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Original research

Portable air filtration and the incidence of follow-up meetings in office workers: a cluster-randomised trial

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Abstract

Background: Meetings can generate further meetings. Portable high-efficiency particulate air (HEPA) cleaners reduce exposure to airborne particles in occupied rooms. Whether they alter the production of follow-up meetings has not been evaluated.

Methods: We randomly assigned 48 office teams and their regular meeting rooms to active HEPA filtration or a sham cleaner for 12 weeks. The primary outcome was the number of new follow-up meetings initiated within seven days per weekly index meeting, ascertained from calendar records and organiser reports. A negative-binomial mixed model accounted for team clustering. Particle concentration, carbon dioxide, scheduled meeting time and work-related burnout were secondary outcomes. Fully remote meetings served as a negative-control setting.

Findings: The 48 teams enrolled 640 staff (322 active, 318 sham). We observed 276 index meetings in the active group and 278 in the sham group. These generated 174 and 336 follow-up meetings, respectively: 0.63 versus 1.21 per index meeting (adjusted rate ratio 0.52, 95% CI 0.40 to 0.68). Mean airborne particle concentrations during index meetings were 420 and 970 particles/cm³, respectively; carbon dioxide concentrations were similar. For fully remote meetings the corresponding rate ratio was 0.98 (0.78 to 1.23). Mean scheduled meeting time at week 12 was 516 versus 556 minutes per participant-week, and work-related burnout was 2.9 points lower (95% CI −5.4 to −0.4) in the active group.

Interpretation: Filtration was associated with fewer follow-up meetings after in-person index meetings but not after remote meetings. The nature of the meeting-forming material, if any, remains to be established.

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Keywords: occupational health; indoor air; meetings; cluster randomised trial

Introduction

Meetings are a common means of coordinating work. They can also create demands for further coordination: a decision deferred at one meeting may require a second meeting, attended by some or all of the original participants. Time spent in meetings competes with other activities during the working day. In experience-sampling studies, a higher proportion of time in meetings was associated with fewer microbreaks and lower energy [1]. Recovery after a meeting may depend on its perceived quality and relevance [2].

Follow-up meetings are usually attributed to unfinished work, rather than conditions in the room where that work was discussed. This distinction matters for prevention. If meeting formation has an airborne component, exposure could be reduced without altering the agenda or asking participants to change their behaviour. In a conference-room experiment, portable HEPA cleaners reduced exposure to simulated exhaled aerosol particles [3]. The presence of an air cleaner does not, however, establish what fraction of subsequent scheduling activity can be attributed to a filterable exposure.

We conducted a cluster-randomised trial of active and sham air cleaners in rooms used for regular team meetings. The primary outcome was the number of follow-up meetings initiated after a prespecified index meeting. We also examined airborne particles, carbon dioxide, participant meeting time and follow-up meetings after fully remote index meetings. The latter provided a setting in which participants could meet without sharing air in a trial room.

Methods

Design, setting and participants

This was a 12-week parallel-group cluster-randomised trial in three administrative organisations in England: a public services agency, a professional services partnership and a membership organisation. We randomised teams and their assigned meeting rooms together because a single cleaner could affect all occupants of a room. The study is reported in accordance with the CONSORT extension for cluster trials [4].

Eligible teams had 8–25 employees, used a shared electronic calendar and held a regular in-person meeting at least weekly in a room assigned principally to that team. Teams were excluded if their rooms had a dedicated air cleaner, if they expected relocation during the trial, or if most team meetings were appointments with members of the public. Employees working at least four days per week could participate. Managers agreed to team allocation; staff gave individual written consent to calendar extraction and questionnaires before allocation. Non-consenting employees could attend meetings but their calendars and questionnaire data were not extracted.

The Fenmere University Occupational Health Research Ethics Committee approved the study (FU-OH-2025-031). The protocol and statistical analysis plan were deposited before recruitment in the Fenmere Work Studies Register (FWSR-25-018). The funder had no role in the trial’s conduct or analysis.

