Variability of Pulmonary Function Associated with Serum Nickel in Women Exposed to Clean and Biomass Fuel in a Rural Tamil Nadu

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Abstract

Background: Indoor air pollutants are constituted by organic compounds, polyaromatic hydrocarbons, transition metals like nickel, chromium etc from biomass smoke, which alter the pulmonary ventilation. Explaining the effect of metal function on pulmonary among cooking women is very minimal. We evaluated the effect of nickel on pulmonary functions among biomass fuel users in rural areas. **Methodology**: 200 healthy subjects selected biomass fuel use and LPG fuel use from the rural area of Kancheepuram District in India. Written consent and demographic data were collected from every participant before the performance of the test. Pulmonary function tests were done by a computerised Spirometer to assess the FEF_{25-75}% and PEFR% parameters. Serum Nickel was estimated in blood by ICP-MS technology. We used multivariate statistical analysis to find the variation on pulmonary function due to the effect of nickel among biomass fuel users. **Results and findings**: PEFR% (34.63±14.90; 41.92± 15.70, p **0.025**) shows significant difference between biomass fuel user and LPG fuel user for the subgroup of <35(µg/dl) nickel concentration. $FEF_{25-75\%}$ (43.87±23.61; 55.28±17.32, p **0.014**) and PEFR% (33.81±14.82; 40.08±12.68, p **0.037**) shows significance difference between biomass and clean fuel users for the subgroup of >35(µg/dl) nickel concentration. After adjustment of BMI, $FEF_{25-75\%}$ and PEFR (p **0.012**; p **0.026**) were showed the significant difference between biomass and clean fuel users for the subgroup of >35(µg/dl) nickel concentration and the variability for $FEF_{25-75\%}$ and PEFR was 6.3% and 5.1%. **Conclusion**: Our study concludes that there is a significant association between Nickel concentration and altered pulmonary function due to nickel exposure among biomass fuel users. To recommend illuminating the potential effect of nickel from biomass smoke pollutants.

Key words: Biomass Fuel, Clean fuel, Transition Metal, Nickel, Pulmonary Function.

Introduction

Indoor air pollution includes pollutants generated by combustion of biomass in the household environment **[1]**. Several compounds and particulate matter are released from smoke of burning biomasses which include organic compounds and transition metals and polyaromatic hydrocarbon PAH etc **[2]**. Various metals play a basic role in the catalytic process, thus stabilizing the macromolecular structure of protein and nucleic acids and affecting the structural and functional integration **[3]**. Metals are released mainly from occupation and non occupational exposure or household environment during several processes like cooking, welding, mining etc **[4, 5]**. The amount and location of deposition of particles are determined by convection, diffusion, sedimentation, interception of particles in the lungs **[6]**. Many heavy metals accumulate in the biological system to cause various human health effects such as pulmonary ventilation, increased in blood pressure, anaemia, neurotoxicity, tubular dysfunction etc by inhalation, ingestion and dermal contact **[7]**.

In 1951 Swedish Chemist “AXEL CRONSTEDT " found the Nickel. It is the 28th element in the modern periodic table. Nickel has various oxidation states from -1 to +4, Ni (II) or Ni^{2+} most prevalent form **[8]**. Nickel and its compounds are released from combustion of wood and fossil fuels **[9].** In humans, the absorption of nickel takes place by three routes: inhalation, GIT, dermal **[10]**. Nickel enters into cells by various process such as phagocytosis **[11]**, lipid soluble, diffusion, which is transported by nickel binding metalloprotein, Nickeloplasmin **[12]** and is distributed to liver, heart, lung, nervous system etc **[13]**.The normal concentration of nickel in serum is 0.2µg/l **[14].** Half-life period varies for different forms of nickel, which is excreted via urine, faeces, sweat, and milk. The physicochemical properties of metals such as total surface area to volume ratio, small size, and other properties can cause toxicity to various organs **[15]**. Effect of nickel on humans is less explored. Previous studies explaining the effect of nickel on pulmonary function among rural women using biomass fuel are very minimal. Purpose of this study is to provide knowledge of nickel toxicity on pulmonary function among biomass fuel users in rural areas.

