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Randomized Trial to Reduce Air Particle Levels in Homes of Smokers and Children

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Introduction: Exposure to fine particulate matter in the home from sources such as smoking, cooking, and cleaning may put residents, especially children, at risk for detrimental health effects. A randomized clinical trial was conducted from 2011 to 2016 to determine whether real-time feedback in the home plus brief coaching of parents or guardians could reduce fine particle levels in homes with smokers and children.

Design: A randomized trial with two groups—intervention and control.

Setting/participants: A total of 298 participants from predominantly low-income households with an adult smoker and a child aged <14 years. Participants were recruited during 2012–2015 from multiple sources in San Diego, mainly Women, Infants and Children Program sites.

Intervention: The multicomponent intervention consisted of continuous lights and brief sound alerts based on fine particle levels in real time and four brief coaching sessions using particle level graphs and motivational interviewing techniques. Motivational interviewing coaching focused on particle reduction to protect children and other occupants from elevated particle levels, especially from tobacco-related sources.

Main outcome measures: In-home air particle levels were measured by laser particle counters continuously in both study groups. The two outcomes were daily mean particle counts and percentage time with high particle concentrations (>15,000 particles/0.01 ft^3). Linear mixed models were used to analyze the differential change in the outcomes over time by group, during 2016–2017.

Results: Intervention homes had significantly larger reductions than controls in daily geometric mean particle concentrations (18.8% reduction vs 6.5% reduction, $p<0.001$). Intervention homes' average percentage time with high particle concentrations decreased 45.1% compared with a 4.2% increase among controls (difference between groups $p<0.001$).

Conclusions: Real-time feedback for air particle levels and brief coaching can reduce fine particle levels in homes with smokers and young children. Results set the stage for refining feedback and possible reinforcing consequences for not generating smoke-related particles.

Trial registration: This study is registered at www.clinicaltrials.gov NCT01634334.

INTRODUCTION

Fine particulate matter ($PM_{2.5}$) comprises particles less than 2.5 micrometers (μm) (about 1/10,000 of an inch) in diameter. Small-diameter particles suspend in the air and can be inhaled deep into the lungs, potentially causing a host of acute and chronic health effects, ranging from irritation of the eye and respiratory system to asthma exacerbation, cardiovascular disease, and lung cancer.[1,2] Fine particle exposure is more harmful to children than adults. The adverse effects of fine particle exposure on children's respiratory system include chronic cough, bronchitis, wheezing, asthma exacerbation, and reduced lung function.[3–5]

Common indoor sources of fine particles include tobacco smoking, cooking, fireplaces, candles, incense, and sweeping.[6–8] Reducing indoor particles could mitigate particle-associated adverse health outcomes.[9] Households with smokers and children are a priority for intervention for several reasons. Cigarettes are strong emitters of fine particles, and households with smokers have higher particle levels than non-smoking households.[10–12] Almost all nonsmokers, including children, who live with smokers are exposed to secondhand tobacco smoke (SHS).[13] SHS is a mixture of more than 4,000 chemicals, more than a hundred of which are toxic, including carcinogenic polycyclic aromatic hydrocarbons particulate.[14] In the U.S. and globally, approximately four to five of every ten children are exposed to SHS, primarily at home.[13,15,16] The health effects of SHS on children include asthma attacks, respiratory infections, ear infections, sudden infant death syndrome, developmental impairment, and various carcinomas.[17]

Previous intervention studies involving children living with smokers have focused on parental smoking cessation or reducing SHS exposure to the children using education, counseling, or coaching approaches rather than cessation of smoking.[18] The strategy of reducing exposure has demonstrated efficacy and does not rely on smoking cessation by all household smokers, which is important because the majority of parents do not quit smoking.[19,20] A new line of intervention research was launched with the provision of delayed feedback of household nicotine levels to families, and delayed feedback of children's cotinine levels (a biomarker of SHS exposure) to clinicians and families.[21–24] The provision of delayed feedback of particle levels measured over 24 hours total was investigated in two recent studies of households with smokers and children. A small randomized feasibility study in the United Kingdom showed promise in improving indoor air quality (maximum $PM_{2.5}$ and percentage time above 35μg/m^3) at 1 month through the provision of delayed home air quality feedback, (i.e., static chart showing $PM_{2.5}$ levels for the prior 24-hour period), combined with brief motivational interviewing (MI).[25] In Armenia, a randomized trial tested the efficacy of a brief, delayed feedback of air quality (e.g., measuring $PM_{2.5}$ for several minutes before, during, and after someone smoked indoors and showing a graph of the $PM_{2.5}$ readings right after), in addition to counseling and brochures. There was no statistically significant effect on hair nicotine and air quality outcomes were not measured.[26]

