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RESEARCH ARTICLE

Gastroesophageal Reflux Disease in the World Trade Center Health Program General Responder Cohort

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ABSTRACT

Background: People participating in the rescue, recovery, and clean-up effort after the September 11, 2001 attack on the World Trade Center (WTC) were exposed to a complex mix of noxious substances and subsequently experienced elevated gastroesophageal reflux disease (GERD) incidence, the second-most-common WTC-related condition.

Methods: Longitudinal WTC Health Program data, collected between July 2002 and December 2022, were used to describe the sample characteristics, diagnostic procedures, and treatment of consenting cohort members with self-reported GERD who reported incident GERD for a year or longer ($n = 19{,}067$). Cross-tabulations and binomial logistic regression, adjusted for confounders including comorbidities, assessed the associations with intermittent and resolved, compared with unresolved, GERD.

Results: 12.6% of the study cohort reported intermittent GERD; 5.5% reported GERD resolution. Analyses indicated that most GERD resolution was reported by people of color and those with body mass index <25, and by cohort members who had longer postdiagnosis follow-up and implemented dietary modifications together with proton pump inhibitors or Program-approved antacids. GERD-certified members who underwent endoscopy, used medications without dietary modifications, or used bed head-elevation, and those with Barrett's disease (5.8%) or esophageal cancer (0.1%) may have had more severe GERD and reported little resolution.

Conclusions: The use of GERD services was consistent with clinical guidelines. Members' implementing dietary modifications in conjunction with proton pump inhibitors or Program-approved antacids reported more resolution and may have had less severe GERD. Earlier diagnosis and intervention might increase earlier therapeutic resolution.

Institution at which the work was performed

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1 | Introduction

People participating in the rescue, recovery, and cleanup after the September 11, 2001 attack on the World Trade Center (WTC) were exposed to a complex mixture of noxious substances [1–3]. Among other conditions, many subsequently experienced an increased rate of gastroesophageal reflux disease (GERD) [4–6]. In North America, GERD prevalence is between 18% and 28% [7]. In firefighters responding to the attack, GERD prevalence was 28% in those with low levels of WTC exposure and 54% in those with high levels of WTC exposure [8]. Compared to pre-September 11, 2001 levels, an eightfold increase in new onset GERD was observed in the General Responder Cohort (GRC) 9 years after the attack [5].

GERD is a chronic digestive condition commonly identified by heartburn and/or acid regurgitation, the two symptoms with the best, albeit imperfect, diagnostic sensitivity, and specificity [9]. GERD etiology and manifestation is variable and can be multifaceted, thus no "gold standard" diagnostic tool exists [9–13]. Lifestyle modifications and short-term proton pump inhibitor (PPI) use are the first-line treatments, after which objective, invasive diagnostic tools are recommended if GERD persists [9, 14]. Upper endoscopy, the most frequently used diagnostic tool, is often recommended for cases perceived to be persistent or more severe, but its use is variable [9, 13]. Laryngoscopy, to identify suspected laryngeal involvement, is less frequently recommended [9], and monitoring pH levels is recommended for patients with chest pain [9, 10].

The variability in GERD etiology and presentation has resulted in treatments range from lifestyle modifications (dietary modifications, weight loss, smoking cessation, bed head-elevation), through over-the-counter and prescription medications (acid suppressors, and, less often, antibacterials and prokinetics), to surgery [9]. The evidence for the effectiveness of dietary modifications is inconsistent, but lower weight, weight loss, and smoking cessation are associated with a reduction in GERD symptoms [15–17]. For nonrefractory GERD, PPIs are more effective than other first-line medications in relieving symptoms; however, long-term medical management is often required to control symptoms and avoid relapse [18–20]. Short-term evidence indicates that some surgical procedures (transoral incisionless fundoplication and radiofrequency ablation) are equally or more effective than acid inhibitors and can reduce subsequent medication use, but can also be associated with more adverse events than medication [21]. Laparoscopic Roux-en-Y gastric bypass may reduce the risk of GERD while laparoscopic sleeve gastrectomy may increase its risk [22].

The WTC Health Program provides treatment cost-coverage benefits for the use of Program-approved health service providers for Program-certified conditions [23, 24]. Certification of WTC-related conditions is based on medical documentation that the condition was substantially caused or contributed to by participation in activities in response to the September 11, 2001 attack and/or the toxic exposures resulting from the attack and on Program-established criteria (including intensity, duration, and temporality of WTC exposures, presence of WTC-related comorbidities and clinical judgement) [24, 25]. Thirty-five percent of all GRC members have been certified for WTC-related GERD.