Aim and Objective

1. To compare the Nickel concentration among biomass and clean fuel users.
2. To evaluate the effect of nickel on pulmonary functions among biomass and clean fuel users.

Materials and Methods

An analytical study, we selected a population of Biomass fuel users and clean fuel users from rural Kancheepuram district. This research was approved by the Institutional Ethical Committee. Based on sample size calculation, 100 selected subjects were using biomass fuel and 100 clean fuel (LPG)user, with inclusion criteria such as, Age (18 to 50 years) of healthy females exposed to cooking for minimum of 5 yrs, an exclusion criteria such as cardiovascular disease condition and respiratory illness, pregnant women and postpartum women, smoking. Before performing the test, we collected the details of anthropometry data, kitchen ventilation and cooking profile. The selected subjects provided written consent before performance of the test. We assessed the pulmonary function by SPIROMETRY - *MODEL: Helios 401* **[16]**, which is based on European Respiratory standards **[17]** and assessed **[18]** the Parameters such as PEFR (Peak Expiratory Flow Rate) and FEF $_{25-75\%}$. The blood serum was used to analyze the Nickel by ICP-MS **[19, 20]**. The data was analysed by student t test and multivariate analysis.

Results

We classified two subgroups for biomass fuel and clean fuel users, which was based on median value (35 µg/dl) of nickel concentration. They were grouped as Subgroup I – <35(µg/dl) of Nickel concentration and Subgroup II – >35(µg/dl) of Nickel concentration

Table 1: Comparison of spirometry (FEF $_{25-75}$%P, PEFR%P) between biomass and clean fuel users for subgroup I of <35(µg/dl) of Nickel concentration

PARAMETER	GROUP	N	MEAN±SD	t	P
FEF $_{25-75}$**(L/s)**	Biomass Fuel User	36	3.446±0.286	-2.983	**0.004**
	Clean Fuel User	65	3.615±0.266		
FEF $_{25-75}$%P **(L/s)**	Biomass Fuel User	36	48.56±21.87	-1.907	0.059
	Clean Fuel User	65	56.24±17.92		
PEFR P(L/s)	Biomass Fuel User	36	6.168±0.293	-3.231	**0.002**
	Clean Fuel User	65	6.360±0.284		
PEFR %P(L/s)	Biomass Fuel User	36	34.63±14.90	-2.272	**0.025**
	Clean Fuel User	65	41.92±15.70		

Note: PEFR %P shows the significance (p 0.025) difference between two groups for the subgroup I of <35µg/dl of Ni concentration.

Table 2: Comparison of spirometry (FEF 25-75%P, PEFR%P) between biomass and clean fuel users for subgroup II of >35µg/dl of Ni concentration

PARAMETER	GROUP	N	MEAN±SD	t	P
FEF $_{25-75}$**(L/s)**	Biomass Fuel User	64	3.515±0.286	-2.164	**0.032**
	Clean Fuel User	35	3.643±0.274		

FEF $_{25-75}$%P **(L/s)**	Biomass Fuel User	64	43.87±23.61	-2.510	**0.014**
	Clean Fuel User	35	55.28±17.32		
PEFR P(L/s)	Biomass Fuel User	64	6.176±0.309	-2.753	**0.007**
	Clean Fuel User	35	6.356±0.313		
PEFR %P(L/s)	Biomass Fuel User	64	33.81±14.82	-2.114	**0.037**
	Clean Fuel User	35	40.08±12.68		

Note: FEF $_{25-75}$ %P and PEFR %P shows significance (p 0.014; p 0.037) difference between two groups for the subgroup II of >35µg/dl of Ni concentration.

