Prevalence of Subclinical Hearing Loss in the United States

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Abstract

Objective. Current definitions of hearing loss (HL) may be insufficiently strict, as subclinical hearing loss (SCHL; >0 and ≤25 dB hearing level) has been associated with deleterious age-related conditions. SCHL prevalence and mean age of HL onset in the United States has not been characterized.

Study Design. A cross-sectional epidemiologic prevalence study.

Setting. US Community.

Methods. We analyzed cross-sectional audiometric data in the US National Health and Nutrition Examination Survey (2005-2012, 2015-2018, n = 15,649). Results were scaled to the current population using weighting.

Results. 79.6% of participants (227.32 million Americans) had SCHL. The mean age of HL onset at thresholds of 25, 20, and 15 dB was 74, 66, and 55 years, respectively, for the 4-frequency pure-tone average, and 48, 44, and 35 years for the high-frequency pure-tone average.

Conclusion. We present SCHL prevalence and define HL onset by various sensitive definitions. These results inform ongoing public health efforts to increase hearing aid utilization, particularly given the arrival of over-the-counter hearing aids.

Age-related hearing loss (HL) has been associated with depression,[1-3] cognitive decline,[4,5] and other health concerns.[6] It has been recently cited as the number one potentially modifiable risk factor for dementia.[7] Adult HL is commonly defined as >25 decibels hearing level (dB).[8] Approximately 20% of Americans aged ≥12 years have bilateral HL, rising to almost 75% aged ≥70 years.[9] This is expected to increase as the population ages.

Recently, worse hearing within the category considered "normal" (≤25 dB) has also been associated with depressive symptoms[10] and worse cognition.[7,11-13] This suggests that so-called "normal" hearing levels may not be innocuous. It further suggests that the 25 dB threshold for HL may be too lax.

We term subclinical hearing loss (SCHL) as imperfect hearing (>0 dB) still considered within "normal" limits (≤25 dB). The word subclinical refers to the absence of perceived symptoms, but not necessarily the absence of subtle effects on functioning. It is used across medicine to indicate very early stages of conditions before they are formally diagnosed.[14,15] Its use as a hearing category has been used in previous papers by multiple research teams.[10-13,16,17] The SCHL category includes most Americans, yet a granular prevalence study has not been performed. We aim to report SCHL prevalence using population-level data from the US National Health and Nutrition Examination Survey (NHANES). We stratify SCHL subcategories across age and report prevalence using the high-frequency pure-tone average as an alternative, more sensitive measure. Finally, we plot HL progression throughout the lifespan to identify the mean age at which HL begins according to standard versus more sensitive definitions.

As HL becomes increasingly recognized as a major public health issue, defining onset parameters grows more critical for awareness, prevention, and intervention. This is particularly relevant given the recent arrival of over-the-counter hearing aids, which are being used by individuals with self-perceived HL that includes the SCHL range.

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Methods

This was a cross-sectional study of ≥12 years olds in the multicentered US NHANES, which randomly samples individuals to create a representative sampling of the US population.[18] Cycle years 2005 to 2006, 2007 to 2008, 2009 to 2010, 2011 to 2012, 2015 to 2016, and 2017 to 2018 were included (n = 15,649). Noninstitutionalized civilian citizens with audiometry were included. To account for NHANES complex survey design, survey weights were used to estimate prevalence. Population estimates were computed in combination with 2019 US census bureau data (n = 280,216,744 for included population).[19] More recent estimates were avoided as they may be less accurate due to the COVID-19 pandemic.

The hearing was tested in NHANES mobile examination centers' soundproof booths per published protocols.[20] Briefly, participants' hearing thresholds were measured via standard audiometry, which captures the intensity (loudness, in dB) needed for a sound to be heard at specific frequencies (in Hz). A larger hearing threshold number (in dB) indicates worse hearing. A larger frequency number (in Hz) indicates a higher-pitched sound. The hearing was defined by the commonly used 4-frequency pure-tone average in the better ear (PTA4) at 500, 1000, 2000, and 4000 Hz. This definition has been used in prior nationally representative prevalence studies[9,21] as well as epidemiologic studies.[22,23] Hearing was also defined by the high-frequency pure-tone average (PTAhf) in the better ear at 6000 and 8000 Hz. Because sensorineural HL (which includes presbycusis, and is much more common than conductive HL)[24] usually begins in the high frequencies, using PTAhf represents a more sensitive measure.