According to principles of behavior, the timing and schedule of feedback are important determinants of behavior change and maintenance, with more immediate feedback being more powerful in general and intermittent reinforcement more likely to sustain behavior change.[27–29] Providing feedback from particle monitors in real time and continuously should be more effective than delayed consequences. The advancement from delayed feedback to continuous particle feedback provided in real time was explored in a pilot study.[30] Feasibility and initial changes were demonstrated in the small number of homes over 2 weeks. No large scale study has yet validated that particle feedback can reduce household fine particulate levels.

This paper assesses the efficacy of a randomized trial of the effects of immediate and continuous real-time particle feedback on the reduction of indoor particle levels (mean counts and percentage time above a threshold) in households with children and smokers. This is the first randomized trial to test automated, real-time, continuous particle level feedback combined with brief individualized coaching over several months.

METHODS

Study Sample

This study was a two-group randomized control intervention trial aimed at reducing SHS and fine particle levels in homes with children. The sample comprised 298 homes. Study procedures were approved by the San Diego State University IRB.

Recruitment began with Women, Infants, and Children Programs in San Diego County in May 2012. Women, Infants, and Children is a federal assistance program providing supplemental food and nutrition education for pregnant, breastfeeding, or non-breastfeeding postpartum low-income women, infants, and children up to age 5 years who are at nutritional risk. Recruitment was expanded to include community tabling events, U.S. Naval Medical Center San Diego and Branch Clinic Kearny Mesa, local organizations (e.g., 2-1-1 San Diego), advertisements in local papers, schools, and referrals from healthcare professionals. Recruitment ended in December 2015.

Adults who submitted a recruitment form (in English or Spanish) reporting children aged <14 years in their household and allowing tobacco smoking inside/outside their home were eligible for a phone screen interview. The phone screen confirmed eligibility before scheduling a consent visit at the home. After informed consent during a home visit, study research assistants (RAs) installed two air particle monitors in the home, one in the room where the most smoking occurred, and another in the room where the study child slept (as reported by the participant). At the end of a baseline period, RAs made a second home visit to administer the pretest interview, which included questions about demographics and smoking.

During 2012 to 2015, 298 families who met the following criteria were enrolled: adult parent/guardian aged ≥18 years; smoker living in the household; at least one child aged >14 years (youngest child was selected for participation); planned to stay in San Diego County for the next 3 months; at least three peaks >15,000 counts per 0.01 ft^3 (i.e., 53 million counts per m^3) for particles with a diameter between 0.5 and 2.5 µm during baseline that were consistent with smoking in the home; and at least one of the following: reported child exposure to SHS in the home, reported smoking in the home, reported partial ban or no ban on smoking in the home, or RA's observation of tobacco smoking in the home.

To balance group sizes, participants were allocated to treatment group (intervention or control) in a 1:1 ratio. The first participant was assigned by the field coordinator based on a computer-generated random number, and the second participant was assigned to the alternate group. Figure 1 details the recruitment, consent, and enrollment process resulting in 149 enrolled participants per group.

Measures

Participants in the intervention group were offered the intervention comprising a feedback system (real-time lights and sounds providing feedback about particle levels; four brief coaching sessions with printouts of particle levels), and nominal incentives for participation. The intervention was delivered over ≅2 months.

Figure 2 shows the customized behavioral module with onboard computing, sound processors, lights, and speakers attached to each Dylos air particle monitor (described further below).

The setting on the behavior module was changed to deliver real-time feedback with lights and sounds at the first coaching visit, in the intervention homes only. The real-time feedback was designed to reduce particle levels (e.g., move smoking outdoors) and to encourage reduction of future occurrences of elevated particle levels (e.g., by smoking outdoors).

