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Feasibility and acceptability of remote procedures to study tobacco product use and respiratory health: an observational study

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ABSTRACT

Objective Obtaining ecologically valid biological samples is critical for understanding respiratory effects of tobacco use, but can be burdensome. In two diverse samples, we examined feasibility and acceptability of studying pulmonary function and respiratory health entirely remotely.

Design Observational feasibility and acceptability study.

Setting and participants Adults age 18–25 (Biomedical Respiratory Effects Associated through Habitual Use of E-Cigarettes [BREATHE] Study) and 21–65 (Adult IQOS Respiratory [AIRS] Study) recruited from previous research studies and advertisements in Southern California, USA (BREATHE (AIRS): N=77 (N=31) completed baseline, n=64 (n=20) completed feasibility and acceptability measures). Shared inclusion criteria for the two studies were ownership of a smartphone, willingness to download applications and English fluency. In addition, BREATHE participants reported one of three tobacco use patterns. AIRS participants smoked daily and were willing to use a heated tobacco product. Exclusion criteria were medical contraindications.

Interventions A 4-week study consisted of five virtual study visits, twice daily ecological momentary assessment diaries and spirometry assessments, and weekly Nasal Epithelial Lining Fluid and saliva collection. All study visits were conducted via video conference; study materials and biospecimens were exchanged via mail. Participants reported feasibility and acceptability of daily diaries, breath tests, biospecimen collection and shipments.

Measures Surveys assessed perceptions of timing and overall experience of daily diaries and breath tests, difficulty of and overall experience with biospecimen collection, and experience sending and receiving shipments.

Results Most participants evaluated daily diaries and breath tests as manageable (62.5%–95.0%) and likeable (54.7%–70.0%). Breath tests were frequently described as 'interesting' (55.0%–57.8%) and 'easy' (25.0%–48.4%). Most participants reported that biospecimen collection was easy (50.0%–85.0%), and that shipments were easy to send (87.5%–95.0%), receive (95.3%–95.0%) and schedule (56.3%–60.0%). No participants received shipments in poor condition.

Conclusions Remote research procedures may be feasible and acceptable to facilitate tobacco research studies, potentially resulting in more diverse samples of participants and more generalisable research results.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ Participant samples were sociodemographically diverse.
⇒ Results may not generalise to older adults (age 66+).
⇒ Attrition bias may have affected results.

INTRODUCTION

Use of non-cigarette nicotine/tobacco products among US adults has become increasingly prevalent. E-cigarettes are the most commonly used nicotine/tobacco product among young adults, with approximately 23% of young adults age 21–22 reporting past-month e-cigarette use in 2021.[1] E-cigarette use may have adverse effects on young adults' respiratory health, including acute symptoms of respiratory disease[2–6] and detrimental effects on lung cellular and organ physiology and immune function.[7–10] IQOS, another non-cigarette product, is a heated tobacco product, which was authorised by the US Food and Drug Administration (FDA) in 2020 to be marketed as a modified risk tobacco product.[11] The manufacturer's application for the modified risk designation contained limited data on the respiratory outcomes associated with switching from combustible tobacco to IQOS under real-world conditions.[12] Objectively assessing the respiratory effects of nicotine/tobacco products such as e-cigarettes and IQOS can be enhanced with the use of biological data such as spirometry and collection of biospecimens such as saliva (eg, cotinine as a biomarker of nicotine use) and nasal epithelial lining fluid (NELF; eg, to detect biomarkers of respiratory inflammation or immune changes).