Participants were categorized into age deciles (10-year categories) between 20 and 79 years. Participants <20 years old were included in a 12- to 19-year-old category, as 12 years was the youngest age for which NHANES gathered audiometric data. Participants ≥80 years were included in an open-ended ≥80-year-old category. This was necessary because NHANES masks the true age of the small number of individuals aged ≥80 or ≥85 years (depending on cycle) to preserve anonymity. For analyses requiring continuous age data, individuals ≥80 or ≥85 years (depending on the cycle) were eliminated, as their true age was unknown. A scatter plot of mean hearing level (dB) versus age (years) was used to estimate the age of onset of HL based on varying definitions (15, 20, or 25 dB).

Data analysis was performed in Stata v17 (StataCorp). The Columbia University institutional review board deemed this analysis of public, anonymized data as not human subjects research under 45 CFR 46. Analyses were performed between May 2021 and June 2022.

Results

A total of 15,649 included subjects ≥12 years old had audiometric data, representing 280.22 million Americans using NHANES survey weighting calculations applied to 2019 US Census numbers. All subsequent percentages and numbers refer to US population estimates. 79.64% of the included population (223.16 million individuals) had SCHL, as defined by a PTA4 >0 and ≤25 dB. This is compared to 9.53% (26.70 million) with perfect hearing (≤0 dB), and 10.84% (30.36 million) with outright HL (>25 dB).

Prevalence was stratified by age decile (**Table 1**). In the youngest group (12-19 years), 76.85% (25.83 million) had SCHL and 22.99% (7.73 million) had perfect hearing. SCHL was most common among 40- to 49-year-olds, with a prevalence of 91.18% (36.76 million) compared to 5.67% (2.29 million) with perfect hearing. In the oldest group (≥80 years), 21.20% (2.74 million) had SCHL compared to none with perfect hearing.

SCHL hearing level subcategories also appear in **Table 1**. This allows one to calculate the prevalence of outright HL if cutpoints stricter than 25 dB are used. For example, if the cutpoint were 20 dB, the HL prevalence in ≥12-year-olds would increase by 5.6 percentage points (15.69 million), from 10.84% (30.36 million) to 16.44% (46.05 million). This would represent a 51.7% increase in HL prevalence overall. We additionally report prevalence using the more sensitive PTAhf (**Table 2**).

The mean age of outright HL onset, defined by the typical 25 dB PTA4 threshold was 74 years. We calculated the age of HL onset using alternative HL definitions, varying thresholds, and frequencies (**Figure 1**). Using 20 and 15 dB thresholds, the mean age of outright HL onset would be 66 and 55 years, respectively. Using the PTAhf, the mean age of onset at 25, 20, and 15 dB thresholds would be 48, 44, and 35 years, respectively.

Discussion

This study represents the most detailed characterization of SCHL to date. We define SCHL as imperfect hearing (>0 dB) still considered normal by the common US adult cutpoint of ≤25 dB. These prevalence data are especially relevant given the recent arrival of over-the-counter hearing aids (mandated by the Over-the-Counter Hearing Aid Act of 2017). As barriers to hearing aids lower, we predict those with less HL, including some with SCHL, will opt for treatment.[25] Indeed, some individuals with SCHL may have difficulty understanding speech in background noise[26] and may have already sought treatment. We estimated that 30.36 million Americans have outright HL (>25 dB). If those with the highest subcategory of SCHL (>20 to ≤25 dB) considered hearing aids, the potential market would grow by over 50% or by almost 16 million individuals.

Biologically, HL is a continuum and the arbitrary 25 dB cutpoint is being challenged. To our knowledge, there is no scientific reason why this was chosen. The value of 0 dB was artificially set based on normative data from standardizing organizations (eg, American National Standards Institute).[27] In theory, any value higher than 0 dB is worse

Table I. Prevalence of Subclinical HL Categories in Individuals ≥12 y Old in the United States by Age, Per the National Health and Nutrition Examination Survey (2005-2006, 2007-2008, 2009-2010, 2011-2012, 2015-2016, 2017-2018 cycles)