The behavior module was programmed to emit a blinking yellow LED light and a brief aversive auditory alert when levels of indoor particles (with diameter between 0.5 and 2.5 µm) reached 15,000 particles per 0.01 ft^3, as measured by the Dylos air monitor. The 15,000 count threshold was designed to provide near-immediate light and sound feedback when a cigarette was lit in the room with a monitor or in an adjacent room. The pilot study preceding the present study showed that cigarette and other combustion-derived particle sources often led to peak counts of ≥20,000 when smoking locations were near the Dylos air monitors.[30] When particle concentrations reached 30,000 particles per 0.01 ft^3 (i.e., 106 million counts per m^3), the LED began blinking red and a slightly more aversive brief auditory alert was triggered, indicating a higher degree of concern (for details on the audiovisual alerts, see Bellettiere et al.[31]). The 30,000 count threshold was chosen as twice the initial threshold, to inform the participant that particle counts continue to rise above the level of concern. When particle levels were <15,000 count threshold, a steady green light was displayed and no sound was emitted.

Participants’ and field staff’s blinding of treatment assignment was not possible because they were aware of whether the intervention (e.g., lights and sounds) was being delivered. The outcome measures for this paper were fine particle levels that were measured by the air monitors.

The real-time feedback received by intervention participants was bolstered by four brief coaching sessions utilizing particle level graphs during home visits. A trained RA was assigned to provide brief one-on-one coaching with each enrolled parent/guardian during four brief (≅20 minutes) sessions, primarily in-person, over ≅2 months. On average, 3.5 sessions were completed, with 118 (79%) of the intervention participants completing all four sessions, with 24 (16%) of intervention participants completing one to three sessions, and 7 (5%) not completing any sessions.

No compensation related to the coaching sessions was provided initially to participants (*n*=18). Up to $50 total (for all coaching sessions) was added with IRB approval, when it became clear that four coaching visits were difficult to complete.

Coaching was guided by previous SHS reduction research and the Behavioral Ecological Model, with emphasis on reducing particle concentrations in the home, while targeting reductions in

SHS-related particles specifically.[24,32–34] The coaching emphasized the protection of children from SHS exposure in the home and did not require smoking cessation. Participants who smoked were guided to smoke outside the home and to urge all other smokers, including family and friends, not to smoke in the home. Brochures (in English or Spanish) related to prevention of SHS exposure and to tobacco cessation were provided at the first coaching visit.[35–37]

The delayed particle feedback charts and the coaching were individualized for each home. At each session, the RA provided the study participant with graphs of indoor air particle levels from the past 7 days, as measured by the air monitors in the home. Figure 2 displays the graph showing data from the main room monitor. The RA incorporated MI techniques, (e.g., asking open-ended questions, affirming, reflective listening, resolving ambivalence, developing discrepancy, and evoking change talk).[38] They discussed keeping particle levels below the first (15,000 counts per 0.01 ft^3) threshold from all particle sources, as indicated by the real-time monitor feedback (sounds and lights), and how elevated particle levels from most sources, (e.g., tobacco smoking, burning food or wood, and dust) may affect their children's health. The RA guided participants in setting goals for behavior change that would reduce particle levels.

At subsequent visits, after reviewing the latest week's air particle graphs, the RA and participant discussed any progress and difficulties in achieving goals from the previous session. The RA provided praise for successes, (e.g., days $<15,000$ count threshold, days with fewer particle peaks above the threshold, peaks of shorter duration, or reported behavioral changes, such as actions taken to meet their goal or to establish or enforce a complete home smoking ban). The RA introduced the concept of thirdhand smoke (dust and surface contamination) and its effects.[39]

For control homes, particle monitors measured concentrations of particles during their entire study participation; no light or sound alerts or coaching sessions were provided. At the end of the study, control participants received and discussed their summary chart of their indoor air particle levels with the RA, were debriefed about SHS exposure and its likely health risks, and received brochures (in English or Spanish) related to tobacco use cessation and prevention of SHS exposure.[35,37]

This trial involved continuous measurement of fine particles in each of the control and experimental group homes for ≅3 months. For intervention homes, the baseline period extended from the day that monitoring equipment was installed in the home to the day that the lights and sounds intervention began. The post-baseline period extended from the day after the lights and sounds intervention began to the day that the monitoring equipment was removed from the home. For control homes, which did not receive alerts, the baseline period was set equal to the duration of baseline for the paired home. The average number of days (mean [SD]) for the baseline and post-baseline periods was 37.5 (SD=16.3) days and 61.8 (SD=24.3) days, respectively.

