Evaluating movement breaks as a public health strategy to mitigate the harms of prolonged sitting: a large-scale pragmatic intervention

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ABSTRACT
OBJECTIVES
Brief, regular movement breaks have been proposed as a public health strategy to offset the harms of prolonged sedentary behaviour; however, their real-world viability is unclear. This study aimed to assess the implementation potential, effectiveness on psychosocial outcomes and optimal dosing of movement breaks in naturalistic settings.

Methods Adults (n=19 342) enrolled in a 2-week pragmatic intervention embedded within an interactive podcast; of whom 59.4% (n=11 484) initiated the intervention. Participants took 5-minute walking breaks at their self-selected break frequency (three arms: every 30, 60 or 120 min). Implementation potential was assessed using the Feasibility, Acceptability and Appropriateness of Intervention Measures (FIM, AIM, IAM). Fatigue, positive affect and negative affect were assessed pre-intervention and post-intervention.

Results All arms exceeded the viability threshold (>3.0) for implementation outcomes. Feasibility was higher at lower break frequencies (FIM: 30 min=3.41, 60 min=3.80, 120 min=4.01), while acceptability and appropriateness were high across arms (AIM: 30 min=3.91, 60 min=4.03, 120 min=4.03; IAM: 30 min=4.00, 60 min=4.04, 120 min=3.99). Reported fatigue and negative affect decreased and reported positive affect increased significantly across all arms. Improvements showed a dose-response pattern: the 30-minute and 60-minute arms exceeded minimal important difference thresholds for fatigue (change: 30 min=−1.55, 60 min=−1.41, 120 min=−1.19) and positive affect (change: 30 min=1.86, 60 min=1.65, 120 min=1.27), with only the 30-minute arm exceeding the threshold for negative affect (change: 30 min=−1.00, 60 min=−0.92, 120 min=−0.67).

Conclusion In this large-scale, pragmatic intervention, movement breaks demonstrated good implementation potential and effectiveness for improving psychosocial outcomes over the 2-week intervention period. Hourly breaks offered the best balance between feasibility and effectiveness. These findings support movement breaks as a potentially viable public health strategy to reduce the harms of prolonged sedentary behaviour.

WHAT IS ALREADY KNOWN ON THIS TOPIC
- ⇒ Prolonged sedentary behaviour has emerged as a significant public health concern that incurs increased risk of many chronic conditions, poorer mental health and mortality, necessitating a need for scalable strategies to mitigate its health impact.
- ⇒ Laboratory studies suggest that brief, regular movement breaks (ie, a 5-minute walk every hour) can counteract the harmful health effects of prolonged sedentary behaviour and could constitute a promising public health strategy.
- ⇒ Existing research has examined strategies to prompt movement breaks, but gaps remain in understanding the optimal dosing of movement breaks and how it influences implementation potential and effectiveness in real-world settings.

WHAT THIS STUDY ADDS
- ⇒ In real-world conditions, movement breaks were rated as feasible, acceptable and appropriate across all doses, showing strong implementation potential.
- ⇒ Movement breaks were effective in improving self-reported psychosocial outcomes in a dose-response pattern and had no adverse effects on work outcomes.
- ⇒ Hourly movement breaks offered the best balance between feasibility and effectiveness.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY
- ⇒ Scalable, population-level strategies to mitigate the health impact of sedentary behaviour are limited.
- ⇒ This large-scale study demonstrates that movement breaks are implementable and effective, supporting their potential as a public health strategy and providing new insights into feasible and effective dosing for real-world implementation that can be integrated into existing guidelines and tested in future trials.

INTRODUCTION
Prolonged sedentary behaviour (eg, excessive waking time spent sitting, reclining or lying with low energy expenditure) has become ubiquitous in industrialised societies. Advances in labour-sparing and screen-based technologies have reshaped occupational, domestic and social environments to require or encourage prolonged sedentary behaviour.[1–3] Adults in high-income countries

now spend 11–12 hours/day sedentary, corresponding to over three-quarters of the waking day.[4 5] Excessive sedentariness has emerged as a significant public health concern that incurs increased risk of many chronic conditions, poorer mental health and mortality and poses a substantive economic burden to healthcare systems.[6–8] With sedentary time continuing to rise in industrialised societies,[9] there is an urgent need for scalable, population-level strategies to mitigate its health impact.

Sedentary behaviour is purported to increase chronic disease risk in part via pathophysiological processes linked to reduced skeletal muscle contractile activity and bends in the lower limb arterial tree induced by the sitting posture.[10] In this context, periodic movement may counteract these pathways by regularly reactivating metabolic processes mediated by skeletal muscle (ie, glucose uptake, lipid hydrolysis) and restoring lower limb blood flow.[10] Experimental evidence suggests that brief, regular movement breaks (ie, interruptions to prolonged sitting achieved by walking, such as a 5-minute walk every half hour) can counteract the harmful cardiometabolic effects of prolonged sedentary behaviour and improve psychosocial well-being.[11–13] Accordingly, movement breaks have emerged as a promising public health strategy for mitigating the harms of prolonged sedentary behaviour. However, translating this experimental evidence into real-world adoption remains a challenge and the existing evidence base is limited.[14–17] An earlier Cochrane review highlighted uncertainty regarding the applicability of findings from controlled laboratory studies to real-world settings, emphasising a need for trials evaluating movement break interventions under free-living conditions given a dearth of identified studies.[18] More recent evidence suggests that this gap still largely persists. While a growing body of literature has examined strategies to prompt or facilitate breaks in sedentary time (eg, computer-based reminders, wearable devices and workplace interventions), the number of interventions identified in more recent reviews remains relatively small and most have included modest sample sizes, focused on standing rather than movement-based interventions and yielded mixed effects on health-related outcomes.[17 19–22] Moreover, these studies have largely focused on the delivery mechanisms used to encourage breaks, rather than the characteristics and dosing of movement breaks themselves. A critical next step to effectively scale movement breaks is determination of the movement break dose that optimally balances real-world feasibility with effectiveness. While some dose-finding studies have been conducted or are underway in controlled laboratory settings,[23 24] little is known about how different movement break doses perform under real-world conditions. More broadly, the viability of movement breaks as a public health strategy with potential for scale across occupations, lifestyles and demographic groups has not been evaluated. Evidence on both the implementation potential (feasibility, acceptability, appropriateness) and effectiveness of movement breaks in real-world conditions is urgently needed to inform public health guidelines, which remain vague (‘sit less, move more’) and lack specific, actionable recommendations or strategies.[25 26]

To address this evidence gap, we conducted a large-scale, pragmatic intervention to evaluate the real-world viability of movement breaks across three dosing conditions for break frequency. Our primary aims were to assess the implementation potential and effectiveness on psychosocial outcomes of different movement break frequencies when adopted in everyday settings. This study represents one of the first large-scale attempts to evaluate the viability of movement breaks as a public health strategy in naturalistic conditions and to inform dosing recommendations grounded in both implementation and effectiveness outcomes.