	12-19 y	20-29 y	30-39 y	40-49 y	50-59 y	60-69 y	70-79 y	≥80 y	Overall
Prevalence of HL (%, 95% CI)									
Perfect hearing (≤0 dB)	22.99 (20.90, 25.22)	20.09 (17.31, 23.20)	12.97 (10.42, 16.03)	5.67 (4.01, 7.95)	1.32 (0.72, 2.42)	0.48 (0.14, 1.70)	0.06 (0.01, 0.27)	-	9.53 (8.45, 10.72)
Subclinical HL (>0 to ≤25 dB)	76.85 (74.63, 78.93)	79.21 (76.07, 82.04)	85.81 (82.69, 88.45)	91.18 (88.93, 93.00)	87.68 (85.09, 89.87)	76.66 (73.69, 79.39)	53.77 (48.73, 58.73)	21.20 (18.03, 24.76)	79.64 (78.43, 80.79)
>0 to ≤5 dB	45.48 (43.53, 47.43)	46.17 (43.04, 49.34)	39.45 (35.93, 43.09)	26.88 (23.38, 30.68)	12.14 (9.57, 15.30)	7.45 (5.91, 9.36)	0.91 (0.34, 2.38)	-	27.03 (25.25, 28.88)
>5 to ≤10dB	23.82 (22.18, 25.55)	23.53 (20.65, 26.68)	29.69 (27.20, 32.31)	31.61 (28.25, 35.17)	28.56 (25.03, 32.37)	16.99 (13.83, 20.70)	5.77 (4.69, 7.07)	1.05 (0.45, 2.42)	24.04 (22.88, 25.24)
>10 to ≤15 dB	5.80 (5.14, 6.54)	6.42 (4.79, 8.54)	11.31 (9.21, 13.80)	19.01 (16.43, 21.90)	24.77 (22.05, 27.72)	21.52 (18.79, 24.54)	14.06 (11.75, 16.74)	2.47 (1.45, 4.18)	14.51 (13.58, 15.51)
>15 to ≤20 dB	1.37 (0.96, 1.96)	2.53 (1.49, 4.26)	3.93 (3.08, 5.00)	9.65 (7.90, 11.73)	13.71 (11.54, 16.22)	16.65 (13.90, 19.83)	16.28 (13.35, 19.71)	7.73 (5.85, 10.16)	8.46 (7.75, 9.24)
>20 to ≤25 dB	0.39 (0.21, 0.69)	0.57 (0.26, 1.22)	1.43 (0.79, 2.59)	4.03 (3.05, 5.32)	8.48 (6.63, 10.80)	14.04 (11.50, 17.04)	16.75 (14.18, 19.68)	9.95 (7.98, 12.34)	5.60 (5.07, 6.18)
Outright HL (>25 dB)	0.16 (0.08, 0.28)	0.69 (0.36, 1.33)	1.22 (0.69, 2.15)	3.15 (2.15, 4.61)	11.00 (8.72, 13.79)	22.86 (20.12, 25.84)	46.17 (41.20, 51.22)	78.80 (75.24, 81.97)	10.84 (9.82, 11.94)
Prevalence of HL (number in millions, 95% CI)									
Perfect hearing (≤0 dB)	7.73 (7.02, 8.48)	9.07 (7.81, 10.47)	5.73 (4.60, 7.08)	2.29 (1.62, 3.21)	0.56 (0.30, 1.03)	0.18 (0.05, 0.65)	0.01 (0.00, 0.06)	-	26.70 (23.68, 30.05)
Subclinical HL (>0 to ≤25 dB)	25.83 (25.08, 26.52)	35.76 (34.34, 37.04)	37.90 (36.52, 39.07)	36.76 (35.86, 37.50)	37.14 (36.04, 38.06)	29.15 (28.02, 30.19)	12.73 (11.54, 13.91)	2.74 (2.33, 3.20)	223.16 (219.78, 226.39)
>0 to ≤5 dB	15.28 (14.63, 15.94)	20.84 (19.43, 22.27)	17.43 (15.87, 19.03)	10.84 (9.43, 12.37)	5.14 (4.05, 6.48)	2.83 (2.25, 3.56)	0.22 (0.08, 0.56)	-	75.73 (70.75, 80.93)
>5 to ≤10dB	8.00 (7.45, 8.58)	10.62 (9.32, 12.04)	13.11 (12.01, 14.27)	12.74 (11.39, 14.18)	12.10 (10.60, 13.71)	6.46 (5.26, 7.87)	1.37 (1.11, 1.67)	0.14 (0.06, 0.31)	67.36 (64.10, 70.73)
>10 to ≤15 dB	1.95 (1.73, 2.20)	2.90 (2.16, 3.85)	4.99 (4.07, 6.10)	7.67 (6.62, 8.83)	10.49 (9.34, 11.74)	8.18 (7.14, 9.33)	3.33 (2.78, 3.96)	0.32 (0.19, 0.54)	40.67 (38.05, 43.45)
>15 to ≤20 dB	0.46 (0.32, 0.66)	1.14 (0.67, 1.92)	1.74 (1.36, 2.21)	3.89 (3.18, 4.73)	5.81 (4.89, 6.87)	6.33 (5.29, 7.54)	3.86 (3.16, 4.67)	1.00 (0.76, 1.31)	23.71 (21.71, 25.88)
>20 to ≤25 dB	0.13 (0.07, 0.23)	0.26 (0.12, 0.55)	0.63 (0.35, 1.14)	1.63 (1.23, 2.15)	3.59 (2.81, 4.58)	5.34 (4.37, 6.48)	3.97 (3.36, 4.66)	1.29 (1.03, 1.59)	15.69 (14.21, 17.30)
Outright HL (>25 dB)	0.05 (0.03, 0.10)	0.31 (0.16, 0.60)	0.54 (0.30, 0.95)	1.27 (0.87, 1.86)	4.66 (3.69, 5.84)	8.69 (7.65, 9.83)	10.93 (9.76, 12.13)	10.18 (9.72, 10.59)	30.36 (27.52, 33.46)