Custom Dylos DC1700 particle monitors were used to count air particles with a diameter between 0.5 and 2.5 μm every second. Monitors were installed in homes for the full duration of the study. Particle counts per second were averaged and stored every 10 seconds.

Data from the main smoking room monitor were used to derive two summary measures of air particle concentrations. The primary outcome, daily mean particle counts per 0.01 ft^3, was derived by computing the arithmetic mean particle counts for each calendar day.

The secondary outcome was percentage time ≥15,000 particle counts per 0.01 ft^3 (i.e., the first threshold for alerts to indicate elevated levels because of cigarette events or emissions from other indoor particle sources, such as cooking or incense). The percentage time above the criterion level was computed for the baseline and post-baseline periods by dividing the number of 10-second epochs with ≥15,000 particle counts by the total number of 10-second epochs and multiplying by 100.

Statistical Analysis

Approximately 650,000 hours of particle data were collected over 28,911 days. After data cleaning and excluding days with ≥5 consecutive hours of missing air particle data, 95% of the total days remained for analyses.

Both outcome measures were natural log transformed (to better approximate normal distributions) and were summarized using geometric means.

Linear mixed effects models tested each outcome for differential change by group from baseline to post baseline. This modeling approach adjusts for repeated measures nested within homes and accommodates missing data within homes.[40] The model allows for random intercepts and random slopes, to accommodate, respectively, different baseline particle levels and different change over time among homes.

Percentage change in the geometric mean of each outcome measure was computed as $(e^{\beta}-1)*100$, where β was the coefficient of the binary variable for baseline versus post baseline, as recommended for linear regression models with a natural log-transformed dependent variable (i.e., log-linear regression).[41]

For each outcome variable, different model specifications were tested (i.e., all combinations of random intercept only versus random intercept and random slope and unstructured versus autoregressive order 1 correlation structures), and the model with the lowest Akaike information criterion values, indicating best fit of the data, was selected. The final model for mean particle counts included group, time, and group-by-time as fixed effects, contained a random intercept and random slope for each home, and used an autoregressive correlation structure of order 1. For the percentage time >15,000 counts per 0.01 ft^3, a random intercept model with unstructured correlation structure was the best fit. For the final models, influential data points were investigated by visually inspecting qq-plots of residuals for any data points that were clearly separated from the 45 degree line. There were no influential data points for either final model.

A priori sample size calculations were not done, as the outcomes for this paper were not the primary outcome (child cotinine level) for the randomized trial. Analyses followed an intention-to-treat approach.[42] All statistical tests were two-tailed with an α of 0.05. Data analyses were conducted using SPSS, version 23, and R, version 3.2.2 during 2016–2017.

RESULTS

Overall, homes were mostly condominiums, apartments, or detached homes, averaging 2.6 bedrooms and 1.7 bathrooms. Most participants opened a window (94%), almost half burned incense/candles, >40% used a window fan or air conditioner, and approximately a third used central air, within the 7 days prior to the pretest interview. Enrolled children were 47% female and aged 4.0 (SD=3.6) years on average. Enrolled parents or guardians were 95% female, and on average were aged 32.9 (SD=8.5) years. Additional characteristics are provided by experimental group in Table 1.

The baseline (geometric) average concentration of particles between 0.5 and 2.5 µm per 0.01 ft^3 of air was 2,210 for the control group and 2,051 for the intervention group (Table 2). Particle levels in child's room were highly correlated with the main room and are not reported (r =0.86, $p<0.05$). During baseline, intervention homes averaged 13 minutes per day (0.92% of a 24-hour period) with particle concentrations >15,000 counts compared with 12 minutes per day (0.86% of a 24-hour period) in control homes.

There were larger decreases in geometric mean particle counts from baseline to post baseline for the intervention group than for the control group for both outcomes. Statistically significant decreases in estimated geometric mean particle counts were determined for both the intervention (18.8% decrease, $p<0.001$) and control groups (6.5% decrease, $p<0.01$). The decrease among intervention homes was 13.1% (95% CI=6.7%, 19.1%) greater relative to controls ($p<0.001$).

There was a 45.1% reduction in the percentage time with particle levels >15,000 counts per 0.01 ft^3 ($p<0.001$) for the intervention group, whereas the control group's percentage time increased

4.2%. Compared with control homes, intervention homes had nearly 50% greater reduction in baseline to post-baseline changes in percentage time >15,000 counts (p<0.001).