Table 3: Variation in Tests of Between-Subjects Effects for subgroup I of <35(µg/dl) of Nickel concentration

Tests of Between-Subjects Effects									
Source	Dependent Variable	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
GROUP I		6.168	1	6.168	.107	.745	.001	.107	.062
	FEF_P	.715	1	.715	9.549	.003	.089	9.549	.864
	FEF_%P[d]	1104.477	1	1104.477	2.915	.091	.029	2.915	.394
	PEFR_P	.861	1	.861	10.338	.002*	.095	10.338	.889
	PEFR_%P[f]	1008.339	1	1008.339	4.216	.043*	.041	4.216	.529
d. R Squared = .040 (Adjusted R Squared = .020)									
f. R Squared = .055 (Adjusted R Squared = .036)									

Table 4: variation in Tests of Between-Subjects Effects for subgroup II of >35(µg/dl) of Nickel concentration

Tests of Between-Subjects Effects									
Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
GROUPII	NI	1328.604	1	1328.604	2.053	.155	.021	2.053	.295
	FEF_P	.589	1	.589	7.716	.007	.074	7.716	.785
	FEF_%P[a]	3058.093	1	3058.093	6.494	.012*	.063	6.494	.713
	PEFR_P	.898	1	.898	9.424	.003	.089	9.424	.860
	PEFR_%P[c]	1027.529	1	1027.529	5.144	.026*	.051	5.144	.612
a. R Squared = .064 (Adjusted R Squared = .044)									
c. R Squared = .051 (Adjusted R Squared = .031)									

Discussion

Nickel affects different organs, primarily the lung, upper respiratory tract through inhalation exposure and kidney through oral exposure **[21]**. Nickel and its compounds such as Nickel oxide, nickel subsulfide, nickel sulphate is classified as human carcinogens by IARC because of prolonged interactions of particles which are resulting in failure of macrophages to phagocytose in pulmonary epithelium **[22]**. In our study, there was a significant reduction in FEF_{25-75}%P (p **0.014**) and PEFR %P (p **0.037**) for biomass fuel users for subgroup II rather than subgroup I. The multivariate analysis shows the variability for FEF_{25-75}%P (p **0.012**) and PEFR %P (p **0.026**) was 6.3% and 5.1%, even after adjustment of BMI which indicates the dysfunction of small and large airways. Our study supports the earlier study which also shows a higher exposure index to decline in PEFR among women exposed to biomass fuels, which denotes the deterioration of lung functions due to deposition of biomass smoke particles in lungs **[23]**.Similarly, 28.0% factory workers had reduction in FEF 25-75%P, developed deficit in ventilatory function such as respiratory obstruction, airway resistance or both due to direct absorption due to entry into cellular membrane by Nickel and chromium in lungs **[24]**. Related to our study, small reductions of PEFR associated with increased exposure of Nickel and Sulphur elements among 8yrs subjects suggest that the elements are independently associated with lung function after adjustment of PM mass **[25]**. Both soluble and insoluble nickel and its compounds activate hypoxia inducible pathways. Mainly Ni (II) develops permanent intracellular hypoxia, which then activates HIF-1α and IL-8 which cause hypoxic stress and inflammation **[26, 27]**. Analysis of the effect of nickel shows pulmonary dysfunctions in biomass fuel users due to deposition of Nickel particles in pulmonary epithelium from the biomass pollutants.

Conclusion

This study explained the effect of Nickel on pulmonary function for biomass fuel users. Our study concludes that there is a significant association between serum Nickel concentration and pulmonary function such as FEF_{25-75}%P and PEFR%P among biomass fuel users. Our study concluded that the values of FEF_{25-75}%P and PEFR %P shows significant in the subgroup II which indicates the development of irreversibly airway damage, chronic bronchitis, shortness of breath and obstructive airway resistance due to nickel exposure among biomass fuel users. We recommend wide range assessment of Nickel and its compound in related rural area with significant biomass fuel exposures.

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