Association of Perfluoroalkyl Substance with Lung Function in the U.S. Population

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Background

Perfluoroalkyl and polyfluoroalkyl substances (PFASs) are synthetic chemicals used in carpets, clothing, food packaging, firefighting foam, and non-stick cookware coatings.[1] PFASs are made up of a carbon backbone, which can vary from a length of four carbons to twelve carbons, with fluorine substitutions[2] (Figure 1). PFASs accumulate in multiple tissues in humans, including the lungs.[1] However, their association with lung function is not completely understood.

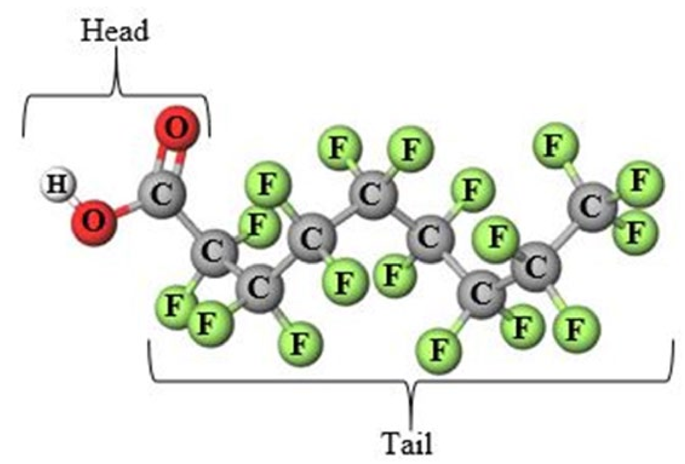

Figure 1. PFNA molecule structure. Made using MolView.[3]

Hypothesis

Increasing serum levels of PFASs, specifically perfluorononanoic acid (PFNA), perfluorooctanoic acid (PFOA), perfluorooctane sulfonic acid (PFOS), and perfluorohexane sulfonic acid (PFHxS), in the U.S. population will be associated with decreased lung function, as assessed by spirometry, and will differ by gender.

Methods

Data from 1,450 participants (52% men), aged 12 to 79 years, from the 2011-2012 U.S. population data from the National Health and Nutrition Examination Survey (NHANES) were analyzed. Descriptive analysis of the data was conducted overall, and by gender. De-identified data used for analysis; therefore, ethical review not required.

Serum concentration of four PFASs, PFNA, PFOA, PFOS, and PFHxS were assessed using mass spectrometry and were categorized into tertiles.

Lung function was measured by spirometry as forced vital capacity (FVC), forced expiratory volume in one second (FEV1), and the ratio of FVC/FEV1 (%). Sex stratified adjusted linear regression analysis was used to predict lung function with PFASs tertiles.

Results

Figure 2 shows that there is a significant difference between PFASs levels in males and females.