Participating in studies with intensive biological data collection has traditionally required in-person study visits. During the COVID-19 pandemic, remotely administered study procedures became necessary to keep both participants and study staff safe. Beyond the pandemic, remotely administered procedures are needed to increase sociodemographic diversity in participant pools, improve generalisability and ecological validity of results, and promote equitable opportunities to contribute to scientific research. In-person visits can create barriers to study participation, as they can be burdensome or inaccessible for participants who do not live near the study site or do not have reliable transportation.[13] Studies requiring in-person visits may exclude populations who face accessibility challenges, such as socioeconomically disadvantaged individuals, people living in rural areas and those with disabilities. These populations, along with racial/ethnic minorities and sexual/gender minorities, are under-represented in biomedical research, detrimentally affecting the benefit of science to broader society.[14] Fully remote self-report data and biological data collection may address some barriers to research participation, such as travel time, cost and accessibility needs. Although higher-income Americans are more likely than lower-income Americans to have reliable Internet access, the 'digital divide' is closing as more people obtain Internet and smartphone access.[15]

Mobile spirometry devices and procedures have been validated for home use, with demonstrated feasibility and acceptability in patient populations.[16–18] While past research studies have collected salivary cotinine and carbon monoxide measurements remotely,[19] little is known about the feasibility and acceptability of intensive remote procedures (eg, daily spirometry measurements, weekly biospecimen collection and video meetings). To address this gap, we examined feasibility and acceptability of studying adults' pulmonary function and respiratory health entirely remotely. Over a 4-week study period, adult participants in two diverse samples completed five sessions with study staff via video conference, twice daily diaries and spirometry measurements, and weekly collection of saliva and nasal epithelial fluid, with study materials and biospecimens sent via mail. Participants reported their experience with study procedures in feasibility and acceptability surveys throughout the study. This study described participants' experience with study procedures.

METHODS

Participants

Biomedical Respiratory Effects Associated through Habitual Use of E-Cigarettes Study

The Biomedical Respiratory Effects Associated through Habitual Use of E-Cigarettes (BREATHE) Study examined changes in pulmonary functioning and respiratory health by tobacco product use status. Participants were young adults recruited in ninth grade in 2013 from 10 Southern California high schools to participate in a prospective cohort study of health and well-being (IRB protocol #HS-12–00180).[20] Cohort members who had agreed to be contacted about future studies were invited to complete an online eligibility screener for the BREATHE Study. Inclusion criteria were: (A) ownership of a smartphone and willingness to download applications; (B) past 3-month exclusive e-cigarette use, past 3-month couse of e-cigarettes and other tobacco products, or no past 6-month tobacco product use; (C) age 18–25; and (D) English fluency. Exclusion criteria were: (A) self-reported lung disease (eg, cystic fibrosis); (B) unstable or significant psychiatric conditions; (C) past 3-month cardiac event or distress; (D) current COVID-19 illness or past 3-month hospitalisation for COVID-19 and (E) current pregnancy, plans to become pregnant or breast feeding. Recruitment spanned April–October 2021; feasibility and acceptability data collection occurred May–December 2021.

Adult IQOS Respiratory Study

The Adult IQOS Respiratory Study (AIRS) examined perceptions and use of IQOS, a heated tobacco product. Participants were adults who smoked cigarettes daily, recruited from previous studies and from social media and other advertisements in the greater Los Angeles area. Inclusion criteria were: (A) ownership of a smartphone and willingness to download applications; (B) current daily smoking (ie, more than five cigarettes/day for the past 6 months); (C) age 21–65; (D) English fluency; (E) never having used IQOS previously and (F) willingness to try IQOS for the next 30 days. Exclusion criteria were the same as those in BREATHE, except that participants could not have used other tobacco products or marijuana more than 5 days of the past 30. Recruitment spanned January–December 2021; feasibility and acceptability data collection occurred February–December 2021.

Procedures

Overview

After recruitment, the BREATHE and AIRS studies followed the same procedure. The 4-week study period consisted of a baseline visit, twice daily ecological momentary assessment (EMA) diaries and spirometry assessments, and weekly NELF and saliva collection. All study visits were conducted over a university-approved video conferencing platform. At the baseline visit, study staff obtained informed consent and participant contact information and explained the study procedures and compensation schedule. After the baseline visit, staff emailed a baseline survey and mailed a study materials kit to the participant. The study kit contained a spirometer kit, disposable mouthpieces for the spirometer, a saliva cotinine collection kit, an NELF nasal swab kit, disposable gloves, cotton balls, alcohol wipes, ice packs and three prelabelled return packages. Additional 30 min study visits were conducted via video conference on days 1, 8, 15 and 22, during which participants collected NELF