Randomisation and masking

An independent statistician allocated teams 1:1 within organisation in randomly permuted blocks of two and four. Allocation was concealed until baseline data collection and consent were complete. Identical cabinets housed the active and sham units. In the

sham unit, an internal bypass returned air to the room without passing it through the HEPA filter; the fan, indicators and exterior were the same. Technicians matched fan noise to within 2 dB at the table centre before deployment. They knew allocation but did not code calendar outcomes. Participants, outcome coders and the trial statistician were masked to the assignment. At 12 weeks, participants were asked to guess their allocation.

Intervention and exposure measurement

Active cleaners had a nominal clean-air delivery rate of 350 m³/hour. They were positioned beside the meeting table with their outlets unobstructed. With the median room volume of 70 m³, this corresponded to approximately five equivalent air changes per hour in addition to existing ventilation. The corresponding figure describes particle removal under a well-mixed assumption and is not an outdoor-air ventilation rate. Sham units had the same fan setting but negligible filtration through the bypass. The units were switched on 15 minutes before each index meeting and left running until 15 minutes after it ended. Neither group was given instructions about meeting content, cancellation or scheduling.

An optical particle counter at seated head height recorded particle number concentration in the 0.3–3 µm size range at one-minute intervals. A separate sensor recorded carbon dioxide. The device log recorded fan operation; a technician inspected the units every two weeks. Particle instruments were checked against a common reference instrument before and after the study. The mean of available one-minute measurements during an index meeting was used for that meeting; carbon dioxide was

used to describe occupancy and ventilation, not as a measure of particles removed by a HEPA filter.

Index meetings and follow-up ascertainment

Before allocation, each team identified its regular weekly in-person meeting as the index meeting. A meeting was eligible for analysis if at least four consenting team members attended in the assigned room, it lasted at least 15 minutes and a calendar record was available. Rescheduled meetings counted once in the week in which they occurred. The index meeting itself and later occurrences of the same recurring series were not follow-up meetings.

A follow-up meeting was a new calendar event for at least two people, initiated within seven calendar days of an index meeting and scheduled to occur within 21 days, whose organiser reported that it was called to continue a matter discussed at that index meeting. Rescheduling an existing event did not constitute a new follow-up. Cancelled follow-ups were retained if the invitation had been issued; the outcome is meeting formation rather than attendance. The organiser had to be a consenting participant who attended the index meeting. An organiser could name only one index meeting as the immediate parent. When a proposed follow-up related to more than one index meeting, the most recent was assigned as parent. The denominator was the number of eligible index meetings, including those that produced no follow-up.

Calendar exports supplied invitation dates, participant identifiers, recurrence status and scheduled duration. Organisers completed a brief structured linkage form each week; coders masked to allocation reconciled forms and event identifiers. No email or meeting transcript was collected. Two coders independently assessed 120 randomly sampled

proposed links against the organiser forms; disagreements were resolved before unmasking. Because the reason for a meeting was reported by its organiser, linkage could not establish that the event would not otherwise have been scheduled.

For a negative-control analysis, we identified fully remote meetings of participating staff in which everyone joined from an individual workstation rather than a trial room. Organisers used the same form and seven-day definition. These meetings could involve people from either trial arm. Their organisers’ team allocation defined the comparison; no randomised cleaner was operating in the meeting setting.

Outcomes and analysis

The primary outcome was the count of directly linked follow-up meetings per index meeting. Counts were analysed with a negative-binomial mixed model with a random intercept for team and fixed effects for allocation, organisation and the team’s mean follow-up count over the four-week baseline period. All eligible index meetings contributed according to assigned group, irrespective of whether the unit was operating. The adjusted rate ratio and 95% confidence interval describe the ratio of mean counts per index meeting. Recurring index meetings and multiple invitees to the same follow-up were not counted as additional offspring.

We planned 24 teams per group. With a standard deviation of 0.55 for team mean follow-up counts, 24 independent teams per group give approximately 80% power at a two-sided 5% level to detect a difference of 0.45 meetings per index meeting. This calculation used team means and did not assume independence of repeated meetings within teams.

Secondary outcomes were particle number and carbon dioxide during index meetings, total scheduled meeting time per participant in week 12, and work-related burnout at week 12. Calendar time included accepted or tentative events with at least two invitees, excluding cancelled events, personal holds and all-day entries; overlapping intervals were counted once. A valid week required at least four working days excluding leave. Work-related burnout was measured with the seven-item Copenhagen Burnout Inventory subscale (0–100; higher scores indicate greater burnout) [5]. Meeting time and burnout were analysed using baseline-adjusted linear mixed models with a team random intercept. The burnout analysis included respondents with both baseline and follow-up questionnaires. The calendar analysis included participants with a valid week-12 record; no missing records were imputed.