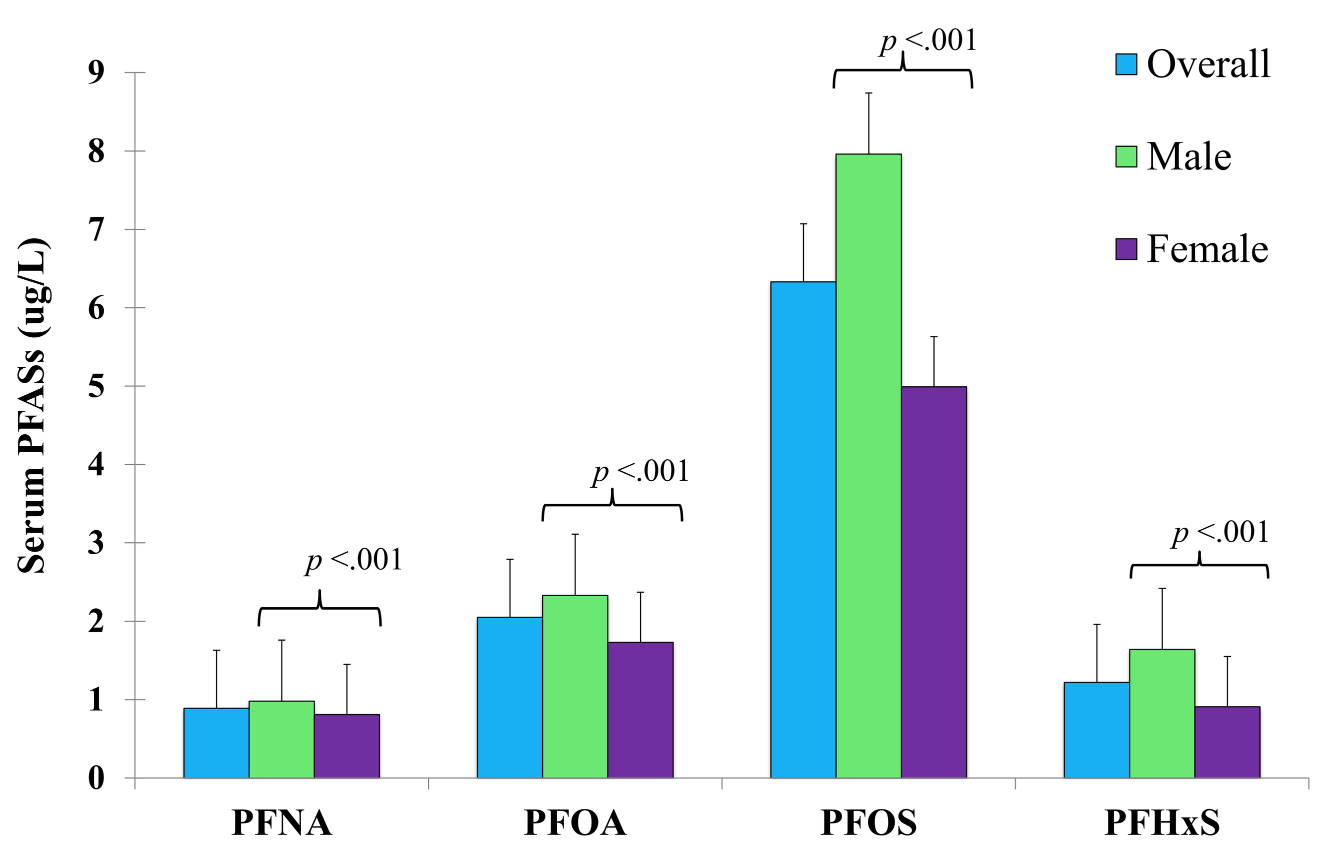

Figure 2. Serum PFASs median accumulation of the NHANES 2011-2012 participants, overall and by gender.

Results (Continued)

Figure 3 shows that there is a significant difference of the outcomes of the three spirometry tests between gender.