We conducted this study with two principal objectives. The first was to assess the extent to which the GRC reported diagnostic procedures and treatments received, providing insight into the coverage and gaps in GERD care among the members. The second was to determine the characteristics of members who experienced GERD, and how therapies and potential GERD outcomes (Barrett's disease and esophageal cancer) were associated with GERD resolution.

2 | Materials and Methods

2.1 | Data Source

Five WTC Health Program clinical centers of excellence serve cohort members in the New York–New Jersey–Pennsylvania metropolitan statistical area. Since July 1, 2002, the clinical centers conduct periodic health monitoring and provide diagnostic procedures and treatment for the GRC, a large, longitudinal, open (continuing to enroll eligible members) cohort. Since then, sociodemographic status and WTC response-related exposure information have been collected and reported by clinical staff using standardized questionnaires at members' first health evaluation visit 1 (V1). Information on self-reported health status, diagnostic procedures, GERD treatment including medication use, and information from physical and laboratory examinations are ascertained at V1 and subsequent visits.

2.2 | Ethics Review and Approval

The WTC Health Program research was approved by the Institutional Review Boards of the GRC Data Center and Clinical Centers of Excellence. The research was conducted in concurrence with the principles of the World Medical Association Declaration of Helsinki (1975, revised 2013) and national and institutional committees' standards regarding the conduct of human studies. Written informed consent was obtained for all members included in the study.

2.3 | Inclusions/Exclusions

Of 52,641 GRC members who attended Program monitoring visits through December 31, 2022, 48,813 (92.7%) provided written, voluntary consent for data aggregation and research use. Of those consenting, this study excluded members who: never reported GERD ($n = 24{,}407$); reported GERD before September 11, 2001 ($n = 1928$); or did not report the earliest date they experienced GERD ($n = 492$). To assess the associations between diagnostic procedures, treatment, and GERD resolution, additional exclusions were 1758 members who attended only one monitoring visit, 773 with no longitudinal GERD data (e.g., beyond its first being reported), 379 with less than 1 year of GERD follow-up and nine who reported some GERD resolution but whose dates of resolution were recorded as occurring before the earliest dates of GERD diagnosis, producing a study sample of 19,067 GERD cohort members.

2.4 | Measures

The study primary outcomes are resolution of self-reported GERD and self-reported use of health services for GERD including diagnostic procedures (endoscopy, laryngoscopy, nighttime pH monitoring), behavior modification (dietary modification or bed head-elevation), medication use (proton pump inhibitors [PPI], histamine 2 receptor antagonists [H2], and antacids) [9, 15–20, 26, 27].

This study analyzed data collected from interview questionnaires and physical examinations. Since 2007, these data have been directly entered into electronic databases by clinic staff.

A positive response to any of the following questions: "Have you ever been diagnosed with GERD," "Since we last saw you, have you been diagnosed with GERD?," "Do you still have GERD?," and "Are you currently under the care of a doctor for GERD?" was defined as a diagnosis of GERD. GERD diagnostic procedures and their occurrence date were also self-reported. For members reporting GERD, the interviewer-assisted questionnaire asked "Since [September 11, 2001/your last exam have you made/do you still use] diet modifications/elevate head [in bed]." Details of types of dietary modifications and reasons for weight loss were not captured. Similarly, information on endoscopy and laryngoscopy was captured from questions "Since... endoscopy/laryngoscopy" and "Date of last" procedure. We do not report on hospitalizations or surgeries other than endoscopy or laryngoscopy as their purpose (to diagnose or to treat GERD) was not specified. Current use of medications was self-reported by brand or generic medication name at each visit. Except for "other antacids," we assessed only GERD medications approved on the Program's formulary per the January 2023 Program's Pharmacy Benefits Manager.

Using the study's longitudinal data, three types of GERD resolution were defined: resolved (without relapse)—when resolution was reported after its first diagnosis and GERD was not subsequently reported (Formula 1); intermittent GERD—when the earliest resolution was reported after first diagnosis and before a subsequent report of GERD; and unresolved—when no resolution was reported (Formula 2). Per the study inclusion criteria, only incident cases of GERD occurring on or after September 11, 2001, who had longitudinal data and GERD follow-up of more than 1 year were assessed.

The analyses assessed GERD duration, which was calculated for each GERD resolution status as follows: no resolution—the interval between date of earliest report of GERD and last visit date; intermittent GERD—the interval between date of earliest report and latest report of GERD; and resolved GERD—the interval between date of earliest report of GERD and date of resolution. GERD follow-up was calculated as the interval between earliest date of reported GERD and last monitoring visit date.