For the primary outcome, sensitivity analyses excluded index meetings without documented fan operation and used the earliest rather than the most recent index meeting as parent where a follow-up had multiple candidates. We also compared follow-up counts in fully remote meetings and described the cumulative number of invitations over the seven-day ascertainment period. These analyses were prespecified. Confidence intervals for secondary outcomes were not adjusted for multiplicity.

Results

Participants and intervention delivery

From 6 January to 21 February 2025, 60 teams (921 staff) were assessed. Twelve teams comprising 153 staff were excluded: five lacked an eligible meeting room, four expected relocation and three declined team participation. In the remaining 48 teams, 640 of 768 eligible staff consented and completed baseline assessments. Twenty-four

teams (322 participants) were allocated to active filtration and 24 (318 participants) to sham filtration (Figure 1). All teams remained in the study.

The active and sham groups had similar baseline characteristics (Table 1). Across 576 planned weekly meetings, 22 did not meet the index definition: 12 in active rooms and 10 in sham rooms. Thus 276 and 278 index meetings, respectively, entered the primary analysis. Device logs documented operation during 269 active and 271 sham index meetings. The remaining 14 meetings stayed in the primary analysis as allocated.

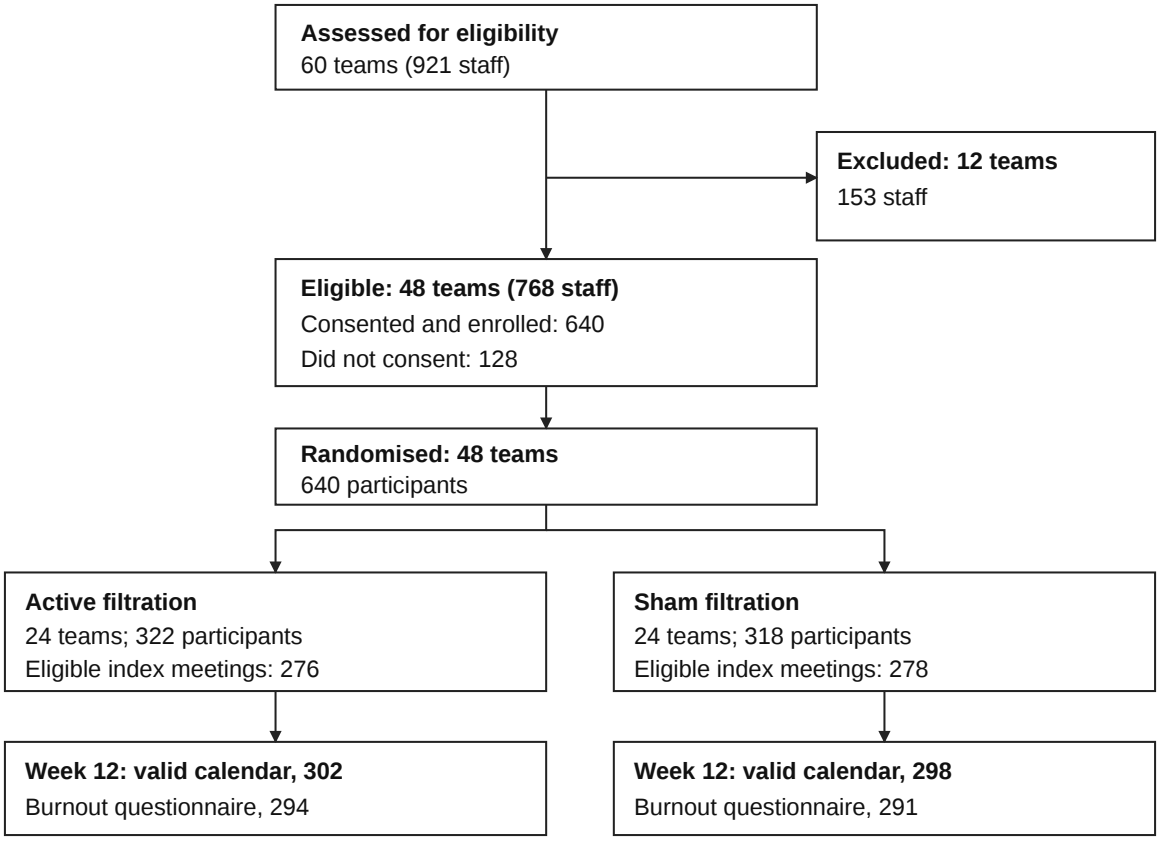


Figure 1. Trial profile. Eligible index meetings required at least four consenting staff in the assigned room, a duration of at least 15 minutes and an available calendar record.

Table 1. Baseline characteristics by allocated group. Values are mean (SD) or n (%) unless stated. Baseline follow-up counts are per eligible index meeting over four weeks.

Characteristic	Active (n=322)	Sham (n=318)
