



Ultrafine Particles and Cardiac Responses: Evaluation in a Cardiac Rehabilitation Center

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ABSTRACT:

This study examines the effects of ultrafine particles (UFP) on cardiovascular responses in patients undergoing medically monitored exercise rehabilitation in Rochester, NY following hospitalization for acute coronary events, such as myocardial infarctions (heart attacks) or unstable angina. 75 patients will be participating and are closely monitored during their rehabilitation 12-week protocol; to date, 29 patients have been enrolled and 19 have completed the entire protocol. The patients undergo electrophysiological monitoring (Holter monitor) as well as blood sampling; complete medical histories and diaries are also recorded. The program involves supervised, graded twice or thrice weekly exercise sessions for a total of 12 weeks. Ultrafine particle number and size (Wide range Particle Spectrometer, MSP Corp.) are being measured continuously outdoors (3.8 ± 2.1 (SD) $\times 10^3$ p/cm³ from Sept. 06 to Sept. 07) and indoors (1.3 ± 0.8 (SD) $\times 10^3$ p/cm³) at the rehab site. Particle number, size (TSI SMPS model 3071), and mass (TEOM) are also measured continuously at a central measuring site in eastern Rochester. Other EPA criteria pollutants are measured at the eastern Rochester DEC site. In addition, one-third of the patients (n = 25) will have personal particle count monitoring in their cars to and from the rehab facility (n = 8 completed, particle count concentration = 17.3 ± 7.7 (SD) $\times 10^3$ p/cm³, and in their homes (n = 12 completed, particle count concentration = 9.4 ± 7.8 (SD) $\times 10^3$ p/cm³ for 48 hours using a portable nuclei counter (TSI model 3781).

With completion of enrollment, levels of ambient ultrafine and fine particles will be linked with cardiac electrophysiology and blood markers of clotting and inflammation. A unique strength of the design is the availability of longitudinal measurements on each subject, enabling each subject to be used as their own control.

DATA ACQUISITION:

Measured continuous size-fractionated particulate matter samples from **indoor** and **outdoor** air of a functional cardiac rehabilitation facility located in Rochester, NY (Fig. 1). The Spectrometer was run in SMS mode allowing for measurement of particles in the size range 10 – 500 nm every four minutes. Also, outdoor number concentrations and size distributions of fine and ultrafine particles in the same size range (10 – 500 nm) are being measured every five minutes at the New York State Department of Environmental Conservation (NYS DEC) monitoring site in Rochester, NY (Fig. 2). NYS DEC site measurements are being made using an SMPS™ consisting of a DMA and CPC (TSI Models 3071 and 3010, respectively). The simultaneously measured outdoor concentrations at this site (Fig. 4) were compared with measurements made at the DEC site (Fig. 3). A subset of subjects are measuring particle number concentration at home and in their automobile using a water-based CPC (TSI model 3871).



Figure 2: Locations of sampling sites and major local stationary sources as listed by EPA Point source emissions inventory.



Figure 3: DEC outdoor sampling location, within 1/4 mile of two converging expressways.



Figure 4: Cardiac Rehab Center outdoor sampling location, within 1/4 mile of expressway.



Figure 5: Cardiac Rehab Center indoor sampling location.

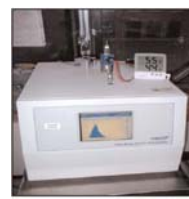


Figure 6: Sampling equipment at Cardiac Rehab Center.