As can be seen for each outcome analysis in Table 2, n-sizes for baseline and post baseline differed. The differential group by time changes detected could have in part been because of differences between the subsamples available for each of the two time periods. Therefore, sensitivity analyses were conducted by selecting only those cases having a minimum of 7 days of valid data in both time periods, producing identical subsamples for baseline and post baseline. Results of the sensitivity analysis for each outcome were nearly identical to the results shown in Table 2. Analysis with imputed data for the missing subjects was conducted using the last week's observations carried forward, and the results remained essentially the same as shown in Table 2, with very slight differences in the absolute change and in the percentage change.

DISCUSSION

This study determined whether real-time feedback on household particulate matter levels along with intermittent MI coaching could reduce fine particle levels in homes where children and smokers live. Both measures of change in particle levels from the baseline to the post-baseline period showed differential decreases in particle counts between 0.5 and 2.5 µm by group favoring the intervention group (all p<0.001). Homes in the intervention group had greater decreases relative to controls in geometric mean daily particle counts per 0.01 ft^3 and in percentage time above 15,000 particle counts per 0.01 ft^3. The results support the efficacy of real-time feedback intervention and brief coaching in reducing particulate levels, including particulates from cigarettes.

This study is the first large-scale randomized trial to test automated real-time, continuous particle level feedback provided in residential settings over several months. The most comparable study was a feasibility study with a small group of mothers in the United Kingdom. that tested delayed home air quality feedback for the prior 24-hour period, plus MI.[25] The authors reported reductions in the percentage of time above 35µg/m^3 (the 24 hour $PM_{2.5}$ outdoor standard in the U.S.) and maximum $PM_{2.5}$ in both the control and intervention groups, and although the percentage reductions were larger in the intervention group, paired analyses did not find statistically significant differences between the two groups. To date, there are no other published results from trials that tested the efficacy of particle feedback on particle levels in the homes of smokers.

A major strength of the study was the collection and feedback of particle data in real time and continuously in homes. This study is expected to lead to follow-on studies with more advanced feedback technology and behavior-shaping methodology. Technologic advances and the burgeoning availability of the internet of things, as well as machine learning algorithms will facilitate data collection, processing, and adaptive behavior shaping. It is anticipated that the moderate validation of general principles of behavior in the present study will be refined as nuanced shaping and schedules of enforcement become more feasible in large studies and can be tailored for individual families. Modest effect sizes from this study suggest that future studies should consider more powerful feedback and micro-incentives to achieve more complete removal of particles from the home. Such studies might lay the foundation for telemedicine interventions to prevent particle-related (including tobacco particles) morbidity, as well as to reduce particle exposure to those already suffering from defined disease, (e.g., pulmonary disease).

Limitations

Particle levels measured in a room are a surrogate measure of actual exposures. Ideally, breathing zone concentrations of particles for each resident would be measured, but this was not feasible. Although the Dylos air monitor has been non-linearly related to $PM_{2.5}$ for various sources in individual controlled experiments, the Dylos monitor is generally not well suited for estimating absolute mass particle concentration for $PM_{2.5}$ (i.e., particles with diameters less than 2.5 µm).[43] The Dylos cannot measure particles with diameters below 0.5 µm, whereas the full size-distribution of $PM_{2.5}$ particles extends below 0.5 µm and varies by source and over time as a function of size-dependent removal. However, the differences measured in this study reflected real changes in particle counts in the 0.5 to 2.5 µm range of respirable particles, which are particles that are capable of penetrating into the human lung. The Dylos particle monitor was used for several reasons, including reasonable cost, quiet fan, good inter-unit consistency, and because particle monitoring has high sensitivity to $PM_{2.5}$ released by cigarette smoking that is appropriate for homes with resident smokers.[25,44,45] The Dylos' real-time measurement capability allowed detection of changes in particle counts in real time and provision of lights and sounds for feedback to occupants when particle levels increased rapidly, thereby signaling a particle generating event while it was occurring.