METHODS

Study design

The Body Electric Study was a pragmatic, non-randomised intervention with three arms: movement breaks every 30 min, every 60 min or every 120 min. Movement break frequency was self-selected at enrolment to reflect real-world preference and feasibility, consistent with the pragmatic, participant-driven design of the study. The selected movement break frequency remained fixed throughout the study.

The study consisted of a 7-day baseline monitoring period followed by a 14-day intervention period. During the baseline period, participants were instructed to go about their typical daily routines without altering their behaviour. In the intervention period, participants were instructed to complete movement breaks at their self-selected frequency during the intervention phase. A survey battery was administered online both before the baseline period and immediately post-intervention. To assess between-day and within-day changes, participants were assigned to one of two survey protocols: most participants received a daily end-of-day survey via email at 20:00 hours throughout the 21-day study period, while a stratified random sample of 1200 full-time employed participants completed an ecological momentary assessment (EMA) protocol designed to evaluate the momentary effects of movement breaks. Participants assigned to the EMA protocol received five SMS-based surveys per day at 09:00, 12:00, 15:00, 18:00 and 21:00 hours. Randomisation to the EMA protocol was stratified by movement break arm and sex.

Study population

Participants were recruited as part of an interactive podcast series on health and technology, *Body Electric*, produced by National Public Radio (NPR), a major US-based public media organisation. In the first episode, the podcast featured findings from a laboratory-based study by Columbia University Medical Center researchers examining the optimal frequency and duration of movement breaks to improve cardiometabolic risk factors.[27] As part of the interactive component, listeners were invited to participate in the ‘Body Electric Challenge’ to test the feasibility of implementing those same movement breaks in real-world settings. Enrolment was open for 6 days following the release of the first episode.

Participation was open to working and non-working (eg, students, homemakers, unemployed, retirees) adults globally. Eligible participants were ≥18 years of age, English-speaking and had access to a smartphone with a data and text messaging plan. Exclusion criteria included a recent history of bone, joint or soft tissue injury that could be exacerbated by physical activity; chest pain at rest, during activities of daily living or with movement or a physician’s recommendation to engage only in supervised exercise.

Intervention

The 2-week ‘Body Electric Challenge’ was a self-administered behavioural intervention embedded in an interactive podcast series. Although participants implemented the intervention independently, the shared timing, framing and narrative context created a naturalistic social experiment, with all participants engaging simultaneously as part of a broader listener community. The podcast released weekly episodes that highlighted the health risks of prolonged sitting, the benefits of movement breaks and featured testimonials from listeners completing the challenge, which were submitted in real time.

Participants were instructed to take movement breaks at their self-selected frequency (every 30, 60 or 120 min) throughout the day (ie, all waking hours), across all contexts including work, home and public settings. Instructions were delivered through the podcast and via email communication. Breaks consisted of walking at a comfortable pace for 5 min. This duration was selected based on prior experimental evidence from a randomised crossover trial demonstrating greater improvements in cardiometabolic risk markers, mood and fatigue with 5-minute movement breaks compared with shorter duration breaks.[27] The intervention was carried out continuously across weekdays and weekends. Participants were provided with a movement break log for self-monitoring, delivered as a fillable PDF that could be completed electronically or printed for paper-based use. Consistent with the pragmatic and minimally structured design, no external cues, reminders or behaviour change tools were provided; participants were encouraged to use any supports or strategies they found helpful to facilitate adherence. Study materials, podcast episode transcripts and data are available at https://osf.io/c9r7x/.

Outcomes

Implementation outcomes were assessed using the validated Feasibility of Intervention Measure (FIM), Acceptability of Intervention Measure (AIM) and Intervention Appropriateness Measure (IAM), each consisting of four items scored on a 5-point Likert scale (1=completely disagree; 5=completely agree).[28] Given the deliberately pragmatic and minimal nature of the intervention, a mean score >3.0 (ie, above neutral) on these measures was considered a generally positive response, indicating promising implementation potential for a given movement break dose.

Compliance with the intervention was assessed via self-report. Participants self-reported the number and average duration of movement breaks either at the end of each day (daily surveys) or since the last prompt (for participants assigned the EMA protocol).

Effectiveness outcomes included reported fatigue, affect and work performance/engagement. Primary effectiveness outcomes were derived from the pre-post surveys and included the three-item version of the Fatigue Symptom Inventory, the Positive and Negative Affect Schedule Short Form, six items from the WHO Health and Work Performance Questionnaire (past 2-week recall) and the three-item version of the Utrecht Work Engagement Scale.[29–32] Secondary and exploratory effectiveness outcomes were assessed via daily and EMA surveys. For participants assigned the daily surveys, fatigue, affect and work performance were each assessed once daily using single-item measures: fatigue and affect with visual analogue scales (VAS), and work performance with a single-item rated on a 1–10 scale. For participants assigned the EMA surveys, fatigue and affect were assessed five times daily using VAS, while work performance was assessed once daily in the final evening prompt. Given that EMA-derived work performance was assessed once daily (ie, not momentarily), these data were not included in the EMA-based within-day analyses. Work-related outcomes were assessed only among participants who reported working, using survey logic to restrict these items to relevant participants. Additional details concerning outcome measures are provided in the online supplemental methods.