The hearing was defined by the 4-frequency pure-tone average (0.5, 1, 2, and 4kHz) in the better-hearing ear. Numbers are in millions of Americans based on 2019 US Census population data. A graphic representation appears in Supplemental Figure S1, available online.
Abbreviations: CI, confidence interval; dB, decibel hearing level; HL, hearing loss.

Table 2. Prevalence of High-Frequency Subclinical HL Categories in Individuals ≥12 y Old in the United States by Age, Per the National Health and Nutrition Examination Survey (2005-2006, 2007-2008, 2009-2010, 2011-2012, 2015-2016, 2017-2018 cycles)

	12-19 y	20-29 y	30-39 y	40-49 y	50-59 y	60-69 y	70-79 y	≥80 y	Overall
Prevalence of HL (%, 95% CI)									
Perfect hearing (≤0 dB)	26.08 (24.33, 27.91)	9.51 (7.55, 11.90)	4.37 (3.05, 6.21)	1.87 (1.18, 2.96)	0.03 (0.004, 0.26)	0.05 (0.02, 0.16)	0.07 (0.01, 0.47)	-	5.99 (5.28, 6.80)
Subclinical HL	72.65 (70.94, 74.29)	86.54 (84.24, 88.55)	88.93 (87.11, 90.53)	74.03 (69.77, 77.88)	51.81 (47.71, 55.87)	27.19 (23.26, 31.51)	10.96 (8.59, 13.88)	1.86 (0.91, 3.77)	62.33 (60.38, 64.25)
(>0 to ≤25 dB)									
>0 to ≤5 dB	29.93 (28.08, 31.84)	20.50 (17.54, 23.82)	14.86 (12.91, 17.03)	5.13 (3.75, 6.97)	0.50 (0.31, 0.81)	0.06 (0.02, 0.21)	0.15 (0.05, 0.48)	-	10.52 (9.55, 11.58)
>5 to ≤10dB	24.07 (22.41, 25.81)	31.19 (28.77, 33.71)	28.82 (25.46, 32.44)	14.97 (12.65, 17.64)	6.09 (4.19, 8.77)	2.02 (1.23, 3.31)	0.80 (0.38, 1.68)	0.23 (0.03, 1.72)	16.47 (15.37, 17.63)
>10 to ≤15 dB	12.54 (11.43, 13.74)	21.70 (18.88, 24.82)	24.42 (22.04, 26.97)	23.90 (20.88, 27.21)	14.02 (11.05, 17.64)	5.71 (4.53, 7.18)	1.53 (0.89, 2.62)	0.04 (0.01, 0.28)	16.01 (14.90, 17.19)
>15 to ≤20 dB	4.66 (3.93, 5.53)	9.72 (7.63, 12.31)	13.54 (11.38, 16.03)	19.79 (17.35, 22.47)	16.44 (14.45, 18.65)	9.33 (6.72, 12.83)	3.01 (1.78, 5.06)	0.81 (0.28, 2.37)	11.66 (10.77, 12.62)
>20 to ≤25 dB	1.45 (1.11, 1.90)	3.43 (2.50, 4.70)	7.30 (5.83, 9.10)	10.24 (8.36, 12.49)	14.75 (12.60, 17.19)	10.06 (7.75, 12.97)	5.46 (4.00, 7.42)	0.77 (0.34, 1.77)	7.67 (6.96, 8.44)