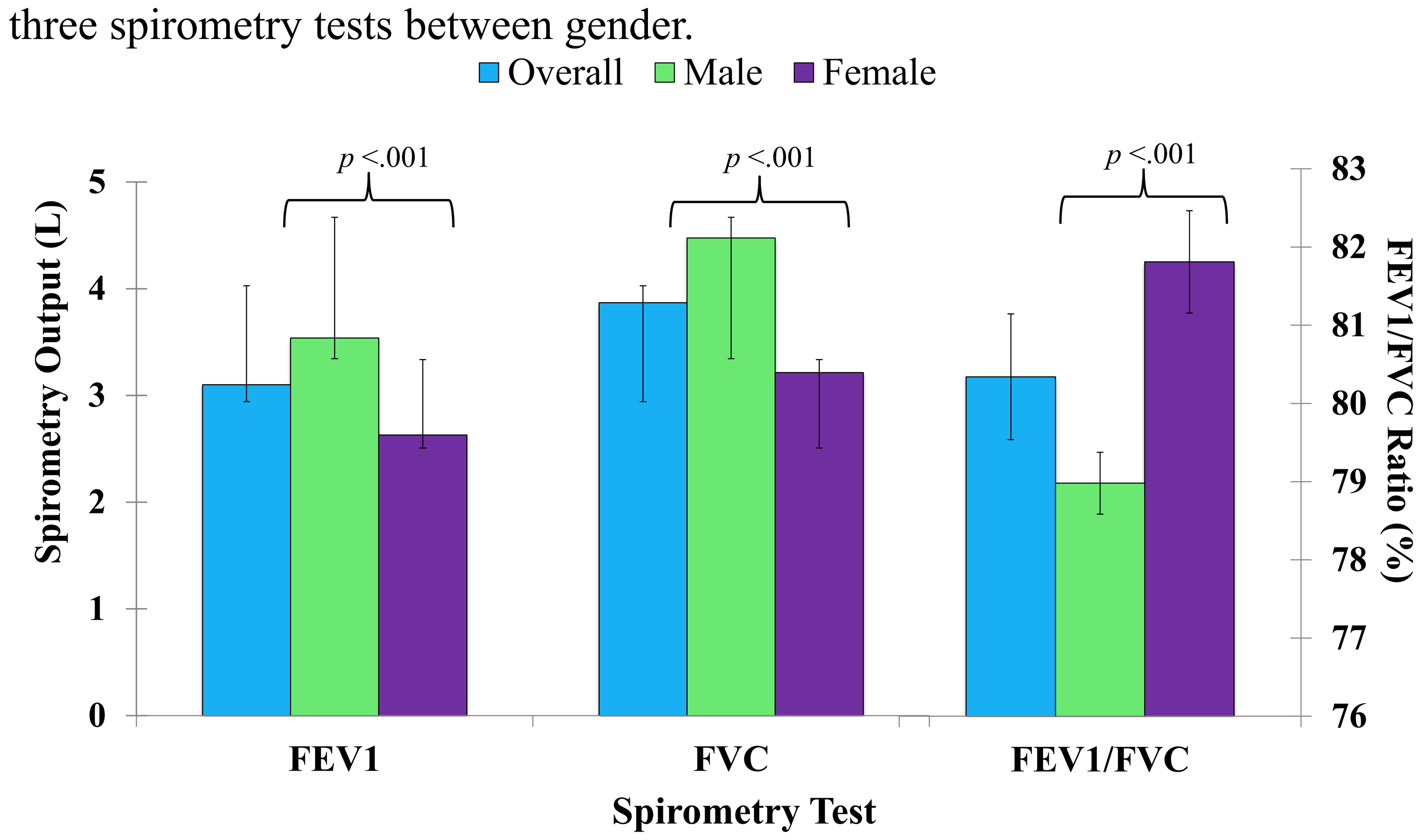

Figure 3. Spirometry test output of the NHANES 2011-2012 participants, overall and stratified by gender.

Table 1 demonstrates the decreasing lung function in the medium and high tertiles of PFASs of female participants. All four of the PFASs have a significant decrease of lung function associated with the high tertiles of FEV1 and the FEV1/FVC; PFNA and PFHxS has a significant decrease in the medium tertiles of FEV1 and FEV1/FVC.

Table 1
Association of PFASs serum concentration with FEV1, FVC, & FEV1/FVC in NHANES 2011-2012 female participants in unadjusted linear regression.

		FEV1		FVC		FEV1/FVC	
		B (95% CI)	*p*-value	B (95% CI)	*p*-value	B (95% CI)	*p*-value
PFOA*							
Unadjusted†	Med	-33.40 (-144.15, 77.34)	.554	-14.45 (-142.25, 113.36)	.824	-0.74 (-2.22, 0.75)	.331
	High	**-149.69 (-260.56, -38.82)**	**.008**	-95.03 (-222.98, 32.91)	.145	**-2.90 (-4.38, -1.41)**	**<.001**
PFOS*							
Unadjusted†	Med	-76.68 (-184.96, 21.60)	.165	-53.90 (-179.44, 71.65)	.400	-1.08 (-2.57, 0.41)	.154
	High	**-333.91 (-442.31, -225.52)**	**<.001**	**-315.71 (-441.39, -190.03)**	**<.001**	**-2.89 (-4.38, -1.40)**	**<.001**
PFNA*							
Unadjusted†	Med	**-117.68 (-227.24, -8.12)**	**.035**	**-134.43 (-260.81, -8.05)**	**.037**	-0.56 (-2.05, 0.93)	.463
	High	**-241.86 (-351.54, -132.18)**	**<.001**	**-239.92 (-366.44, -113.39)**	**<.001**	**-1.77 (-3.26, -0.28)**	**.020**
PFHxS*							
Unadjusted†	Med	-39.68 (-150.09, 70.72)	.481	30.63 (-96.90, 158.16)	.637	**-2.13 (-3.61, -0.65)**	**.005**
	High	**-186.67 (-296.83, -76.51)**	**.001**	115.80 (-243.05, 11.45)	.074	**-3.31 (-4.79, -1.83)**	**<.001**

*Age-Adjusted and Multivariable adjusted models were non-significant
†In all models, the reference category was the respective low PFASs tertile. Med = Medium
N = 1,450

Table 2 demonstrates the decreasing lung function in the high tertiles of PFASs of male participants. The FEV1/FVC ratio has the greatest number of PFASs with a significant decrease in lung function (PFOA, PFNA & PFHxS).