Table 1 Participant characteristics in two samples of adults

	BREATHE Study (N=77)	AIRS Study (N=31)
	% (n)	
Age (M/SD)	21.5 (0.6)	49.6 (8.1)
Gender		
Cisgender man	33.8 (26)	54.8 (17)
Cisgender woman	58.4 (45)	45.2 (14)
Transgender or another gender*	5.2 (4)	0.0 (0)
Unreported	2.6 (2)	0.0 (0)
Sexual identity		
Straight	70.1 (54)	83.9 (26)
Gay/lesbian	5.2 (4)	6.5 (2)
Bisexual or pansexual	11.7 (9)	6.5 (2)
Asexual	3.4 (3)	3.2 (1)
Another sexual identity†	5.2 (4)	0.0 (0)
Unreported	3.9 (3)	0.0 (0)
Race/ethnicity		
Hispanic	41.6 (32)	12.9 (4)
Non-Hispanic white	10.4 (8)	25.8 (8)
Black	5.2 (4)	45.2 (14)
Asian	23.4 (18)	12.9 (4)
American Indian/Alaska Native	0.0 (0)	3.2 (1)
Native Hawaiian/Pacific Islander	1.3 (1)	0.0 (0)
Multiple races/ethnicities	13.0 (10)	0.0 (0)
Another race/ethnicity	2.6 (2)	0.0 (0)
Unreported	2.6 (2)	0.0 (0)
Yearly income		
Less than US$10 000	28.6 (22)	19.4 (6)
US$10 000–US$29 999	31.2 (24)	38.7 (12)
US$30 000 or more	11.7 (9)	41.9 (13)
Student	14.3 (11)	0.0 (0)
Unknown or unreported	14.3 (11)	0.0 (0)
Financial status		
Better or much better than others	22.1 (17)	6.5 (2)
Same as others	45.5 (35)	22.6 (7)
Worse or much worse than others	22.1 (17)	54.8 (17)
Unknown or unreported	10.4 (8)	16.1 (5)
Educational attainment		
High school or less	11.7 (9)	25.8 (8)
Some college	48.1 (37)	48.4 (15)
Associate's degree or more	37.7 (29)	25.8 (8)
Unreported	2.6 (2)	0.0 (0)
Current employment		
Unemployed	18.2 (14)	51.6 (16)
Employed part time	29.9 (23)	29.0 (9)
Employed full time	23.4 (18)	16.1 (5)
Student	22.1 (17)	0.0 (0)
Unreported	6.5 (5)	3.2 (1)

*Includes transgender (n=1) and gender variant/non-binary (n=3)
†Includes queer (n=1) and questioning/unsure (n=3).
AIRS, Adult IQOS Respiratory Study; BREATHE, Biomedical Respiratory Effects Associated through Habitual Use of E-Cigarettes.

and saliva. Participants stored biospecimens in their own freezers while awaiting return shipments. Biospecimens were picked up from the participant's home and sent back to the study team on days 8 and 22. After the day 22 visit, study staff coordinated a shipment pick-up time with participants. Feasibility and acceptability questionnaires were administered after the day 1 visit (device and biological data collection experience) and at the completion of the study (study engagement and remote sampling mailing experience). Participants were compensated US$50 for the baseline visit, US$20 weekly for completed saliva and NELF collection (up to US$60 total), US$2 for completed daily diaries and spirometry measurements (up to US$44 total) and an additional US$76 for completing 75% or more of the daily diaries, for a total possible compensation of US$230.