Statistical analyses

Baseline characteristics of intervention arms were summarised as means (SD) or percentages. Group differences were evaluated using analysis of variance or χ^2 tests, as appropriate. When overall group differences were statistically significant ($p<0.05$), pairwise comparisons were evaluated using Hedges' *g* for continuous variables and Cohen's *h* for categorical variables, with values ≥0.10 interpreted as meaningful differences between arms.

Implementation outcomes (feasibility, acceptability and appropriateness) were analysed using general linear models with covariate adjustment for age, sex, race/ethnicity, education, region of residence, employment status, employment setting and self-rated general health. Details of covariate measures are provided in the online supplemental methods. Standardised effect sizes (Hedges' *g*) were calculated to quantify the magnitude of between-arm differences. To examine potential effect modification, we repeated analyses including an interaction term (study arm×covariate) for each covariate. From these models, we also derived adjusted mean scores for each demographic subgroup (eg, age group, sex, race/ethnicity, etc).

For effectiveness outcomes, intention-to-treat analyses were conducted using linear mixed-effects models for repeated measures and included all participants who provided an outcome measure for at least one time point (pre-intervention or post-intervention survey) or time period (≥1 daily survey during baseline or intervention periods).[33] Fixed effects included time (pre-intervention vs post-intervention for surveys; baseline vs intervention period for daily data), intervention arm, their interaction and covariates (listed above). A random intercept for participant and compound symmetry correlation structure accounted for individual differences in outcome levels and within-subject correlation. A per-protocol analysis was also conducted as a sensitivity analysis, restricted to participants with good adherence to their selected arm, defined as 75% protocol adherence assuming 8 hours of daily sedentary time (the approximate study mean determined via self-report at baseline). This corresponded to ≥12, ≥6 and ≥3 breaks per day (averaged across all reported days) for the 30-minute, 60-minute and 120-minute arms, respectively. While participants were not explicitly prescribed daily movement break targets, this analysis was used to examine dose effects among participants who met the implied goals of their intervention arm.

To evaluate the more immediate effects of movement breaks, a secondary momentary-level analysis was conducted among the subsample assigned to the EMA protocol. Mixed-effects models compared momentary fatigue and affect ratings at prompts where a break had occurred since the prior prompt versus those without a break. Models included fixed effects for break status (break vs no break), intervention arm, their interaction and covariates, with random intercepts and a compound symmetry structure to account for repeated measures across prompts. Analyses were restricted to participants with ≥3 EMA prompts completed on ≥1 day during the baseline and intervention periods.

For effectiveness outcome analyses, minimal important difference (MID) thresholds were used to interpret meaningful within-arm changes. Where available, MIDs were derived from prior literature; otherwise, we applied anchor-based or distribution-based methods (0.5 SD).[34 35] Details on MID values and their derivation methods are provided in online supplemental table 1 and online supplemental methods. Analyses were conducted using SAS, V.9.4 (SAS Institute).

Equity, diversity and inclusion statement

The author team included 70% females and comprised males and females from diverse backgrounds including racial/ethnic minority (40%) and disabled (20%) subpopulations. All podcast listeners, regardless of age, sex, race/ethnicity and nationality were invited to participate in this study. For participants with physical disabilities for whom walking-based movement breaks were challenging or not possible, they were encouraged to move in whatever way was most convenient including wheeling, walking with assistive device or performing upper body exercises (eg, dancing with upper arms, chair-based upper arm exercises).

Patient and public involvement

Members of the public were involved in the design of this study through a partnership with NPR. The interactive podcast component was developed through iterative discussions between the research team and NPR producers to ensure accessibility and engagement for a broad audience. While patients or members of the public were not directly involved in defining the research questions or selecting outcome measures, they contributed indirectly by shaping how the intervention was delivered and experienced. Participants were not asked to assess study burden in advance, but their experience was captured through post-intervention surveys on feasibility and acceptability. Study findings were disseminated back to participants and the wider community through a dedicated NPR podcast episode.

RESULTS

Participant characteristics

Enrollment, dose selection and retention are summarised in figure 1. Among the 19 342 participants who were eligible and completed the baseline questionnaire, 31.6% (n=6108), 47.1% (n=9116) and 21.3% (n=4118) self-selected movement breaks every 30, 60 or 120 min, respectively. Of these, 59.4% completed the 7-day baseline monitoring period and began the intervention. Among participants who initiated the intervention, 81.6%, 83.3% and 82.6% were retained through study completion (defined as providing either pre-post outcome surveys, both-period daily surveys or both-period EMA data) in the 30-minute, 60-minute or 120-minute arms, respectively. In an adjusted logistic regression model controlling for demographic and health-related covariates, there was no significant difference in study retention by intervention arm (p=0.384). Online supplemental table 2 shows the characteristics of participants with complete versus incomplete outcome data. Those with complete data were slightly older (47.9 vs 46.4 years), but no other differences met the threshold for a meaningful effect size (≥0.10), suggesting that participants with complete outcome data were broadly representative of the full enrolled population.

Demographic characteristics of participants overall and stratified by movement break dose are shown in table 1. Participants