Table 2. *Association of PFASs serum concentration with FEV1, FVC, & FEV1/FVC in NHANES 2011-2012 male participants in unadjusted linear regression.*

		FEV1		FVC		FEV1/FVC	
		B (95% CI)	*p*-value	B (95% CI)	*p*-value	B (95% CI)	*p*-value
PFOA*							
Unadjusted†	Med	67.23 (-84.25, 218.71)	.384	50.63 (-118.96, 220.22)	.558	0.62 (-0.93, 2.18)	.431
	High	35.66 (-116.28, 187.60)	.645	129.61 (-40.49, 299.71)	.135	**-1.37 (-2.93, 0.19)**	**.086**
PFOS*							
Unadjusted†	Med	135.53 (-13.34, 284.39)	.074	232.91 (65.64, 400.18)	.006	-1.22 (-2.76, 0.31)	.118
	High	**-190.78 (-341.75, -39.80)**	**.013**	-76.71 (-246.35, 92.93)	.375	**-3.05 (-4.61, -1.49)**	**<.001**
PFNA*							
Unadjusted†	Med	35.12 (-115.83, 186.08)	.648	-15.14 (-184.43, 154.15)	.861	1.23 (-0.33, 2.78)	.123
	High	**-144.09 (-295.20, 7.01)**	**.062**	**-173.39 (-342.86, -3.93)**	**.045**	-0.04 (-1.60, 1.52)	.958
PFHxS*							
Unadjusted†	Med	75.61 (-75.85, 227.07)	.327	158.84 (-10.26, 327.94)	.066	-1.06 (-2.61, 0.50)	.182
	High	52.96 (-98.66, 204.57)	.493	214.11 (44.84, 383,37)	.013	**-2.42 (-3.97, -0.86)**	**.002**

*Age-Adjusted and Multivariable adjusted models were non-significant
†In all models, the reference category was the respective low PFASs tertile. Med = Medium
N = 1,450

Results (Continued)

Figure 4 illustrates the decrease of lung function among females and males based on the FEV1/FVC spirometry test and PFHxS exposure.

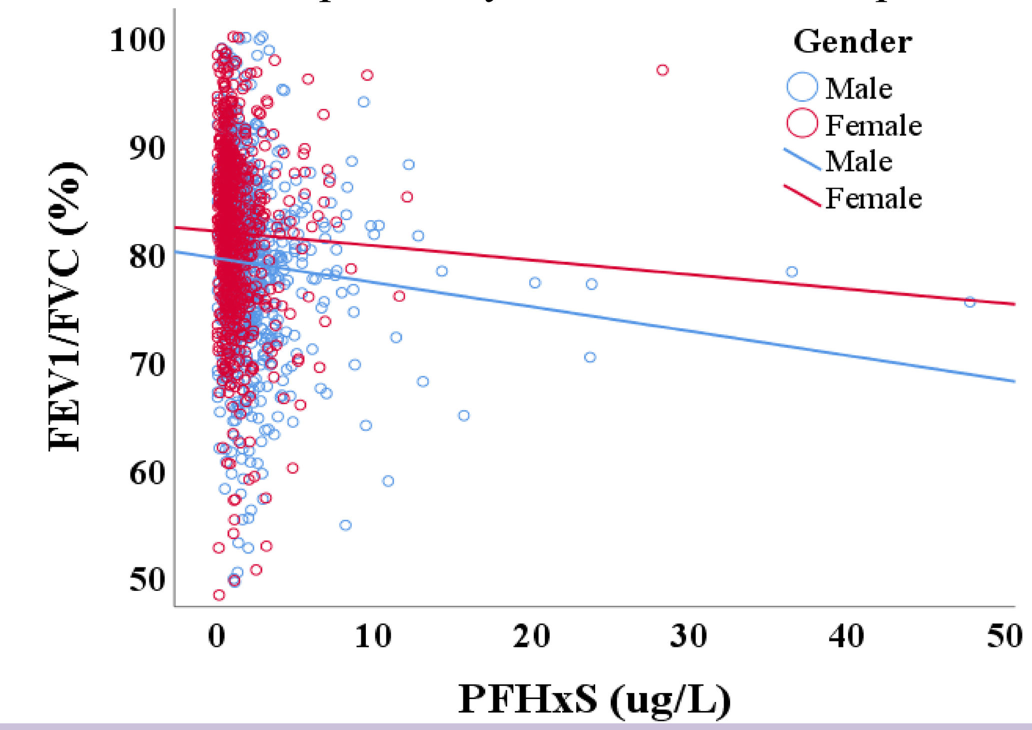

Figure 4. Association of PFHxS and FEV1/FVC % in the NHANES 2011-2012 participants, by gender.