Daily diaries and spirometry tests

Daily diaries were administered twice daily via the LifeData app. Daily diary morning prompts were pushed between awakening and the start of any school or work commitments, and evening prompts were pushed before the participant's bedtime. Spirometry was conducted with a Spirobank[21] handheld spirometer and smartphone app immediately after each daily diary. Because participants were not monitored every time they used the spirometer, we could not confirm whether all American Thoracic Society standards of acceptability and reproducibility[22] were met each time. However, staff provided all necessary training and equipment. Participants completed a study staff-led directed training via video conference and viewed an instructional video on spirometer use during the day 1 visit. To use the spirometer, participants placed the device in their mouths, took a deep breath and exhaled as quickly as possible. Measurements were repeated at least three times, and spirometric indices were automatically recorded for the best test.[23] The training video was easily accessible in the spirometry app for reviewing instructions at any time.

Table 2 Feasibility and acceptability of daily diaries and breath tests

	BREATHE Study (N=64)	AIRS Study (N=20)
	% (n)	
What did you think about the timing of the daily diaries?		
Very manageable	37.5 (24)	85.0 (17)
Somewhat manageable	35.9 (23)	10.0 (2)
Neutral	12.5 (8)	5.0 (1)
Somewhat disruptive	12.5 (8)	0.0 (0)
Very disruptive	1.6 (1)	0.0 (0)
What did you think of the amount of daily diaries?		
Just right	89.1 (57)	85.0 (17)
Too many	10.9 (7)	15.0 (3)
What did you think about the timing of the breath tests?		
Very manageable	29.7 (19)	50.0 (10)
Somewhat manageable	32.8 (21)	25.0 (5)
Neutral	15.6 (10)	5.0 (1)
Somewhat disruptive	18.8 (12)	10.0 (2)
Very disruptive	3.1 (2)	10.0 (2)
What did you think about the number of breath tests we asked you to complete?		
Just right	82.8 (53)	90.0 (18)
Too many	17.2 (11)	10.0 (2)
I found the breath tests to be…		
Easy	48.4 (31)	25.0 (5)
Interesting	57.8 (37)	55.0 (11)
Enjoyable	10.9 (7)	5.0 (1)
Challenging	31.3 (20)	30.0 (6)
Very challenging	3.1 (2)	5.0 (1)
Uncomfortable	6.3 (4)	15.0 (3)
Overall, how was your experience using the breath device?		
Liked a great deal	28.1 (18)	25.0 (5)
Liked a moderate amount	26.6 (17)	30.0 (6)
Neither liked nor disliked	32.8 (21)	30.0 (6)
Disliked a moderate amount	12.5 (8)	0.0 (0)
Overall, how was your experience using the daily diary app?		
Liked a great deal	31.3 (20)	25.0 (5)
Liked a moderate amount	26.6 (17)	45.0 (9)
Neither liked nor disliked	39.1 (25)	30.0 (6)
Disliked a moderate amount	1.6 (1)	15.0 (3)
Disliked a great deal	1.6 (1)	0.0 (0)

AIRS, Adult IQOS Respiratory Study; BREATHE, Biomedical Respiratory Effects Associated through Habitual Use of E-Cigarettes.

NELF and saliva collection

Saliva and NELF were collected once weekly during each study check-in visit conducted via video conference. Participants viewed instructional videos during the day 1 visit. Participants collected saliva using standardised methods by providing passive drool into a collection tube. Nasal epithelial fluid was collected using validated procedures.[10 24 25] Specifically, participants sprayed their nostrils with a sterile, normal saline irrigation solution, inserted test strips into their nostrils and clamped their nostrils shut for 2 min, then removed the test strips and placed them into marked tubes. Biospecimens were stored in participants' freezers until scheduled return shipment pickup times.

Self-reported measures of feasibility

Daily diaries and breath tests

Participants rated the timing (forced choice: very manageable, somewhat manageable, neutral, somewhat disruptive, very disruptive), number (too little, just right, too many) and overall experience (liked a great deal, liked a moderate amount, neither liked nor disliked, disliked a moderate amount, disliked a great deal) of the daily diaries and breath tests. In addition, participants described breath tests selecting all that apply from a menu of options (easy, interesting, enjoyable, challenging, very challenging, uncomfortable).