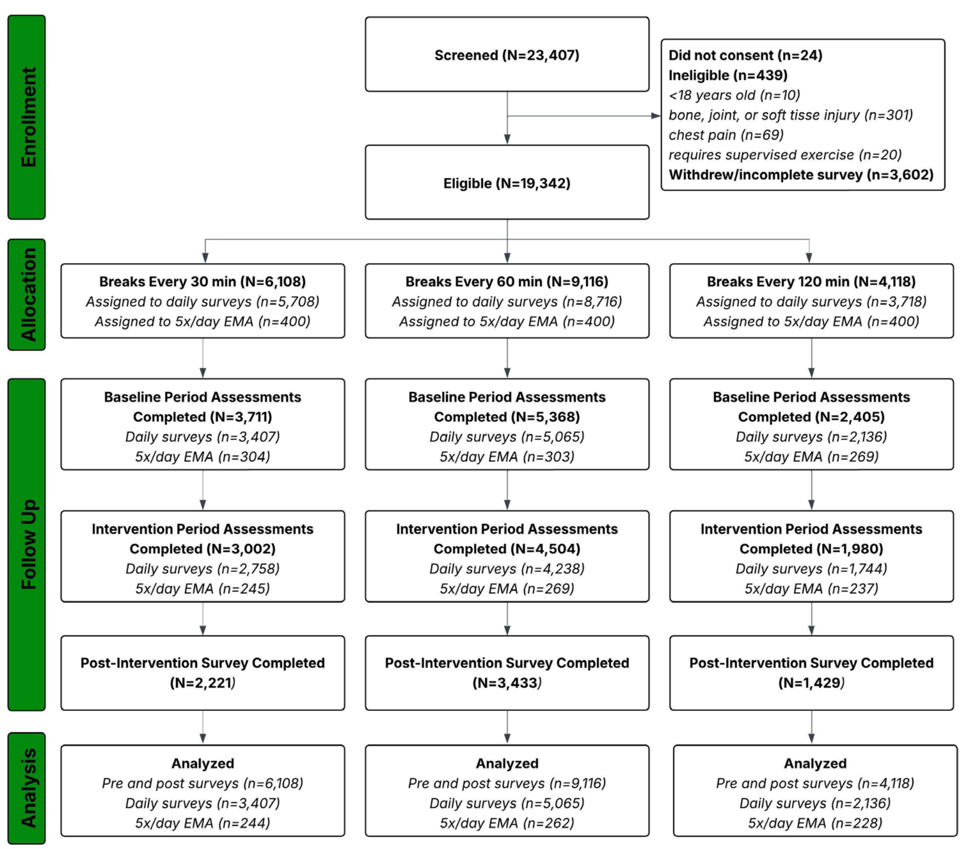

Figure 1 Consolidated Standards of Reporting Trials (CONSORT) diagram. Baseline and intervention periods are denoted as completed if ≥1 daily survey was completed during baseline and intervention periods (for those assigned to daily surveys) or ≥3 ecological momentary assessment (EMA) prompts were completed on ≥1 day during the baseline and intervention periods (for those assigned to EMA protocol). Analyses were conducted using an intention-to-treat approach (ie, all participants with baseline data were included) for pre-post and daily surveys. Analyses for EMA protocol were restricted to participants with ≥3 EMA prompts completed on ≥1 day during the baseline and intervention periods.

Table 1 Baseline participant characteristics

Variable	All (n=19342)	Breaks every 30 min (n=6108)	Breaks every 60 min (n=9116)	Breaks every 120 min (n=4118)	P value*
Age (years)	46.9 (12.8)	47.5 (12.9)†	47.2 (12.9)†	45.6 (12.2)‡§	<0.001
Age category (%) (years)					<0.001
18–25	1.4	1.3	1.5	1.3	
25–44	45.9	44.2†	44.9†	50.4‡§	
45–64	42.3	43.1	42.9	40.0	
65+	10.4	11.4†	10.7	8.3‡	
Male (%)	15.4	16.8†	16.2†	11.5‡§	<0.001
Race/Ethnicity (%)					<0.001
Non-Hispanic white	80.3	81.0	80.9	78.1	
Non-Hispanic black	3.0	2.6	3.2	3.4	
Hispanic	5.2	5.4	4.6	6.2	
Asian	5.3	4.7	5.3	6.2	
Mixed	4.7	4.8	4.5	4.8	
Other	1.5	1.5	1.5	1.4	
Education (%)					0.023
≤High school/GED	0.6	0.6	0.5	0.6	
Some college/Trade school	8.7	9.3	8.0	9.2	
Bachelor's degree	35.7	36.3	35.7	35.0	
Master's degree	38.4	38.3	38.4	38.5	
Professional degree/Doctorate	16.6	15.6	17.3	16.6	
Region of residence (%)					0.054
Northeast USA	20.9	20.1	20.8	22.1	
Midwest USA	19.4	19.3	19.3	19.7	
South USA	25.7	25.3	25.7	26.2	
West USA	29.5	30.6	29.5	27.9	
International	4.6	4.6	4.8	4.1	
Employment (%)					<0.001
Full-time	78.8	73.9§†	80.3‡	82.7‡	
Part-time	8.1	9.8	7.3	7.2	
In school	1.6	1.5	1.6	1.9	
Homemaker	1.8	2.7	1.5	1.4	
Unemployed	2.2	2.7	2.0	1.8	
Retired	7.4	9.3†	7.3	5.1‡	
Employment setting (%)					<0.001
Remote	33.0	36.0	31.5	32.1	
Hybrid	40.6	38.8†	41.0	42.2‡	
In-person	25.3	24.1	26.5	24.4	
Other	1.1	1.1	1.0	1.2	
Self-rated general health (%)					<0.001
Excellent	8.8	9.6	8.7	7.9	
Very good	30.9	32.9	30.7	28.7	
Good	44.8	42.9	45.4	46.3	
Fair	14.5	13.6	14.3	15.9	
Poor	1.0	0.9	0.9	1.1	

Date presented as mean (SD) or %.
*P value reflects an overall test of group differences. For a given measure, when the overall group effect was statistically significant (p<0.05), all pairwise comparisons were evaluated using standardised effect sizes. Pairwise comparisons with an effect size (Hedges' *g* for continuous variables; Cohen's *h* for categorical variables) ≥0.10 are considered meaningful.
† vs. Every 120 min
‡vs. Every 30 min
§vs. Every 60 min

were predominantly female, non-Hispanic white, college educated, employed full-time and, on average, middle-aged (mean age: 46.9 years). Among the full sample, 13.0% were not working, including 1.6%, 1.8%, 2.2% and 7.4% who were in school, homemakers, unemployed or retired, respectively.