Outright HL (>25 dB)	1.27 (0.89, 1.80)	3.95 (2.83, 5.50)	6.70 (5.38, 8.31)	24.10 (20.15, 28.54)	48.16 (44.08, 52.27)	72.76 (68.45, 76.68)	88.97 (86.07, 91.33)	98.14 (96.23, 99.09)	31.67 (29.48, 33.95)
Prevalence of HL (number in millions)									
Perfect hearing (≤0 dB)	8.76 (8.18, 9.38)	4.29 (3.41, 5.37)	1.93 (1.35, 2.74)	0.76 (0.48, 1.19)	0.01 (0.00, 0.11)	0.02 (0.01, 0.06)	0.02 (0.00, 0.11)	-	16.80 (14.80, 19.04)
Subclinical HL	24.41 (23.84, 24.96)	39.07 (38.03, 39.97)	39.28 (38.48, 39.98)	29.85 (28.13, 31.40)	21.94 (20.21, 23.66)	10.34 (8.85, 11.98)	2.60 (2.03, 3.29)	0.24 (0.12, 0.49)	174.67 (169.18, 180.04)
(>0 to ≤25 dB)									
>0 to ≤5 dB	10.06 (9.43, 10.70)	9.26 (8.52, 10.75)	6.56 (5.70, 7.52)	2.07 (1.51, 2.81)	0.21 (0.13, 0.34)	0.02 (0.01, 0.08)	0.04 (0.01, 0.11)	-	29.48 (26.76, 32.45)
>5 to ≤10 dB	8.09 (7.53, 8.67)	14.08 (12.99, 15.22)	12.73 (11.24, 14.33)	6.04 (5.10, 7.11)	2.58 (1.78, 3.71)	0.77 (0.47, 1.26)	0.19 (0.09, 0.40)	0.03 (0.00, 0.22)	46.15 (43.07, 49.41)
>10 to ≤15 dB	4.21 (3.84, 4.62)	9.80 (8.52, 11.20)	10.79 (9.73, 11.91)	9.64 (8.42, 10.97)	5.94 (4.68, 7.47)	2.17 (1.72, 2.73)	0.36 (0.21, 0.62)	0.005 (0.00, 0.04)	44.87 (41.76, 48.17)
>15 to ≤20 dB	1.57 (1.32, 1.86)	4.39 (3.44, 5.55)	5.98 (5.03, 7.08)	7.98 (7.00, 9.06)	6.96 (6.12, 7.90)	3.55 (2.56, 4.88)	0.71 (0.42, 1.20)	0.11 (0.04, 0.31)	32.68 (30.17, 35.37)
>20 to ≤25 dB	0.49 (0.37, 0.64)	1.55 (1.13, 2.12)	3.22 (2.57, 4.02)	4.13 (3.37, 5.04)	6.25 (5.34, 7.28)	3.83 (2.95, 4.93)	1.29 (0.95, 1.76)	0.10 (0.04, 0.23)	21.48 (19.50, 23.64)
Outright HL (>25 dB)	0.43 (0.30, 0.60)	1.78 (1.28, 2.48)	2.96 (2.38, 3.67)	9.72 (8.12, 11.51)	20.40 (18.67, 22.14)	27.67 (26.03, 29.16)	21.07 (20.38, 21.63)	12.68 (12.43, 12.81)	88.75 (82.62, 95.12)

The hearing was defined by an alternative, more sensitive high-frequency pure-tone average (6 and 8 kHz) in the better-hearing ear. Numbers are in millions of Americans based on 2019 US Census population data. A graphic representation appears in Supplemental Figure S2, available online.