Nasal swabs (NELF) and saliva collection

Participants rated the difficulty (easy, somewhat challenging, very challenging) and frequency (too frequent, just right, too sparse) of the nasal swabs and saliva collection, and selected all applicable descriptors for the nasal swab and saliva collection (difficult to find a place to do the swab/collection, easy to find a place to do the swab/collection, gross, uncomfortable, frustrating, manageable, uncomplicated and time-consuming).

Shipments

Using two items, participants rated their experience receiving (arrived on time, arrived late, easy to receive, easy to schedule, difficult to receive, difficult to schedule, received in good condition, received in poor condition) and sending (easy to schedule, easy to ship, difficult to schedule, difficult to ship) shipments, selecting all applicable descriptors for each item.

Sociodemographic characteristics

Participants reported their age, gender identity (male, female, transgender, gender variant/non-binary, other), sexual identity (asexual, bisexual, gay, straight, lesbian, pansexual, queer, questioning/unsure, other), race (American Indian or Alaska Native, Asian, Black or African American, Native Hawaiian or Pacific Islander, white, another race), Hispanic/Latinx ethnicity (yes/no), yearly income (less than US$10 000, US$10 000–US$99 999 (in increments of US$10 000), over US$100 000, student, unknown), perceived financial status compared with others (much better, better, same, worse, much worse, unknown), educational attainment (less than high school, some high school, high school graduate, some college, associate degree, bachelor's degree, master's degree, doctorate degree, professional school degree) and current employment status (unemployed, employed part time, employed full time, student).

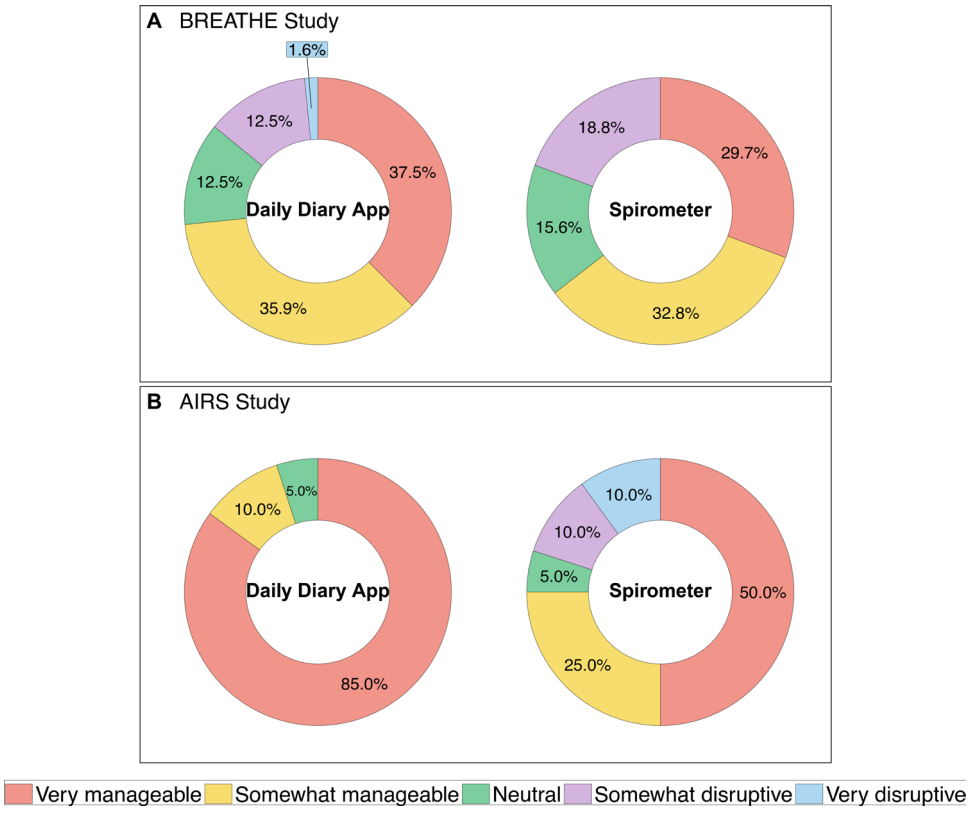

Figure 1 Perceived manageability of completing daily diaries and spirometry in the Biomedical Respiratory Effects Associated through Habitual Use of E-Cigarettes (BREATHE) (A) and Adult Respiratory IQOS Study (AIRS) (B) studies.