Although intention-to-treat analyses were conducted, not all participants in the intervention condition received the full intervention as intended. Some intervention participants did not complete all of the coaching sessions and had interruptions of lights and sounds for feedback because of technical problems with the equipment or interference with the equipment's operation by residents, (e.g., temporary unplugging of the equipment from the electrical outlet). Thus, the results suggest larger magnitude effects are possible if more participants comply with all procedures and measures. For a few participants in both the intervention and control groups, data collection during the post-baseline period was attenuated due to participants leaving the study early. However, the majority (96%) of participants provided post-baseline particle data, including some who left the study early but provided particle outcome data because the data were collected longitudinally every 10 seconds. The composition of the sample was diverse in ethnicity/race and household income, however, generalizability of the findings to different populations may be limited.

CONCLUSIONS

This study illustrates how air quality instruments might be deployed successfully to reduce fine particle exposure. Similar applications should be considered for children exposed to fine particles and SHS in other settings, such as day care and others where proximity to smoke is likely. This study sets the stage for a new line of innovative behavioral interventions for tobacco control that are just in time and adaptive, and that could compete more effectively with participant's real-time urges to smoke or generate fine particles in their daily natural environments. Refinements in measures of fine particle and SHS exposure remain to be developed for real-time assessment and automatic shaping of reduced exposures.[46]

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Benjamin Nguyen, John Bellettiere, and Sandy Liles helped draft the concept, helped with data acquisition, conducted data analyses, and helped draft the manuscript; Savannah Bradley assisted with data preparation and writing; Melbourne F. Hovell, Neil E. Klepeis, Penelope J. E. Quintana, C. Richard Hofstetter, Suzanne C. Hughes, Saori Obayashi, and Vincent Berardi

drafted the concept and design, aided in data interpretation, and assisted with drafting the manuscript. All authors had final approval of the submitted manuscript.

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LIST OF FIGURES

Figure 1. Participant flow.

Figure 2. Air monitor with behavior module attached (left) and sample graph showing particle concentration measured by the monitor (right).

SD Card, Secure Digital Card

Table 1. Baseline Characteristics by Assigned Group, n=298[a]

Characteristic	**Control (*n*=149)**	**Intervention[b] (*n*=149)**
Home characteristic		
Home type, %		
Condo/Apartment	43.0	40.3
Detached house	41.6	43.0
Other	15.4	16.8
Number of bedrooms, mean (SD)	2.7 (1.1)	2.6 (1.0)
Number of bathrooms, mean (SD)	1.7 (0.7)	1.7 (0.7)
Particle and ventilation activities, % (median)[c]		
Incense or candles	49.3 (2.0)	45.5 (3.0)
Central air	37.2 (7.0)	34.0 (6.5)
Window fan or window air conditioner	41.9 (7.0)	45.2 (7.0)
Open a window	94.0 (7.0)	93.9 (7.0)
Participant characteristic		
Child[d] is female	47.0	47.0
Child age, years		
0 to 1.9	37.6	38.9
2 to 5.9	33.6	43.0
6 to 13.9	28.9	18.1
Child race/ethnicity		
Hispanic	46.3	49.7
Non-Hispanic black	12.8	13.4
Non-Hispanic white	18.1	19.5
Non-Hispanic other[e]	22.8	17.4
Parent[f] education, years completed		
<12	18.8	17.0
12	23.5	17.7
>12	57.7	65.3
Parent is a single parent	35.6	40.9
Parent is employed	39.9	39.4
Annual household income		
<$10,000	18.6	25.2
$10,000–$19,999	16.3	21.5
$20,000–$29,999	19.4	17.0
$30,000–$39,999	16.3	8.9
$40,000–$49,999	12.4	7.4
$50,000–$59,999	6.2	5.9
$60,000–$69,999	2.3	4.4
$70,000–$79,999	3.9	3.7
$80,000–$89,999	1.6	1.5
≥$90,000	3.1	4.4

[a]Enrolled longitudinal sample.
[b]Pearson chi-square tests for categorical variables and t-tests or Mann-Whitney U tests for quantitative variables showed no statistically significant group differences (all $p>0.05$).
[c]Median number of days for homes that reported the activity in the past 7 days.

[d]Enrolled child.
[e]"Non-Hispanic other" includes: Native American, Asian, Pacific Islander, mixed, unspecified.
[f]Enrolled parent/guardian.