Table 2 Movement break characteristics by intervention arm among participants completing daily surveys

	Every 30 min (n=2758)	Every 60 min (n=4238)	Every 120 min (n=1744)
Daily breaks (# per day)			
Mean (SD)	5.5 (4.2)	4.1 (2.7)	2.8 (1.8)
10th percentile	1.0	1.0	0.4
25th percentile	2.6	2.2	1.5
50th percentile	4.6	3.8	2.6
75th percentile	7.7	5.6	4.0
90th percentile	11.5	7.9	5.1
Weekday mean (SD)	5.9 (4.3)	4.4 (2.8)	2.9 (1.8)
Weekend mean (SD)	4.5 (4.6)	3.4 (3.3)	2.4 (2.3)
Participants meeting ≥75% adherence threshold (%)*	10.1	23.7	46.0
Break duration (min)			
Mean (SD)	6.7 (1.8)	6.8 (1.8)	7.1 (1.8)
10th percentile	4.9	5.0	5.0
25th percentile	5.0	5.1	5.5
50th percentile	6.4	6.5	7.0
75th percentile	8.0	8.0	8.5
90th percentile	9.6	9.6	10.0
Weekday mean (SD)	6.5 (1.8)	6.6 (1.8)	6.8 (1.9)
Weekend mean (SD)	7.6 (2.2)	7.7 (2.2)	8.1 (2.1)

*Defined as achieving ≥75% of expected breaks based on intervention frequency (assuming eight waking sedentary hours/day; the approximate study mean determined via self-report at baseline). This corresponded to ≥12, ≥6 and ≥3 breaks per day (averaged across all reported days) for the 30-minute, 60-minute and 120-minute arms, respectively. While participants were not explicitly prescribed daily movement break targets, this metric is reported to illustrate between-arm differences in meeting the implied goals of each intervention arm.

Compared with those in the 30-minute arm, participants in the 120-minute arm were, on average, younger; more likely to be female, employed full-time and working in a hybrid setting. Participants represented a wide range of occupations, most commonly in management, education, healthcare and technology sectors (online supplemental table 3).

Movement breaks

Participants in the 30-minute, 60-minute and 120-minute arms reported an average of 5.5, 4.1 and 2.8 movement breaks per day, respectively, based on daily surveys (table 2). Average break duration ranged from 6.7 to 7.1 min per break across arms. Similar patterns were observed in the EMA sample, although with higher mean daily breaks observed (online supplemental table 4). The distribution of movement breaks by intervention arm is shown in online supplemental figure 1. Using a 75% protocol adherence threshold (assuming 8 hours of daily sedentary time), 10.1%, 23.7% and 46.0% of participants met this benchmark on average in the 30-minute, 60-minute and 120-minute arms, respectively (though no explicit target was provided to participants).

Implementation outcomes

Adjusted mean scores for feasibility (FIM), acceptability (AIM) and appropriateness (IAM) by intervention arm are shown in figure 2 and online supplemental table 5. All arms exceeded the viability threshold of 3.0 for each implementation outcome. Feasibility showed a clear dose-response pattern,

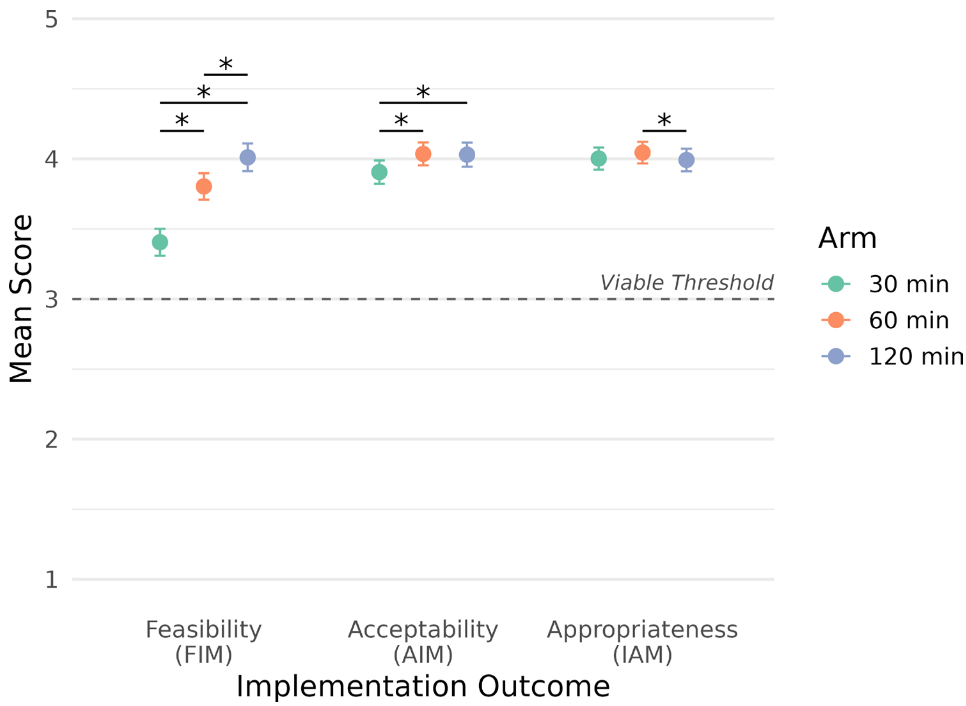

Figure 2 Adjusted mean scores (95% CI) for implementation outcomes by intervention arm. A score of 3.0 (dashed horizontal line) was used as the threshold for indicating dose viability. Asterisks denote statistically significant pairwise differences between intervention arms ($p<0.05$). Models were adjusted for age, sex, race/ethnicity, education, region of residence, employment status, employment setting and self-rated general health. AIM, Acceptability of Intervention Measure; FIM, Feasibility of Intervention Measure; IAM, Intervention Appropriateness Measure.

with significantly higher FIM scores at lower movement break frequencies. Acceptability was lower in the 30-minute arm compared with both the 60-minute and 120-minute arms, with no significant difference between the latter two arms. Appropriateness scores were similar across arms, with only a modest but statistically significant difference between the 60-minute and 120-minute arms.

Implementation outcomes stratified by demographic subgroups are presented in online supplemental table 6. All subgroups exceeded the viability threshold of 3.0 for feasibility, acceptability and appropriateness. While some statistically significant arm-by-subgroup interactions were observed for sex, employment status and employment setting, absolute differences were modest.