Statistical analysis

Descriptive statistics were examined to characterise the sample's sociodemographic characteristics and reported feasibility and acceptability of the daily diaries, breath tests, NELF, saliva collection and shipments. Missing data were handled using listwise deletion. Analyses were conducted with SPSS V.27. Of the 77 participants who completed the BREATHE baseline questionnaire, 83.1% (n=64) completed the feasibility and acceptability questionnaires (n=13 did not). Of the 31 participants who completed the AIRS baseline questionnaire, 64.5% (n=20) completed the feasibility and acceptability questionnaires (n=11 did not). Reported percentages for the feasibility and acceptability items reflect the participants (n=64 in BREATHE, n=20 in AIRS) who completed the questionnaires.

Patient and public involvement

None.

RESULTS

Participant characteristics

Participant demographic characteristics for BREATHE (N=77) and AIRS (N=31) are presented in table 1. Taken together, the two samples comprise a diverse group of adults. The BREATHE sample contained a notably high proportion of sexual and gender minority participants. A plurality of participants in BREATHE were Hispanic; a plurality in AIRS were non-Hispanic Black. Both samples were diverse in indicators of socioeconomic status, such as educational attainment and perceived financial status relative to others. In BREATHE, 10 participants completed the baseline survey but withdrew from the study or were lost to follow-up, an attrition rate of 13.0%. Five were lost to follow-up. The remaining five withdrew, or were withdrawn, from the study due to the perceived time burden, loss of interest in participating, non-compliance with study procedures, safety concerns or undisclosed reasons. An additional three participants did not complete the feasibility and acceptability questionnaires. In AIRS, seven participants withdrew or were withdrawn (attrition rate=22.6%). Three had technical difficulties with biospecimen storage, downloading study apps or using IQOS. One stopped attending study sessions. The remaining three expressed that the procedure was too burdensome or that they were no longer interested. An additional four participants did not complete the feasibility and acceptability questionnaires.

Feasibility and acceptability

Daily diaries and breath tests

Perceptions of the daily diaries and breath tests are reported in table 2. Across both studies, most participants rated the daily diaries as somewhat to very manageable (BREATHE: 73.4%; AIRS: 95.0%; see figure 1). Most rated the number of daily diaries (ie, every morning and night) as 'just right' (BREATHE: 89.1%; AIRS: 85.0%). Over half of participants liked the daily diary app a great

Table 3 Feasibility and acceptability of biospecimen collection and shipment

	BREATHE (N=64)	AIRS (N=20)
	% (n)	
What was the difficulty level of doing the nasal swabs?		
Easy	79.7 (51)	85.0 (17)
Somewhat challenging	20.3 (13)	15.0 (3)
How was the frequency of the nasal swabs?		
Too frequent	4.7 (3)	0.0 (0)
Just right	93.8 (60)	100.0 (20)
Too sparse	1.6 (1)	0.0 (0)
The nasal swabs were…		
Easy to find a place to do the swab	50.0 (32)	55.0 (11)
Difficult to find a place to do the swab	4.7 (3)	0.0 (0)
Gross	12.5 (8)	5.0 (1)
Uncomfortable	17.2 (11)	5.0 (1)
Frustrating	4.7 (3)	0.0 (0)
Manageable	67.2 (43)	65.0 (13)
Uncomplicated	42.2 (27)	35.0 (7)
Time-consuming	1.6 (1)	0.0 (0)
Giving enough spit for the saliva collection tubes was…		
Easy	50.0 (32)	60.0 (12)
Somewhat challenging	46.9 (30)	40.0 (8)
Very challenging	3.1 (2)	0.0 (0)
How did you find the frequency of the saliva tests?		
Too frequent	3.1 (2)	0.0 (0)
Just right	95.3 (61)	100.0 (20)
Too sparse	1.6 (1)	0.0 (0)
The saliva tubes were…		
Difficult to find a place to collect the saliva	7.8 (5)	15.0 (3)
Easy to find a place to collect the saliva	54.7 (35)	60.0 (12)
Gross	10.9 (7)	5.0 (1)
Uncomfortable	10.9 (7)	5.0 (1)
Frustrating	6.3 (4)	5.0 (1)
Manageable	57.8 (37)	60.0 (12)
Uncomplicated	29.7 (19)	25.0 (5)
Time-consuming	15.6 (10)	5.0 (1)
My experience receiving the shipments was…		
Easy to receive	95.3 (61)	95.0 (19)
Easy to schedule	56.3 (36)	60.0 (12)
Received in a good condition	50.0 (32)	65.0 (13)
Difficult to receive	3.1 (2)	0.0 (0)
Difficult to schedule	3.1 (2)	0.0 (0)
My experience sending the shipments was…		
Easy to send	87.5 (56)	95.0 (19)
Easy to schedule	56.3 (36)	60.0 (12)
Difficult to send	4.7 (3)	0.0 (0)
Difficult to schedule	7.8 (5)	0.0 (0)