Table 2. Baseline, Post Baseline and Change in Particle Level Outcomes, by Experimental Condition

Outcome variables	n	Baseline Geometric mean[a] (95% CI)	n	Post baseline Geometric mean[a] (95% CI)	Change in geometric mean	% Change: % change in geometric mean[a]	% Change: % change in time effect[d] relative to control[a, e] (95% CI)
Daily particle counts/0.01 ft^3							
Intervention	5,273[b]	2,210 (1,988, 2,457)	8,596[b]	1,795 (1,627, 1,981)	–415	**–18.8****	**–13.1 (–19.1, –6.7)****
Control	5,310[b]	2,051 (1,845, 2,280)	8,261[b]	1,917 (1,737, 2,116)	–134	**–6.5***	ref
Percent of time >15,000 particle counts/0.01 ft^3							
Intervention	149[c]	0.92 (0.69, 1.24)	142[c]	0.51 (0.38, 0.68)	–0.41	**–45.1****	**–47.3 (-62.1, –26.9)****
Control	149[c]	0.86 (0.64, 1.15)	144[c]	0.89 (0.67, 1.20)	0.03	4.2	ref

Notes: Boldface indicates statistical significance (**p*<0.01; ***p*<0.001).

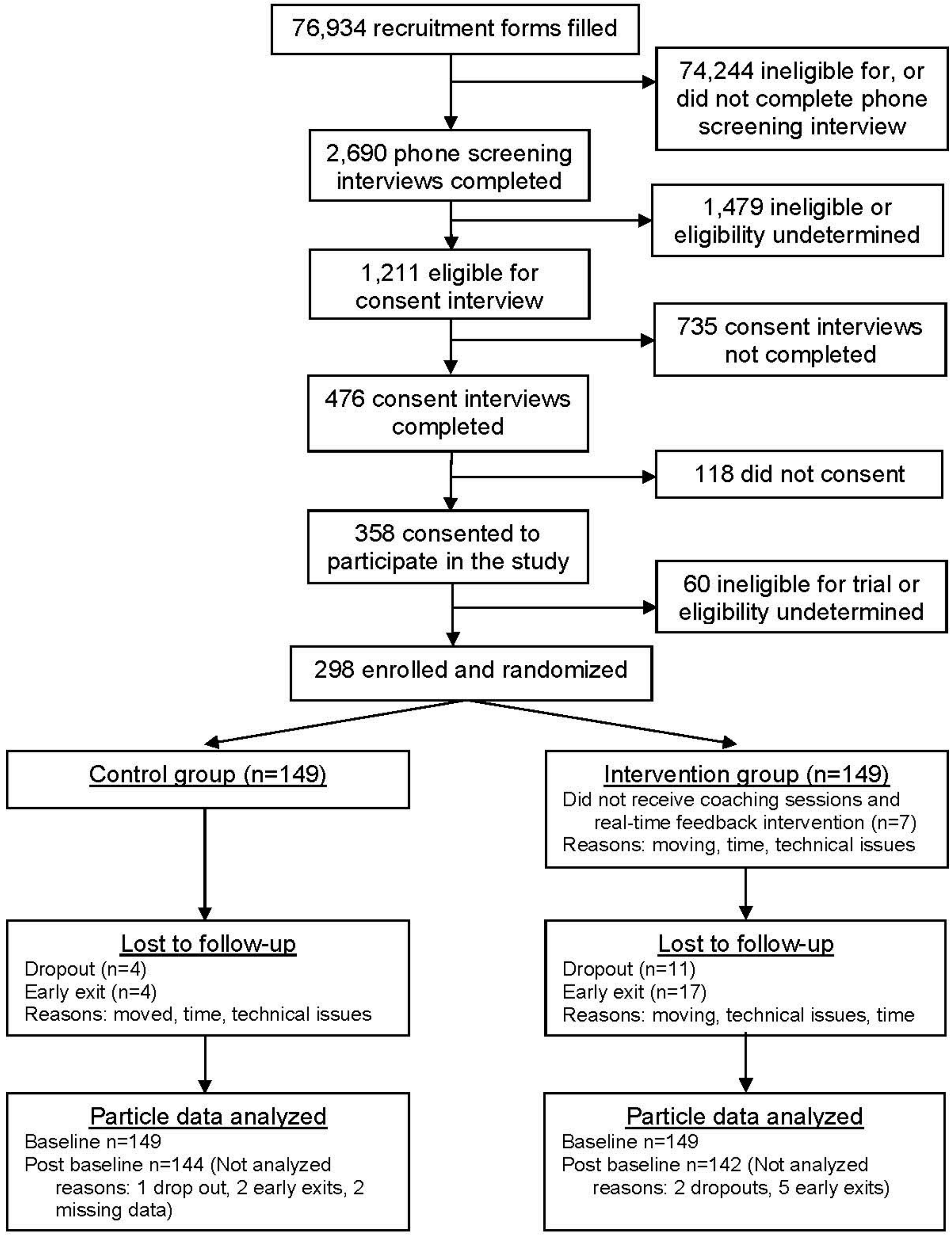
[a]Estimate from linear mixed effects models.