Formula 1: Resolved = All reported GERD dates < first resolution date

Formula 2: Intermittent = First resolution date (>first reported GERD date & <last reported GERD date)

The temporality of "exposure" to a GERD diagnostic procedure or therapy was assigned according to a member's resolution status. Members with no resolution that reported a procedure or therapy were classified as "exposed" to the procedure or therapy, both during and after their unresolved GERD. Members with any GERD resolution that reported diagnostic procedures or therapies before or on the earliest date of GERD resolution were classified as having been used during GERD (e.g., before resolution), while diagnostic procedures or therapies reported after the earliest date of GERD resolution were classified as "exposed after GERD resolution." Members who did not report a procedure or therapy were classified as unexposed during and after GERD resolution.

2.5 | Statistical Analysis

Descriptive statistics were generated to characterize the sample, diagnostic procedures as reported from the second monitoring visit (when this information was first captured) onwards, treatments and Program-certified GERD for members who completed monitoring visits since July 1, 2011, when GERD became a Program-certified condition, and the dependent variable, resolution of self-reported GERD. Cross-tabulations of sociodemographic characteristics and GERD treatments reported are presented with two-tailed chi-square 95% probability values. Independent binomial logistic regressions were used to assess the associations of treatment with intermittent GERD and resolved GERD, compared with members reporting no resolution. Four regression models were assessed. Model 1 adjusted for the major potential confounders for GERD including age, sex, race (black, Asian, other, not reported, compared to the referent category, white), Hispanic ethnicity (compared to non-Hispanic or those not reporting ethnicity), measured body mass index (BMI 25–29 considered as overweight, ≥ 30 considered as obese, compared to < 25) calculated as 703× (pounds/inches^2]), and marital status (married/partnered, other, compared to single) at visit 1, occupation (construction, electrical/telecommunications, and other installation/repair, transportation and material moving, other jobs, compared to protective services) on September 10, 2001, lifetime cigarette smoking status (former, current, compared to nonsmoker), and WTC exposure on September 11, 2001 when toxic exposures were theoretically greatest (compared to afterwards) [3]. Model 2 included model 1 variables, Program GERD certification, GERD follow-up duration, and pre-resolution endoscopy or laryngoscopy, bed head-elevation, dietary modification, and use of PPI, H2, or Program-approved antacids. Model 3 included model 2 variables, Barrett's disease in GERD-certified members and Program certification for the most severe consequence of GERD, esophageal cancer. Model 4 included model 3 variables and two-way interaction terms for age, GERD diagnostic procedures, dietary modifications and use of PPI, H2, and Program-approved antacids. Sensitivity regression analyses were conducted, limited to GERD certified members. The regression analyses are presented with adjusted odds ratios (AOR) and two-tailed 95% confidence intervals (CI). Hosmer–Lemeshow (HL) goodness-of-fit statistics were evaluated [28]. Figure 1 illustrates the use of GERD treatments during and after GERD resolution in members with intermittent and resolved GERD. The analyses were conducted using SPSS for Windows version 28.0.1.1(15) (IBM Corp., Armonk, NY).