	Rehab Indoor	Rehab Outdoor	Take home n=12	Auto n=8	DEC Outdoor	DEC 2002
Average ($\times 10^3$)	1.3	3.8	9.4	17.3	7.1	8.2
Stdev.	0.8	2.1	7.8	7.7	3.8	5.3
% Reported	94.8	94.8	100	100	92.2	91.0

Table 1. Hourly Particle Number Concentration Data: Sept '06 – Aug. '07

	WBC ($\times 10^3$ /ml)	RBC ($\times 10^6$ /ml)	CRP ($\times 10^5$ pg/ml)	Platelet Count ($\times 10^3$ /ml)
Average	6.36	4.71	7.28	239.0
Stdev.	1.61	0.42	8.37	61.8
Normal Range	4.3-10.8	4.2-5.9	1-30	150-400

Table 3. Selected Current Blood Data (n=22)

	PM2.5 ug/m ³	O ₃ ppm	SO ₂ ppm	Temp. °F	RH %	BP inHg	Wind Spd. mph	Precip in.
Average	9.42	0.016	0.004	49.0	65.3	29.49	4.91	0.006
Stdev.	7.44	0.013	0.004	11.1	19.7	0.28	2.31	0.018
% Reported	99.3	97.5	97.8	99.9	99.0	100	99.9	99.9

Table 2. Hourly DEC Ambient Data: Sept '06 – Aug. '07

	Pre HR (bpm)	Peak HR	Post HR	Pre BP (sys/diast)	Peak BP	Post BP
Average	64.5	106.7	70.2	111.8/65.6	139.8/68.4	106.2/64.2
Stdev.	8.6	17.1	8.4	11.5/7.8	17.9/8.0	10.8/6.0
Normal Range	60-70	110-160	60-70	100/70-120/80	120/80-130/90	100/70-120/80

Subjects reported their rated perceived exertion (RPE) as 12.5 ± 1.1 , based on the Borg Scale. A linear scale ranging from 6-20, with 6 being no exertion at all and 20 being maximal exertion.

Table 4. Current Exercise Data (n=22)

RESULTS AND DISCUSSION:

We have gathered ultrafine particle data continuously at both the cardiac rehab site since 2004 and the DEC site since 2002 thus providing ample data to support further analysis of particle size distribution data to estimate source apportionment in relation to outcomes in these subjects. We have previously shown nucleation event based increased particle levels with a relationship to SO₂ or, as a result of emissions from local sources. Consistent measurements from 2002 to 2007 have been made at the DEC site (7.1 ± 3.8 2007, 8.2 ± 5.3 2002). There is a good correlation ($r^2=0.35$) between the DEC and Cardiac Rehab ultrafine particle monitoring and between Indoor and Outdoor measurements at the Rehab site ($r^2=0.48$). Home and car monitoring have shown personal exposure to vary greatly indoors with point sources (stoves, heating) causing large temporary excursions. Cardiac endpoints will be compared to this extensive data set in future analyses.

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Figure 1: Map showing the location of the Cardiac Rehab and DEC sites used for this study.

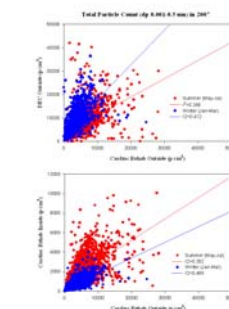


Figure 7: Correlations between number concentrations measured at Rehab and DEC sites

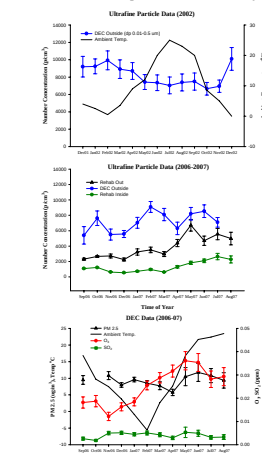


Figure 8: Comparison of daily particle concentrations +/- SEM between 2002 and 2007.

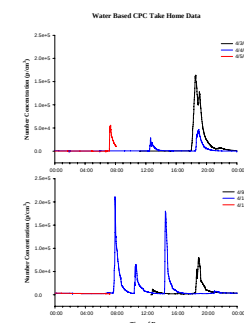


Figure 9: Two different take home data collections. Note excursions around 8am, 12 noon, and 6 pm.