Abbreviations: CI, confidence interval; dB, decibel hearing level; HL, hearing loss.
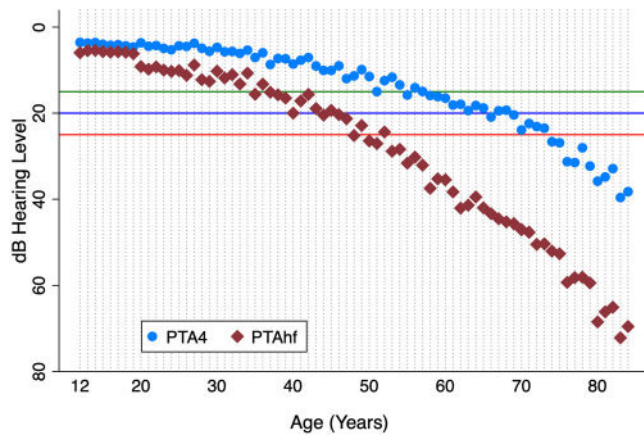
Figure 1. Hearing as a function of age. Hearing is measured by PTA4 (blue circles) and PTAhf (red diamonds) in the better ear. Each point is the mean over a year of age. Horizontal lines indicate thresholds to define hearing loss (red = 25 dB, blue = 20 dB, green = 15 dB). PTA4, 4-frequency pure-tone average; PTAhf, high-frequency pure-tone average.

than "normal." In practice, however, less strict cutoffs are used. In children, a stricter threshold of 20 dB is commonly used in the United States. Likewise, the World Health Organization began defining HL as ≥20 dB, including in adults, with its 2021 World Report on Hearing.[28] Some sources define HL down to 15 dB.[29] Furthermore, SCHL may be clinically consequential. Worse hearing within the SCHL category has been associated with worse cognition[6,7,11] and depressive symptoms.[10] For example, in one study, for every 10 dB worsening in hearing among those in the SCHL hearing group, the score on a common cognitive test dropped by 2.3 points (controlling for confounders), which was clinically meaningful.[11] In another study, for every 10 dB worsening in hearing among those in the same group, the score on a test for depressive symptoms increased by over a point, also considered clinically meaningful.[10] In addition, so-called "hidden hearing loss" may explain the experience of individuals with "normal" pure-tone hearing but with cochlear synaptic damage (termed cochlear synaptopathy).[30] This may cause difficulty hearing in noise, tinnitus, and hypersensitivity to sounds.[26] Stricter HL definitions, or utilization of the PTAhf, may capture more of these individuals. We present SCHL prevalence subcategorized by 5-dB groups to allow for manual prevalence calculations depending on the desired cutpoint to define HL.

This study's limitations include its cross-sectional design. This prevents following changes in individuals over time. NHANES also excludes those who are institutionalized, active military, noncitizens, or living outside the 50 states or the District of Columbia.[20] Despite this, NHANES is the most representative US national dataset containing audiometry. NHANES does not include speech audiometry, including word recognition scores. While word recognition adds an important dimension to hearing ability, most hearing categorization is based on pure-tone audiometry.

This includes efforts to make hearing categorization more accessible to the public.[31] In addition, word recognition in quiet is typically maintained until HL becomes moderate or worse. Word recognition in noise may represent a more sensitive measure for minute degrees of HL; however, it is not part of conventional clinical audiology. We would argue for its inclusion in future studies. Lastly, we used the pure-tone average in the better-hearing ear as it is a widely used and simple measure. However, it ignores the hearing ability in the worse ear. Future studies should take into account bilaterality.

In conclusion, we provide the most detailed analysis to date on SCHL prevalence, using current US population numbers. These estimates will inform ongoing, multifaceted public health efforts to increase hearing aid utilization, particularly in individuals with lesser degrees of HL. This includes those who may be candidates for over-the-counter hearing aids.

Author Contributions

Jacqueline M. Dragon, analysis, figures, writing; **Maeher R. Grewal**, analysis, figures, writing, editing; **Alexandria L. Irace**, initial analysis code, methods; **Emmanuel Garcia Morales**, analysis; **Justin S. Golub**, design, analysis, writing, editing.

Supplemental Material

Additional supporting information is available in the online version of the article.

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