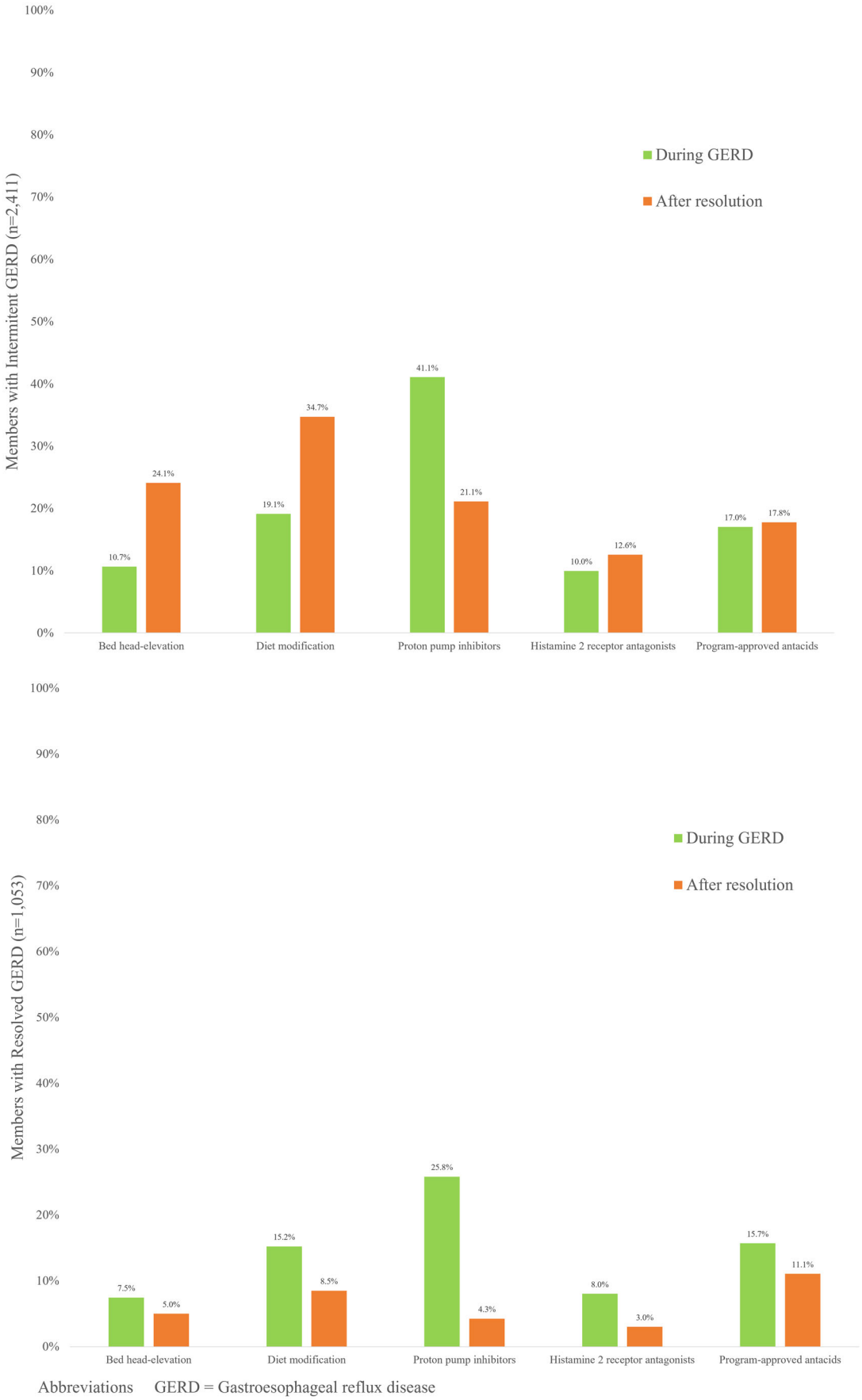

FIGURE 1 | Percentage of members who used a GERD treatment during and after GERD resolution. [Color figure can be viewed at wileyonlinelibrary.com]

3 | Results

3.1 | Sample Characteristics

There were 19,067 consenting, study-eligible members with self-reported incident GERD, 5.8% of whom had Barrett's disease and 0.1% esophageal cancer. Most were married or partnered, white, men, nonsmokers, overweight or obese at their first monitoring visit, and between 32 and 44 years old when they reported GERD first occurred (Table 1). Ninety-seven percent attended Program monitoring visits on or after July 1, 2011 when certification of members for WTC-related conditions began. Forty-four percent of the members with GERD were onsite responders on September 11, 2001. Fifty-nine percent were certified for GERD (considered WTC related-GERD). Approximately half of the members had diagnostic endoscopy; almost none had diagnostic laryngoscopy or nighttime pH monitoring. Proton pump inhibitors and dietary modification were the most commonly used treatments, although many people reported they elevated their heads while in bed and took Program-approved antacids. While some differences between the entire sample (GRC members with self-reported GERD) and the subgroups with visits on or after July 1, 2011 and GERD certified members were statistically significant due to large sample size, most were not substantively different (Table S1). Attending a monitoring visit on or after July 1, 2011 had little substantive influence on the members' use of health services for GERD (Table S1). Members who were certified for GERD had higher rates of Barrett's disease, diagnostic endoscopy, bed head-elevation, and dietary modification, and slightly higher rates of proton pump inhibitor use than did all study members (Table S1).

3.2 | GERD Resolution

Most (81.8%) did not report any GERD resolution, but 12.6% reported intermittent GERD resolution and 5.5% reported resolution without relapse (Table 1). Most members reporting diagnostic procedures or treatments for GERD experienced less GERD resolution than those not reporting these services or therapy. However, members who identified their race as black (OR = 1.53, [1.34, 1.73]), Hispanic (OR = 1.18, [1.08, 1.29]), and members with body mass index < 25 at their first visit (OR = 1.26 [1.13, 1.41]), experienced intermittent or resolved GERD significantly more often than those not reporting any resolution (unadjusted regression data not shown).

The average (mean ± standard deviation) GERD duration was 10.5 ± 6.0 years in members with no resolution, 12.0 ± 5.2 years in members with intermittent GERD and 5.6 ± 4.8 years in members with resolved GERD. Mean GERD follow-up was (identical to GERD duration at) 10.5 ± 6.0 years in members with no resolution, 13.5 ± 4.7 years in members with intermittent GERD and 10.6 ± 5.4 years in members with resolved GERD. Members who reported intermittent GERD increased their use of bed head-elevation, dietary modifications, H2s, and Program-approved antacids after first reporting some resolution, but decreased their use of PPIs after their earliest reported resolution (Figure 1). Conversely, those with resolved GERD reported less use of these therapies after GERD resolution (Figure 1).