Teams and assigned rooms	24	24
Participants per team, median (range)	13 (8–22)	13 (8–21)
Age, years	42.1 (10.4)	41.7 (10.8)
Women	188 (58.4%)	182 (57.2%)
Line-management responsibility	54 (16.8%)	52 (16.4%)
Room volume, m³, median (IQR)	70 (62–81)	71 (63–80)
Follow-up meetings per index meeting	1.10 (0.55)	1.11 (0.57)
Scheduled meeting time, min/week	554 (119)	551 (122)
Work-related burnout, 0–100	43.1 (16.5)	42.8 (16.8)

At week 12, 302 active-group and 298 sham-group participants had a valid calendar week; 294 and 291 completed the burnout questionnaire. A total of 563 participants guessed their allocation: 146 of 284 active-group respondents and 137 of 279 sham-group respondents guessed correctly. Participants reported no serious adverse events attributed to the units. Six teams reported fan noise as an inconvenience (three per group).

Follow-up meetings

The 276 active-group index meetings generated 174 follow-up meetings, compared with 336 after 278 sham-group meetings: means of 0.63 and 1.21 per index meeting. The adjusted rate ratio was 0.52 (95% CI 0.40 to 0.68; p<0.001). A greater proportion of active-group index meetings generated no follow-up (Table 2). The cumulative number of linked meetings diverged during the seven-day ascertainment window (Figure 2).

Table 2. Distribution of directly linked follow-up meetings per index meeting. Each follow-up is counted once regardless of its number of invitees.

Follow-up meetings	Active index meetings, n	Sham index meetings, n
0	157	95
1	78	86
2	28	60
3 or more	13	37
Total index meetings	276	278
Total follow-up meetings	174	336

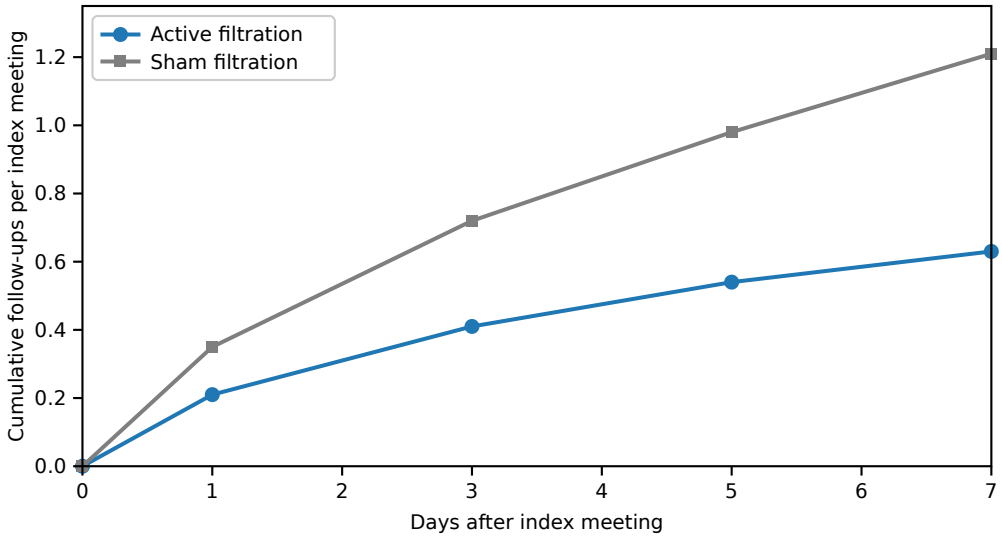


Figure 2. Cumulative follow-up meetings initiated per index meeting, by time since the index meeting. Values are observed cumulative counts divided by 276 active-group or 278 sham-group index meetings; each index meeting had seven days of ascertainment.