Effectiveness outcomes

Reported fatigue and negative affect significantly decreased and positive affect significantly increased from pre-intervention to post-intervention across all intervention arms (figure 3; online supplemental table 7, upper panel). Significant time×condition interactions ($p<0.01$) were observed for all psychosocial outcomes. Improvements in reported fatigue and positive affect followed a dose-response pattern, with the 30-minute and 60-minute arms exceeding the MID threshold for these outcomes. Only the 30-minute arm exceeded the MID threshold for negative affect, with the 30-minute and 60-minute arms yielding significantly greater changes compared with the 120-minute arm. Significant time×condition interactions ($p<0.01$)

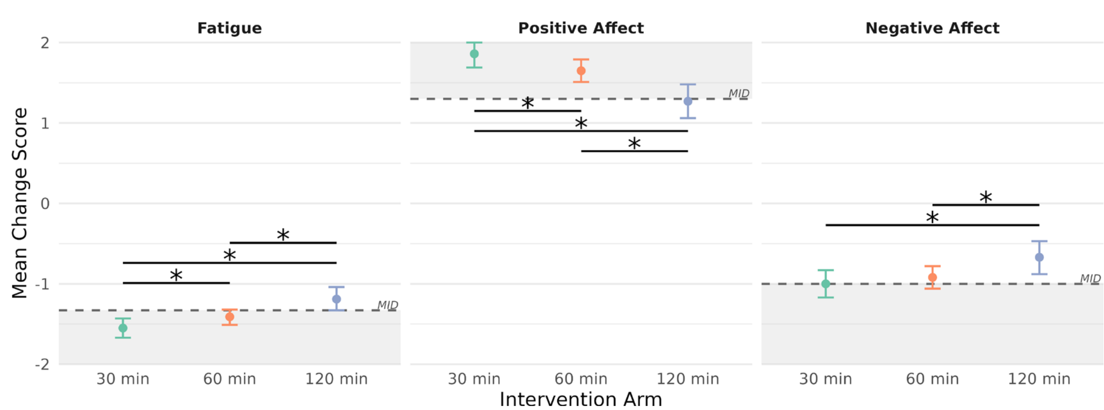

Figure 3 Adjusted mean change scores (95% CI) for fatigue, positive affect and negative affect by intervention arm. Dashed horizontal lines represent minimal important difference (MID) thresholds (fatigue=1.33, positive affect=1.30, negative affect=1.00), with shaded areas indicating values that exceed these thresholds. Asterisks denote statistically significant pairwise differences between intervention arms ($p<0.05$). Models were adjusted for age, sex, race/ethnicity, education, region of residence, employment status, employment setting and self-rated general health.

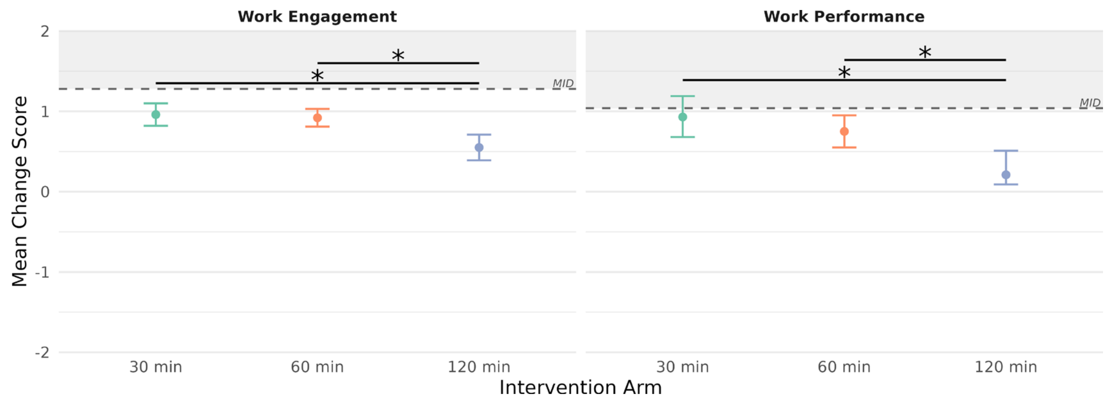

Figure 4 Adjusted mean change scores (95% CI) for work engagement and work performance by intervention arm. Dashed horizontal lines represent minimal important difference (MID) thresholds (work engagement=1.28, work performance=1.04), with shaded areas indicating values that exceed these thresholds. Asterisks denote statistically significant pairwise differences between intervention arms (p<0.05). Models were adjusted for age, sex, race/ethnicity, education, region of residence, employment status, employment setting and self-rated general health.

were also observed for all work-related outcomes. Perceived work engagement improved across all arms, and perceived work performance improved in the 30-minute and 60-minute arms; however, no work-related changes exceeded MID thresholds (figure 4; online supplemental table 7, lower panel).

Daily survey data showed similar dose-response patterns, with statistically significant but sub-MID improvements across all arms for all outcomes (online supplemental table 8). Per-protocol analyses yielded larger intervention effects, with most outcomes (including work-related outcomes) exceeding MID thresholds in the 30-minute and 60-minute arms for the pre-post surveys (online supplemental table 9) but largely sub-MID improvements for the daily surveys across all arms (online supplemental table 10).

Momentary effects

Momentary comparisons accounting for movement break status (ie, was a break taken since the last EMA prompt) showed significantly lower fatigue and higher affect following movement breaks compared with time points without a recent break across all arms (online supplemental table 11). There was a significant break status×condition interaction for fatigue ($p<0.001$), but not affect ($p=0.533$). Fatigue reductions in the 30-minute arm were significantly greater compared with the 60-minute and 120-minute arms.

DISCUSSION

Prolonged sedentary time is pervasive in industrialised societies, yet feasible, effective and practical strategies to offset its harms are not well established. In this study, we evaluated the real-world viability of walking-based movement breaks across multiple doses (every 30, 60 or 120 min) in a large, diverse adult population. We found that movement breaks were rated as feasible, acceptable and appropriate across all doses, indicating implementation potential. Movement breaks were also effective in improving psychosocial outcomes, producing both immediate (momentary) and long-term (pre-post) benefits, with evidence of a dose-response relationship. Importantly, movement breaks did not adversely affect work outcomes and, on average, produced small favourable changes in perceived work engagement and performance among employed participants. Taken together, these findings demonstrate that movement breaks are implementable and effective, supporting their viability as a public health strategy and providing new insights into feasible and effective dosing for real-world implementation.