The four adjusted logistic regression models produced similar results. Consequently, only results for model 3 are presented here unless otherwise specified. Greater age at GERD diagnosis was associated with more resolution (Table 2). Black and Hispanic members had greater odds of experiencing intermittent resolution and resolved GERD than white and non-Hispanic members, respectively. Compared with members with first visit BMIs <25, members with BMI ≥ 25, particularly those with BMI ≥ 30, had less GERD resolution. Members who implemented dietary modifications had significantly greater odds of intermittent resolution. However, members who were current smokers, Program-certified for GERD, had surgical diagnosis (endoscopy or laryngoscopy), used bed head-elevation or used PPIs or H2s for GERD reported less GERD resolution than their referent groups (respectively, nonsmokers, not GERD certified, had no surgical diagnosis, did not use bed head-elevation or GERD medications). The regression results were nearly identical for the indices of diagnosis and therapy in models with and (data not shown) without adjustment for patients with Barrett's disease and esophageal cancer certification and for analyses limited to GERD-certified members.

Similarly, adjusted analyses including two-way interaction terms for GERD services and medications used with age at GERD diagnosis, race, Hispanic ethnicity, and for first visit BMI found people diagnosed ≥ age 40 who had endoscopy had less resolution (AORs 0.47–0.53, 95% CI 0.3–0.8, all $p < 0.01$) and people who implemented dietary modifications who also used PPIs (AOR 1.9, 95% CI 1.5, 2.5, $p \leq 0.001$) or Program-approved antacids (AOR 1.7, 95% CI 1.2, 2.2, $p \leq 0.001$) had significantly more GERD resolution (remaining interaction statistics were not significant and are not shown).

The Hosmer–Lemeshow goodness-of-fit statistic was significant for intermittent resolution but not ($p = 0.21$) for the smaller sensitivity analysis limited to GERD certified members, even though the outcome AORs were nearly identical (data not shown). The HL statistics were not significant for the smaller sample of resolved GERD ($p = 0.14$) or its sensitivity analysis in GERD certified members ($p = 0.08$).

4 | Discussion

Although GERD is generally considered to be chronic, mild cases may be resolved by short-course PPI treatment, antacids, or lifestyle modifications [9, 14, 15, 18]. Even adjusted for various sociodemographic characteristics, confounding factors, and treatment regimens, our study found that nearly 20% of the WTC GRC cases reported intermittent or resolved GERD. Resolution rates were highest among black and Hispanic members, who are, with some uncertainty, thought to experience similar or higher GERD prevalence than white people in the general population [29, 30]. However, people of color generally also experience lower rates of erosive esophagitis and Barrett's disease, and thus perhaps experience less severe GERD and more resolution than white people [7, 29, 30]. Members who were certified for GERD, had Barrett's disease, esophageal cancer, received diagnostic endoscopy, used bed head-elevation or used medications without making dietary modifications, or experienced longer GERD duration may have experienced more severe GERD, as they reported less resolution.

TABLE 1 | Self-reported GERD by sociodemographic characteristics, treatment, and GERD resolution[a].