AIRS, Adult IQOS Respiratory Study; BREATHE, Biomedical Respiratory Effects Associated through Habitual Use of E-Cigarettes.

deal or a moderate amount (BREATHE: 57.8%; AIRS: 70.0%). Breath tests were similarly rated manageable by most participants (BREATHE: 62.5%; AIRS: 75.0%; see figure 1), and most (BREATHE: 82.8%; AIRS: 90.0%) perceived the number of breath tests as 'just right'. Over half of participants liked the breath device (spirometer) a great deal or a moderate amount (BREATHE: 54.7%; AIRS: 55.0%). The most commonly selected adjectives to describe the breath tests were 'interesting' (BREATHE: 57.8%; AIRS: 55.0%), 'easy' (BREATHE: 48.4%; AIRS: 25.0%) and 'challenging' (BREATHE: 31.3%; AIRS: 30.0%). Notably, 'challenging' may have referred to the physical challenge of forced exhalation, not necessarily to the remotely administered aspects of the procedure.

NELF and saliva collection

Feasibility and acceptability of biospecimen collection are reported in table 3. Most participants (BREATHE: 79.7%; AIRS: 85.0%) reported NELF collection was easy. Nearly all (BREATHE: 93.8%; AIRS: 100.0%) described frequency as 'just right'. The most commonly selected adjectives to describe NELF were 'manageable' (BREATHE: 67.2%; AIRS: 65.0%), 'easy to find a place to do the swabs' (BREATHE: 50.0%; AIRS: 55.0%) and 'uncomplicated' (BREATHE: 42.2%; AIRS: 35.0%). Giving enough spit for saliva collection was generally described as 'easy' (BREATHE: 50.0%; AIRS: 60.0%) or 'somewhat challenging' (BREATHE: 46.9%; AIRS: 40.0%), with frequency of collection most often described as 'just right' (BREATHE: 95.3%; AIRS: 100.0%). The most commonly selected descriptors for saliva collection were 'manageable' (BREATHE: 57.8%; AIRS: 60.0%), 'easy to find a place to collect the saliva' (BREATHE: 54.7%; AIRS: 60.0%) and 'uncomplicated' (BREATHE: 29.7%; AIRS: 25.0%).

Shipments

Participants' experience with sending and receiving shipments is reported in table 3. The most commonly selected descriptors for receiving shipments were 'easy to receive' (BREATHE: 95.3%; AIRS: 95.0%), 'easy to schedule' (BREATHE: 56.3%; AIRS: 60.0%) and 'received in good condition' (BREATHE: 50.0%; AIRS: 65.0%). No participants reported receiving shipments in poor condition. The most commonly selected descriptors for sending shipments were 'easy to send' (BREATHE: 87.5%; AIRS:

95.0%), 'easy to schedule' (BREATHE: 56.3%; AIRS: 60.0%) and 'difficult to schedule' (in BREATHE only, 7.8%). A few participants (4.7%) in BREATHE reported that shipments were 'difficult to send', due to their living situation (eg, living on a military base, moving) or difficulties with FedEx pick-ups (eg, late pick-up, lack of communication with FedEx).