Interpretation of results, comparison with other studies and clinical implications

Strategies such as sit-to-stand desks or active workstations (eg, treadmill or cycling desks) have been proposed to reduce the health harms associated with sedentary time, but evidence that standing is a healthier alternative is equivocal and the cost and space demands of furniture-based approaches limit their scalability.[36 37] In contrast, walking-based movement breaks are low cost, familiar and broadly accessible and thus may be a promising alternative. Ultimately, the viability of movement breaks as a public health strategy depends on their implementation potential and capacity for large-scale adoption. However, prior studies evaluating their real-world implementation potential have been limited, small in scale and have yielded mixed findings, with adherence rates ranging from modest to moderate and quantitative assessments of feasibility and acceptability rarely conducted.[14 16 37–39] In this study, participants reported movement breaks as, on average, acceptable, appropriate and feasible, with all arms exceeding the viability threshold of >3.0, which is considered indicative of an intervention generally viewed positively and having implementation potential.[20] While formal cutoffs do not exist, scores approaching or exceeding 4.0 are typically interpreted as reflecting strong endorsement and readiness for broader implementation.[40–42] Each arm achieved mean scores near or above this level for several indices (eg, the 30-minute arm for appropriateness; the 60-minute arm for both acceptability and appropriateness and the 120-minute arm for feasibility, acceptability and appropriateness), suggesting robust implementation potential of movement breaks. These findings are notable given the pragmatic design, where participants received minimal external support, reminders or incentives. Thus, the observed findings likely represent conservative estimates. While adherence to the prescribed break frequencies was modest relative to the movement break regimens used in laboratory settings, this level of compliance is likely a reflection of what can be achieved in everyday settings. Importantly, these results were obtained in a sample that spanned a wide range of ages, occupations and work environments, supporting the potential for movement breaks to be implemented as a population-level strategy. Nonetheless, the moderate feasibility and adherence (especially in the

30-minute arm) highlight opportunities to strengthen implementation through targeted supports (ie, digital prompts, workplace policies or social reinforcement) and other behaviour change strategies. They also underscore a need to evaluate contextual factors that influence when and where movement breaks are most likely to occur, which may help inform intervention strategies. Collectively, these findings provide evidence that movement breaks have strong implementation potential and warrant further evaluation in long-term trials.

In addition to their implementation potential, the effectiveness of movement breaks in improving health and well-being is critical for evaluating their viability as a public health strategy. Experimental evidence has demonstrated that prolonged sedentary behaviour elicits adverse changes in mood, fatigue and anxiety.[43 44] These effects may have downstream consequences as studies have shown that work-related fatigue and stress can negatively impact leisure-time health behaviour engagement (eg, exercise).[45] In this way, the sedentariness inherent in many occupations may contribute to a vicious cycle of fatigue, poor affect and reduced physical activity. Laboratory-based studies have shown that regular movement breaks can offset the detrimental effects of prolonged sedentary behaviour on perceived fatigue and mood/affect.[46] A small pilot trial of sedentary female employees similarly reported improvements in self-reported fatigue and affect following an 8-week movement break intervention.[46] Our study confirms and extends this evidence by providing data from a large-scale, pragmatic, free-living intervention demonstrating that movement breaks improve perceived fatigue and affect. Importantly, contrary to laboratory-based studies that enforce 100% compliance to a given movement break dose protocol, adherence in our study was substantially lower. Nonetheless, meaningful improvements in self-reported outcomes were still observed. Current public health guidelines that endorse breaking up sedentary time have refrained from specifying frequency targets, partly due to concerns about feasibility across occupations.[47] Our findings suggest that even when individuals fall short of ideal frequency targets, meaningful improvements are still obtained. Thus, future trials and guidelines may need to view frequency recommendations as a goal to strive towards, when possible, while acknowledging that imperfect adherence still yields some health benefits. Taken together, these findings demonstrate the effectiveness of movement breaks on psychosocial outcomes under pragmatic, large-scale conditions, providing further support for their potential as a viable public health strategy.

Our observed finding that movement breaks had momentary effects on reported fatigue and affect in naturalistic settings has important implications. These results are consistent with a recent within-person naturalistic experiment among 211 university employees in which 3-minute movement breaks elicited favourable changes in valence and energetic arousal relative to uninterrupted sedentary periods ≥30 min.[48] Together, this prior study and findings from the current study strengthen causal inference for our primary outcomes (eg, pre-post surveys) and provide converging evidence that movement breaks can yield immediate changes in affect and fatigue/energy levels. Consistent with the principle of psychological hedonism, people tend to repeat behaviours that feel good and avoid behaviours that feel unpleasant.[49] Evidence has shown that those who experience a positive affective response to physical activity are more likely to repeat it in the future.[50] Moreover, in the context of health behaviour change, individual decisions to adopt and maintain behaviours may be more strongly influenced by acute/short-term feelings and emotions than consideration of long-term risks and benefits.[51] Thus, the momentary effects observed in the present study may serve as a potential mechanism for facilitating habit formation and long-term maintenance, whereby positive short-term experiences reinforce continued engagement. Future interventions may benefit from explicitly targeting affective responses to support sustaining movement breaks, although more research in this area is warranted.