	Self-reported GERD 07/01/2002–12/31/2022			
	No resolution ($n = 15603$) n (%)	**Intermittent GERD ($n = 2411$) n (%)**	**Resolved GERD ($n = 1053$) n (%)**	**Total ($n = 19067$) n (%)**
Age at first visit diagnosis		$p \leq 0.001$	$p = 0.11$	
< 30	510 (3.3)	94 (3.9)	44 (4.2)	648 (3.4)
30–39	3379 (21.7)	611 (25.3)	237 (22.5)	4227 (22.2)
40–49	6127 (39.3)	991 (41.1)	384 (36.5)	7502 (39.3)
50–59	4184 (26.8)	533 (22.1)	277 (26.3)	4994 (26.2)
≥ 60	1403 (9.0)	182 (7.5)	111 (10.5)	1696 (8.9)
Sex		$p = 0.72$	$p = 0.13$	
Male	13,291 (85.2)	2033 (84.3)	915 (86.9)	16,239 (85.2)
Female	2312 (14.8)	378 (15.7)	138 (13.1)	2828 (14.8)
Race		$p \leq 0.001$	$p \leq 0.001$	
White	8569 (54.9)	249 (10.3)	137 (13.0)	10577 (55.5)
Black	1081 (6.9)	21 (0.9)	22 (2.1)	1467 (7.7)
Asian	132 (0.8)	408 (16.9)	150 (14.2)	175 (0.9)
Other	1936 (12.4)	293 (12.2)	176 (16.7)	2494 (13.1)
Not reported	3885 (24.9)	249 (10.3)	137 (13.0)	4354 (22.8)
Ethnicity		$p \leq 0.001$	$p = 0.63$	
Not Hispanic	12,644 (81.0)	1869 (77.2)	847 (80.4)	15,360 (80.6)
Hispanic	2959 (19.0)	542 (22.5)	206 (19.6)	3707 (19.4)
Marital status at first visit		$p = 0.77$	$p \leq 0.001$	
Single	1503 (9.6)	242 (10.0)	152 (14.4)	1897 (9.9)
Married	11,244 (72.1)	1722 (71.4)	727 (69.0)	13693 (71.8)
Other	2856 (18.3)	447 (18.5)	174 (16.5)	3477 (18.2)
Lifetime cigarette smoking status		$p = 0.1$	$p = 0.63$	
Never	9443 (60.5)	1419 (58.9)	653 (62.0)	11515 (60.4)
Former	5121 (32.8)	861 (35.7)	330 (31.3)	6312 (33.1)
Current	1005 (6.4)	128 (5.3)	69 (6.6)	1202 (6.3)
Not reported	NR[b]	NR[b]	NR[b]	38 (0.2)
Body Mass Index at first visit		$p \leq 0.001$	$p \leq 0.001$	
< 25	1831 (11.7)	343 (14.2)	156 (14.8)	2330 (12.2)
≥ 25–<30	6107 (39.1)	990 (41.1)	437 (41.5)	7534 (39.5)
≥ 30	7185 (46.0)	1017 (42.2)	426 (40.5)	8628 (45.3)
Not measured	480 (3.1)	61 (2.5)	34 (3.2)	575 (3.0)
At WTC site on September 11, 2001		$p = 0.29$	$p = 0.14$	
Yes	6914 (44.3)	1096 (45.5)	442 (42.0)	8452 (44.3)
No	8689 (65.7)	1315 (64.5)	611 (58.0)	10615 (55.7)
Occupation on September 11, 2001		$p \leq 0.001$	$p = 0.02$	
Protective services/military	8346 (53.5)	1285 (53.3)	537 (51.0)	1822 (52.6)
Construction	2716 (17.4)	418 (17.3)	195 (18.5)	613 (17.7)
Electrical, telecom, & other installation & repair	947 (6.1)	155 (6.4)	80 (7.6)	235 (6.8)
Transportation & material moving	888 (5.7)	109 (4.5)	47 (4.5)	156 (4.5)

(Continues)

TABLE 1 | (Continued)

	Self-reported GERD 07/01/2002–12/31/2022			
	No resolution ($n = 15603$) n (%)	**Intermittent GERD ($n = 2411$) n (%)**	**Resolved GERD ($n = 1053$) n (%)**	**Total ($n = 19067$) n (%)**
Other jobs	2114 (13.5)	382 (15.8)	165 (15.7)	547 (15.8)
Unemployed/retired	242 (1.6)	36 (1.5)	8 (0.8)	44 (1.4)
Not reported	350 (2.2)	26 (1.1)	21 (2.0)	47 (1.5)
GERD certified		$p = 0.54$	$p \leq 0.001$	
Yes	9653 (61.9)	1476 (61.2)	263 (25.0)	11392 (59.7)
No	5950 (38.1)	935 (38.8)	790 (75.0)	7675 (40.3)
Barrett's disease		$p \leq 0.001$	$p \leq 0.001$	
Yes	989 (6.3)	109 (4.5)	NR[b]	1105 (5.8)
No	14,814 (93.7)	2302 (95.5)	1046 (99.3)	17,962 (94.2)
Esophageal cancer certification		$p = 0.55$	$p = 0.25$	
Yes	20 (0.1)	NR[b]	NR[b]	22 (0.1)
No	15,583 (99.9)	2409 (99.9)	1053 (100)	19,045 (99.9)
Diagnosis				
≥Visit 2 Endoscopy		$p \leq 0.001$	$p \leq 0.001$	
Yes	7752 (49.7)	572 (23.7)	218 (20.7)	9237 (48.4)
No	7851 (50.3)	1839 (76.3)	835 (79.3)	9830 (51.6)
≥Visit 2 Laryngoscopy		$p \leq 0.001$	$p \leq 0.001$	
Yes	382 (2.4)	33 (1.4)	NR[b]	444 (2.3)
No	15,221 (97.6)	2378 (98.6)	1047 (99.4)	18,623 (97.7)
≥Visit 2 Endoscopy or Laryngoscopy		$p \leq 0.001$	$p \leq 0.001$	
Yes	7857 (50.4)	591 (24.5)	225 (21.4)	9368 (49.1)
No	7746 (49.5)	1820 (75.5)	828 (78.6)	9699 (50.9)
Nighttime pH monitoring		$p = 0.41$	$p = 0.07$	
Yes	143 (0.9)	18 (0.7)	NR[b]	176 (0.9)
No	15,460 (99.1)	2393 (99.3)	1049 (99.6)	18,891 (99.1)
Behavior modification before resolution				
Bed head-elevation		$p \leq 0.001$	$p \leq 0.001$	
Yes	5649 (36.2)	258 (10.7)	79 (7.5)	6578 (34.5)
No	9954 (63.8)	2153 (89.3)	974 (92.5)	12489 (65.5)
Dietary modification		$p \leq 0.001$	$p \leq 0.001$	
Yes	7527 (48.2)	463 (19.2)	161 (15.3)	8995 (47.2)
No	8076 (51.8)	1948 (80.8)	892 (84.7)	10,072 (52.5)
Medication before resolution				
Proton pump inhibitors		$p \leq 0.001$	$p \leq 0.001$	
Yes	11,247 (72.1)	993 (41.2)	273 (25.9)	13,025 (68.3)
No	4356 (27.9)	1418 (58.8)	780 (74.1)	6042 (31.7)
Histamine 2 receptor antagonists		$p \leq 0.001$	$p \leq 0.001$	
Yes	3707 (23.8)	241 (10.0)	85 (8.1)	4351 (22.8))
No	11,896 (76.2)	2170 (90.0)	968 (91.9)	14,716 (77.2)
Program-approved antacids		$p \leq 0.001$	$p \leq 0.001$	
Yes	4277 (27.4)	410 (17.0)	166 (15.8)	5357 (28.1)