DISCUSSION

Adults across the age spectrum, participating in two 4-week studies of the respiratory effects of non-cigarette tobacco products, found remote study procedures to be feasible and acceptable. Participants engaged in twice daily diaries and spirometry measurements and weekly collection of saliva and nasal epithelial fluid during video calls with study staff. Most participants considered the study procedures to be manageable and not excessively frequent. Receiving and scheduling shipments of study materials and biospecimens was typically considered easy, with shipments arriving in good condition. Protocols were entirely remote in order to maintain social distancing and to avoid aerosol-generating procedures during the COVID-19 pandemic. Feasibility and acceptability data suggest that remote administration of an observational study involving spirometry, biospecimen collection and EMA (ie, daily diaries) is a viable alternative to in-person data collection. Beyond the COVID-19 pandemic, remote protocols can still be used to expand access to research participation and to increase the geographical diversity of participant pools. Prior research on young adults' tobacco use has found remote monitoring of carbon monoxide[26] and salivary cotinine[27] to be feasible and acceptable. This study further suggests that repeated collection of multiple forms of biodata, plus EMA, can be done entirely remotely.

Young adults may be more familiar and comfortable with using smartphone apps and video conferencing than older adults, and older adults are less likely than young adults to own a smartphone.[28] However, the increased use of video conferencing for socialising, working and receiving healthcare during the COVID-19 pandemic likely increased many older adults' familiarity with and comfort with using these technologies. Indeed, participants across the age spectrum eligible for these studies (age 18–65) found the study procedures to be feasible and acceptable. Importantly, smartphone ownership was an eligibility criterion for participating in this study. Although smartphone ownership has increased for lower-income Americans, 24% of adults with annual household incomes below US$30 000 reported not owning a smartphone in 2021.[15] However, smartphone ownership is similar across racial/ethnic groups.[28] Despite the requirement of smartphone ownership, this study recruited diverse samples of adults. Only 10.4% of the BREATHE sample was non-Hispanic white (25.8% of the AIRS sample). The majority of the AIRS sample (54.8%) perceived their financial status as worse than other peoples', and only 11.7% of the BREATHE sample reported annual income of US$30 000 or more.

Physical access to a study site is only one barrier to participating in biomedical research. Other barriers include limited exposure to research participation opportunities, information being presented in language that is difficult to understand, receiving information from unfamiliar sources and unaddressed privacy concerns.[13] Many participants in these studies were already familiar with participating in research and received an invitation to participate from a familiar source (ie, the study team), which may have increased participants' willingness to participate in the study. Achieving equity in research participation opportunities will require addressing additional barriers, beyond physical access to study sites.

Limitations and future directions

This study had several limitations in addition to those included above. First, generalisability of results beyond adults in Southern California may be limited. This participant pool was diverse in characteristics such as race/ethnicity, socioeconomic status and sexual identity; however, replication in a national sample would additionally be informative. Second, results may have been affected by attrition bias. Participants who found study procedures to be feasible and acceptable may have been more likely to complete follow-up surveys. In both samples, some participants who encountered barriers to participating in the study were not included in our data due to attrition. For example, several participants stated that they withdrew because the study was too time-consuming or burdensome, or because they were no longer interested in participating. One participant encountered technical difficulty downloading the study apps. Other participants may have had similar or different concerns. Future research could examine participant retention strategies in a remotely delivered study involving biological data collection.

CONCLUSIONS

The COVID-19 pandemic has highlighted the ongoing need for the remote conduct of research studies involving biological data collection. Remote research procedures may improve the diversity of samples and generalisability of research results. Overall, this study demonstrates that mobile apps and devices may be feasible and acceptable in facilitating tobacco research studies involving biological data collection.

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