Among 120 proposed links independently assessed by two masked coders, 108 (90%) had the same classification before adjudication. Twenty-six follow-ups had more than one candidate index meeting. Assigning these to the earliest eligible parent gave a rate ratio of 0.54 (0.41 to 0.70). Restricting analysis to the 540 index meetings with documented fan operation gave 0.53 (0.40 to 0.69).

In the negative-control setting, 162 fully remote index meetings organised by active-group staff and 160 organised by sham-group staff generated 126 and 128 follow-ups,

respectively. The adjusted rate ratio was 0.98 (0.78 to 1.23). Remote and in-person meetings may have differed in purpose; this comparison does not isolate a physical transmission route.

Air measurements and participant outcomes

Mean particle number concentration during index meetings was 420 particles/cm³ with active filtration and 970 particles/cm³ with sham filtration, a 56.7% lower concentration in the active group. Mean carbon dioxide was 715 and 721 parts per million, respectively. These are room averages during meetings, not personal exposure measurements. At week 12, active-group participants had fewer scheduled meeting minutes and a lower mean burnout score (Table 3).

Table 3. Air measurements and week-12 participant outcomes. Air values are means across index meetings with valid sensor records (269 active, 271 sham). Participant means use valid calendar weeks (302 and 298) or completed burnout questionnaires (294 and 291). Adjusted differences are active minus sham.

Outcome	Active	Sham	Adjusted difference (95% CI)
Particles, number/cm³	420	970	—
Carbon dioxide, ppm	715	721	—
Scheduled meeting time, min/week	516	556	−38 (−58 to −18)
Work-related burnout, 0–100	39.9	43.0	−2.9 (−5.4 to −0.4)

Discussion

Active filtration reduced the number of follow-up meetings linked to an in-person index meeting. Follow-up counts after fully remote meetings were similar by organiser allocation. Concentrations of measured particles were lower in active rooms, whereas carbon dioxide concentrations were similar. Scheduled meeting time and work-related burnout were also lower, although these secondary outcomes are subject to missing data and multiple comparisons.

An average of 1.21 follow-ups per sham-group index meeting does not imply unlimited growth: follow-ups were not necessarily observed as index meetings, and events can have several antecedents. We did not estimate a basic reproduction number. Meetings with no offspring remained in the denominator, and each event counted once regardless of invitees.

Filtration could act on a component of the room environment that precedes a decision to convene again. We did not identify such a component. The particle counter measured aggregate concentration, not particle composition or provenance. Carbon dioxide is not removed by HEPA filtration, so similar carbon dioxide concentrations are compatible with lower particle counts. Follow-up meetings can also arise through channels outside the room; the negative control does not rule out differences in the work discussed remotely.

The sham design and masked coding reduce some sources of bias. Organisers supplied the reason for each follow-up, and assignment of a single parent may simplify a chain of decisions. The two parent-assignment rules do not resolve unrecorded links. Eligibility required attendance by four consenting staff, which might itself be affected by allocation. A scheduled invitation does not establish attendance or the value of work completed; fewer follow-ups could reflect work shifted to unmeasured channels.

The intervention was delivered to teams with a regular assigned room; its effect in other settings is uncertain. Burnout and meeting time were secondary outcomes. The trial cannot identify a physical carrier, its particle size or a personal dose-response

relationship. Those questions require analysis of material removed by the filter and independent linkage of meeting content to invitations.

Future work should collect both filter material and a complete record of scheduling across communication channels. Until the active material is characterised, particle concentration remains a proxy for exposure rather than a direct measure of meeting-forming activity.

Data sharing and declarations

The protocol, analysis plan and aggregate tabulations are available from the authors; individual calendar records are not public. EMV and NRS designed the study, TEM led analysis and ACB coordinated follow-up. All authors approved the manuscript and declare no competing interests.

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