(Continues)

TABLE 1 | (Continued)

	Self-reported GERD 07/01/2002–12/31/2022			
	No resolution ($n = 15603$) n (%)	**Intermittent GERD ($n = 2411$) n (%)**	**Resolved GERD ($n = 1053$) n (%)**	**Total ($n = 19067$) n (%)**
No	11,326 (72.6)	2001 (83.0)	887 (84.2)	13,710 (71.9)
Other Antacids		$p \leq 0.001$	$p \leq 0.001$	
Yes	936 (6.0)	35 (1.5)	17 (1.6)	1113 (5.8)
No	14,667 (94.0)	2376 (98.5)	1036 (98.4)	17,954 (94.2)

Abbreviations: GERD = Gastroesophageal reflux disease, WTC = World Trade Center.
[a]Two-tailed Pearson chi-square p values versus no resolution.
[b]NR = Not reported, $n \leq 10$.

The most common GERD medical procedure was diagnostic endoscopy and the most common therapies were PPI medications and dietary modifications, in keeping with clinical guidelines [9, 10, 26, 27]. Consistent with existing evidence that PPIs are the most efficacious therapy to prompt early resolution [18], PPIs were the only therapy with less use after the earliest reported GERD resolution, whether intermittent or without relapse.

Although current literature finds the types of dietary modifications recommended and their effectiveness to be variable, this study found dietary modification was the only single therapy with positive effect when used without Program–approved medications [14–16]. That so many members reported making dietary (e.g., lifestyle) modifications to control GERD is encouraging. However, as our study did not collect further dietary information, we cannot identify which modifications were effective. As dietary modification used in conjunction with PPIs was the therapy with greatest effect, Program clinicians may wish to increase their initial joint recommendation for this approach. Alternatively, providers may also promote dietary modifications in conjunction with Program-approved antacids, which were also jointly effective, though slightly less so than PPIs. Although the GERD prevalence among Program members is already high, GERD-free Program members may also benefit from advice to report GERD symptoms as early as possible as doing so may increase the use and effectiveness of short-course PPIs or antacids together with dietary modifications.

People with BMIs under 25 experience less GERD in the general population and GRC members with lower BMIs experienced more GERD resolution [31]. Program clinicians may also wish to consider increased recommendation of weight loss. Over 40% of the GRC are considered obese, similar to that observed in the adult population of the United States [32].

The study's reliance on data collected by WTC Health Program does not weaken the validity of self-reported GERD, GERD resolution or GERD certification because GERD is often diagnosed solely based on self-reported symptoms [11]. Distinct diagnostic procedures may be needed to identify GERD's different presentations or to identify alternate diagnoses [9, 13]. Simply undergoing procedures like endoscopy or nighttime pH monitoring does not necessarily reflect the condition's diagnosis, or severity [13]. Most of the study sample attended Program health monitoring visits since the Program initiated certifying its members for WTC-related conditions. Based on Program-established criteria, 59% of the sample was certified by the Program as having WTC-related GERD [25].