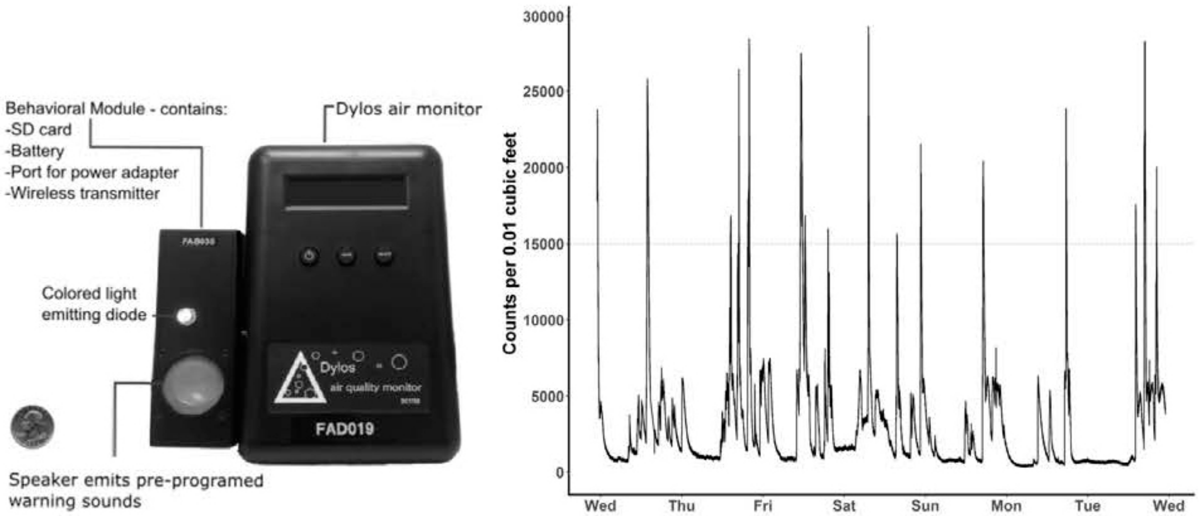
[b]n indicates the number of days of measurement by group included in analyses.

[c]n indicates the number of homes by group included in analyses.

[d]Time effect = Post Baseline geometric mean divided by the Baseline geometric mean.

[e] % change in time effect (for intervention group) relative to control group = [(intervention group time effect - control group time effect) / control group time effect] * 100.


76,934 recruitment forms filled
74,244 ineligible for, or did not complete phone screening interview
2,690 phone screening interviews completed
1,479 ineligible or eligibility undetermined
1,211 eligible for consent interview
735 consent interviews not completed
476 consent interviews completed
118 did not consent
358 consented to participate in the study
60 ineligible for trial or eligibility undetermined
298 enrolled and randomized
Control group (n=149)
Intervention group (n=149)
Did not receive coaching sessions and real-time feedback intervention (n=7)
Reasons: moving, time, technical issues
Lost to follow-up
Dropout (n=4)
Early exit (n=4)
Reasons: moved, time, technical issues
Lost to follow-up
Dropout (n=11)
Early exit (n=17)
Reasons: moving, technical issues, time
Particle data analyzed
Baseline n=149
Post baseline n=144 (Not analyzed reasons: 1 drop out, 2 early exits, 2 missing data)
Particle data analyzed
Baseline n=149
Post baseline n=142 (Not analyzed reasons: 2 dropouts, 5 early exits)


Behavioral Module - contains:
-SD card
-Battery
-Port for power adapter
-Wireless transmitter
Dylos air monitor
Colored light emitting diode
Dylos
air quality monitor
FAD019
Speaker emits pre-programed warning sounds
Counts per 0.01 cubic feet
30000
25000
20000
15000
10000
5000
0
Wed
Thu
Fri
Sat
Sun
Mon
Tue
Wed