Our observed findings for work outcomes among employed participants (~87% of study sample) are particularly important in the context of workplace adoption. Concerns that movement breaks might disrupt work productivity have been documented as a perceived barrier to implementation/adoption.[52] However, our findings counter this perception. While none of the tested movement break doses elicited improvements in perceived work performance or engagement that exceeded MID thresholds, all yielded small but favourable changes, on average (4%–7% for engagement; 1–3% for performance). Importantly, we observed no evidence that movement breaks harmed perceived work engagement or productivity among employed participants. These findings confirm and extend the initial findings from a pilot trial of 58 university employees by Hargreaves *et al*, where small but beneficial effects on perceived work productivity were reported following a 12-week intervention involving 2-minute movement breaks every 30 min.[14] Evidence suggests that breaks in work or study, including breaks that are physical activity-based, can enhance executive function, attention, memory and feelings of being relaxed and refreshed.[53–56] Thus, movement breaks align well with current theory on effort regulation and work performance optimisation. Our findings further reinforce this concept and underscore that movement breaks may not be detrimental to work. While the present study was focused on walking-based movement breaks, movement break modalities that do not entail leaving one's workstation (eg, simple resistance activities[57]) may be more feasible and practical alternatives in some work settings and warrant further investigation. Moreover, workplace culture, job demands and social and physical environments have been documented as barriers to movement break adoption and maintenance.[52 58] As such, a broader set of strategies that address these contextual factors are needed to support workplace implementation of movement breaks.

From a dosing perspective, our findings highlight important trade-offs. The 120-minute break arm demonstrated the strongest implementation potential but the weakest effectiveness, with no outcomes exceeding MID thresholds in primary or per-protocol analyses (with the exception of positive affect in per-protocol analyses). In contrast, the 30-minute arm produced the most robust improvements in reported psychosocial outcomes but had the lowest feasibility and compliance, although all implementation metrics were still above the viability threshold. The 60-minute arm offered the most favourable balance, yielding acceptability and appropriateness ratings comparable to the 120-minute arm, and exceeding MID thresholds for two of three psychosocial outcomes. In addition, it was the most commonly selected dose; selected by nearly half of all participants. To our knowledge, this represents one of the first real-world dosing studies of movement breaks, providing new evidence to guide future trial design. These findings suggest that hourly breaks may represent the most promising candidate for future trials, particularly for targeting psychosocial outcomes. However, it should be noted that our study fixed break duration at 5 min. It is possible that extending break length (eg, 10 min every 2 hours) could enhance the effectiveness of less frequent breaks. Future studies are warranted to test such alternative dosing strategies, particularly given the strong implementation potential observed for the 120-minute arm.

Strengths and weaknesses of this study

The study had several notable strengths. First, the large sample size and diverse representation across age, occupation and work settings (remote, in-person and hybrid), including both employed and non-working adults, allowed for robust evaluation of movement break viability across a broad population. Second, the pragmatic design maximised external validity and provided a test of movement break implementation and effectiveness in real-world, naturalistic settings. Third, effectiveness outcomes were assessed at three levels (pre-post, daily and momentary), with consistency across modalities strengthening causal inference and reducing risk of bias. Finally, the study included a direct dose-response comparison, offering novel insights into the trade-off between feasibility and effectiveness at different break frequencies.

Several limitations should be noted when interpreting our findings. First, the non-randomised design may have introduced selection bias. Although analyses adjusted for baseline differences across groups, we cannot fully rule out unmeasured or residual confounding. Second, the lack of a true no-treatment control group limits causal inference as the observed effects could reflect regression to the mean or expectancy effects. Nonetheless, the three-arm dose-comparison design provides important internal contrasts that lend support to the plausibility of true intervention effects and the consistency of findings across pre-post surveys, daily diaries and momentary assessments further strengthens confidence in the observed effects. Third, all outcomes were assessed by self-report, which may be subject to recall or social desirability bias, and no physiological measures were collected. Although use of self-report was necessary to support the feasibility of this large-scale study, future studies are needed that incorporate objective (ie, work productivity metrics) and physiological measures. Fourth, the intervention period was only 2 weeks in duration. Thus, the long-term adherence to movement breaks and the sustainability of their effects are unknown. Long-term studies are needed to evaluate whether movement breaks can be maintained over time and to determine their sustained impact on health and behavioural outcomes. Fifth, the study population was predominantly white, female and highly educated, reflective of the recruitment catchment of primarily NPR listeners. Thus, it may not fully represent the broader general adult population and could also be subject to volunteer bias. Finally, movement breaks were not assessed at baseline and prior engagement in movement breaks was not a study exclusion criterion. Thus, the observed findings may reflect both the adoption of movement breaks and modification or maintenance of existing movement break habits.

CONCLUSION

In this large-scale, pragmatic intervention conducted in naturalistic settings among adults spanning a wide range of ages, occupations and work settings (including non-working adults), movement breaks demonstrated good implementation potential and effectiveness for improving psychosocial outcomes, with no evidence of harm to work performance for working adults. Dosing evaluation highlighted a critical trade-off between feasibility and effectiveness concerning movement break frequency, with hourly breaks emerging as a promising balance. Collectively, these findings support movement breaks as a potentially viable strategy for future public health efforts to reduce the harms of prolonged sedentary behaviour. However, future studies are needed to establish their long-term sustainability.

Contributors KMD and MZ conceived and designed the study. SM, KM and MZ developed the podcast and recruited participants. KMD, MEM, MAS, AWC, ATD and BDB developed the study questionnaires and data collection protocols and acquired the data. KMD and YKC analysed and interpreted the data. KMD drafted the manuscript. All authors critically revised the manuscript for important intellectual content. KMD is the guarantor. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted. During the preparation of this manuscript, the authors used chatGPT for proofreading and sentence revision to improve readability, but not for intellectual content. After using this tool, the authors thoroughly reviewed and edited the content where necessary. The authors assume full responsibility for the content of the publication.

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Patient and public involvement Patients and/or the public were involved in the design, or conduct, or reporting, or dissemination plans of this research. Refer to the 'Methods' section for further details.

Patient consent for publication Not applicable.

Ethics approval The study was approved by the Columbia University Medical Center (CUIMC) Institutional Review Board (#AAAU8061). All participants provided informed consent electronically prior to participation. Data collection occurred concurrently for all participants in October 2023.

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Data availability statement Data are available in a public, open access repository. Deidentified individual participant data are publicly available at https://osf.io/c9r7x/. Access is open to all qualified researchers for replication purposes. Secondary analyses are permitted following approval of a statistical analysis plan submitted to the study investigators.

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