Figure 5 illustrates the decrease of lung function among females based on the FVC spirometry test and PFNA exposure. It also displays the low, medium and high levels of PFNA exposure.

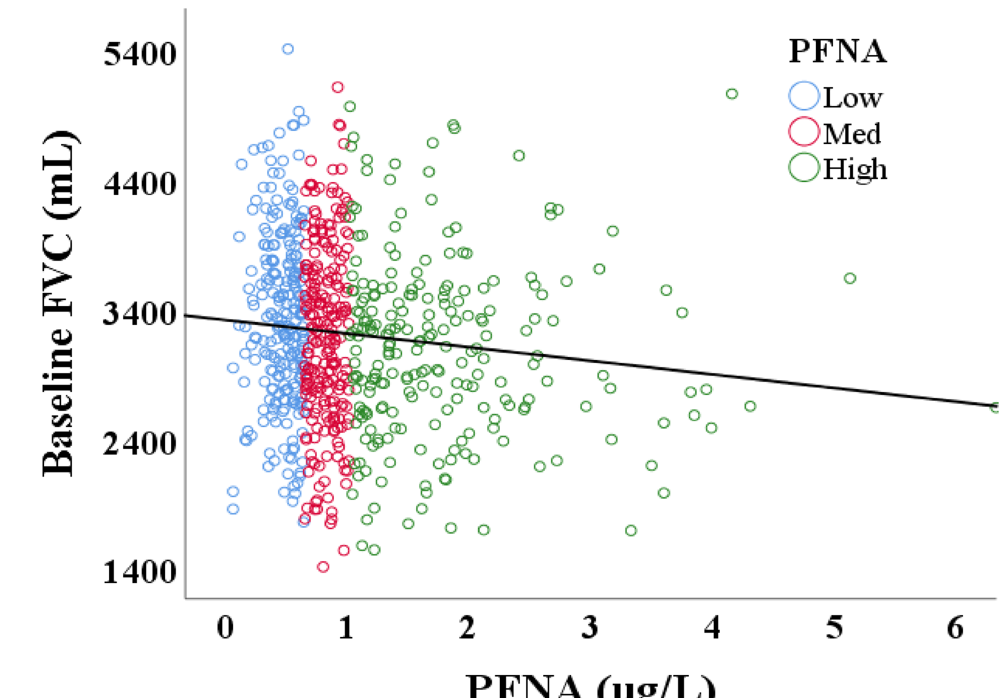

Figure 5. Association of PFNA and FVC (mL) in the NHANES 2011-2012 female participants, by the level of exposure.

Discussion and Conclusion

Overall, we observed a consistent statistically significant negative association between lung function and high PFAS exposure in females and some association in males in the unadjusted models. We did not observe an association that was consistently significant in the age-adjusted and multivariable adjusted models.

One of the possible explanations of the results, could be that PFASs are endocrine disruptors (ED) and ED can impact males and females differently. The different associations between PFASs and lung function across genders noted in this study could be due to the differences in male and female lung function.

PFASs exposure is a public health concern due to its widespread use in consumer products and health implications. More research is needed to explore the association between PFASs exposure and lung function, because the lungs are one of the primary tissues where PFAS accumulate.[1]

References

1. Pérez, F., Nadal, M., Navarro-Ortega, A., Fàbrega, F., Domingo, J. L., Barceló, D., & Farré, M. (2013). Accumulation of perfluoroalkyl substances in human tissues. *Environment International, 59*, 354-362. doi:10.1016/j.envint.2013.06.004
2. Agency for Toxic Substances and Disease Registry (ATSDR). (2018c). *Toxicological profile for perfluoroalkyls (draft for public comment).* Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.
3. Bergwerf, H. (2015). Molview. Retrieved from http://molview.org/