NA	NA	<2e-16	307.29931
s(Slice):FEV1/FVC	NA	NA	<2e-16	4.48937	5.16254	NA	NA	<2e-16	8.41966
Outcome: Psill | Without Race									
Intercept	10.23216	0.44057	<2e-16	NA	NA	9.83754	0.43694	<2e-16	NA
BMI	0.00265	0.00262	0.3	NA	NA	0.00294	0.00260	0.3	NA
Age	0.00106	0.00178	0.6	NA	NA	0.00284	0.00177	0.1	NA
Male	-0.02425	0.04473	0.6	NA	NA	0.00021	0.04436	1.0	NA
Height	-0.00518	0.00569	0.4	NA	NA	-0.00290	0.00564	0.6	NA
s(Slice)	NA	NA	<2e-16	8.28206	8.71013	NA	NA	<2e-16	6.01875
s(ID)	NA	NA	<2e-16	309.86187	314.00000	NA	NA	<2e-16	309.47564
s(Slice):FEV1/FVC	NA	NA	<2e-16	4.49372	5.16732	NA	NA	<2e-16	8.41996
Outcome: Range | With Race									
Intercept	1.65070	0.19624	<2e-16	NA	NA	1.65049	0.19916	<2e-16	NA
BMI	-0.00189	0.00116	0.10	NA	NA	-0.00244	0.00118	0.04	NA
Age	0.00009	0.00078	0.91	NA	NA	0.00107	0.00080	0.18	NA
Male	0.03863	0.02015	0.06	NA	NA	0.02857	0.02045	0.16	NA
Height	-0.00156	0.00252	0.54	NA	NA	-0.00291	0.00255	0.25	NA
Other Races	0.00775	0.03139	0.80	NA	NA	-0.01698	0.03186	0.59	NA
Non-Hispanic White	-0.01945	0.01767	0.27	NA	NA	-0.02112	0.01794	0.24	NA
s(Slice)	NA	NA	<2e-16	3.80697	4.46480	NA	NA	<2e-16	4.89104
s(ID)	NA	NA	<2e-16	295.31996	312.00000	NA	NA	<2e-16	295.85900
s(Slice):FEV1/FVC	NA	NA	<2e-16	7.89890	8.55097	NA	NA	<2e-16	9.10318
Outcome: Range | Without Race									
Intercept	1.63205	0.19406	<2e-16	NA	NA	1.61592	0.19681	2e-16	NA
BMI	-0.00170	0.00115	0.14	NA	NA	-0.00226	0.00117	0.05	NA
Age	0.00003	0.00078	0.97	NA	NA	0.00104	0.00080	0.19	NA
Male	0.03573	0.01970	0.07	NA	NA	0.02368	0.01998	0.24	NA
Height	-0.00144	0.00251	0.57	NA	NA	-0.00262	0.00254	0.30	NA
s(Slice)	NA	NA	<2e-16	3.80698	4.46483	NA	NA	<2e-16	4.89106
s(ID)	NA	NA	<2e-16	297.30919	314.00000	NA	NA	<2e-16	297.82587
s(Slice):FEV1/FVC	NA	NA	<2e-16	7.89900	8.55108	NA	NA	<2e-16	9.10317


Left Psill FEV1/FVC − With Race
Predicted log(Psill)
10.25
10.00
9.75
9.50
Quantiles
0.25
0.50
0.75
Right Psill FEV1/FVC − With Rac
Predicted log(Psill)
10.2
10.0
9.8
9.6
Quantiles
0.25
0.50
0.75
Left Psill FEV1/FVC − No Race
Predicted log(Psill)
10.00
9.75
9.50
Quantiles
0.25
0.50
0.75
Right Psill FEV1/FVC − No Race
Predicted log(Psill)
10.0
9.8
9.6
9.4
Quantiles
0.25
0.50
0.75
Left Range FEV1/FVC − With Ra
Predicted log(Range)
1.4
1.2
1.0
0.8
Quantiles
0.25
0.50
0.75
Right Range FEV1/FVC − With R
Predicted log(Range)
1.3
1.1
0.9
Quantiles
0.25
0.50
0.75
Left Range FEV1/FVC − No Rac
Predicted log(Range)
1.2
1.0
0.8
0.25
0.50
0.75
Normalized Slice
Quantiles
0.25
0.50
0.75
Right Range FEV1/FVC − No Rac
Predicted log(Range)
1.3
1.1
0.9
0.7
0.25
0.50
0.75
Normalized Slice
Quantiles
0.25
0.50
0.75