Our analysis of GERD services and resolution benefitted from a large, longitudinal cohort, limited to members with a year or more of longitudinal GERD data, for whom the earliest date of reported GERD was known. Excluding cases with GERD duration less than 1 year may have left out many mild cases that resolve early in response to short-term therapy or lifestyle modifications, likely minimizing the observed rate of resolution. We analyzed four logistic regression models to assess the services associations with and treatments influence on GERD resolution, finding great similarity of results across the models. Larger samples produce more statistically significant (poorer fit) HL results as observed with the intermittent but not resolved GERD results [28]. Therefore, confidence may be greater for the resolved than the intermittent-resolution results. However, the nearly identical outcome results between the main analyses and the smaller sensitivity analyses of GERD-certified members suggests an acceptable albeit imperfect model fit for the intermittent resolution results.

The health monitoring question "Do you still have GERD" may have under- or over-represented GERD resolution. It is possible that some Program members with GERD symptoms under-reported GERD persistence. Some who continued to take medications that mask their symptoms may have reported they no longer have GERD. However, the fact that members reporting resolved GERD used less bed head-elevation, dietary modifications and Program-approved medications, after reporting they no longer had GERD, while members reporting intermittent GERD increased their use of these modifications and medications (except for PPI), supports the validity of responses concerning still having GERD. Some members reporting resolved GERD also reported continuation of GERD medications, particularly Program-approved antacids. The average GERD follow-up time was generally ample (>10 years) and similar in the groups reporting no resolution and resolved GERD, although members reporting intermittent GERD had 3 years longer follow-up. This could indicate that some of those reporting resolved GERD may join the group with intermittent GERD over time. However, the association of follow-up, adjusted in analysis, for members with intermittent and resolved GERD was almost identical, although GERD duration in people with resolved GERD was less than half (5.6 years) that of those with intermittent GERD, indicating that longer follow-up or recall bias would minimally affect their resolution permanence.

TABLE 2 | Adjusted odds ratios for GERD resolution compared to no resolution by sample characteristics and treatment for GERD.

	Intermittent GERD ($n = 18014$)		Resolved GERD ($n = 16656$)	
	AOR (95% CI)	***p***	**AOR (95% CI)**	***p***
Age at diagnosis				
< 30	Referent		Referent	
30–39	1.16 (0.91, 1.48)	0.23	0.96 (0.66, 1.38)	0.81
40–49	1.44 (1.13, 1.83)	0.003	1.08 (0.75, 1.55)	0.69
50–59	1.59 (1.24, 2.06)	≤ 0.001	1.29 (0.88, 1.89)	0.19
≥ 60	1.97 (1.47, 2.64)	≤ 0.001	1.46 (0.95, 2.23)	0.08
Gender (female vs. male)	0.87 (0.76, 1.00)	0.04	0.68 (0.55, 0.85)	≤ 0.001
Race				
White	Referent		Referent	
Black	1.31 (1.12, 1.54)	≤ 0.001	1.38 (1.10, 1.72)	0.005
Asian	0.78 (0.48, 1.26)	0.31	1.99 (1.18, 3.33)	0.009
Other	0.83 (0.68, 1.02)	0.08	1.12 (0.83, 1.51)	0.46
Not reported	0.46 (0.40, 0.53)	≤ 0.001	0.60 (0.49, 0.72)	≤ 0.001
Hispanic ethnicity	1.56 (1.30, 1.87)	≤ 0.001	1.22 (0.94, 1.58)	0.14
Marital status at first visit				
Single	Referent		Referent	
Married/partnered	1.02 (0.87, 1.19)	0.84	0.73 (0.59, 0.90)	0.003
Other	0.97 (0.81, 1.16)	0.75	0.70 (0.54, 0.89)	0.004
Lifetime smoking status				
Never	Referent		Referent	
Former	1.09 (0.99, 1.20)	0.08	0.93 (0.80, 1.08)	0.35
Current	0.84 (0.69, 1.03)	0.09	0.83 (0.62, 1.09)	0.18
Not reported	0.62 (0.19, 2.08)	0.44	0.20 (0.03, 1.55)	0.12
Body mass index at first visit				
< 5	Referent		Referent	
25—< 30	0.85 (0.74, 0.98)	0.02	0.93 (0.75, 1.15)	0.49
≥ 30	0.77 (0.67, 0.89)	≤ 0.001	0.77 (0.62, 0.96)	0.02
Not measured	0.76 (0.56, 1.03)	0.08	0.93 (0.61, 1.41)	0.73
Occupation on September 10, 2001				
Protective services/military	Referent		Referent	
Construction	0.85 (0.75, 0.98)	0.02	0.99 (0.81, 1.21)	0.93
Electrical, telecom, other installation & repair	0.91 (0.75, 1.10)	0.33	1.01 (0.77, 1.32)	0.96
Transportation & material moving	0.76 (0.61, 0.95)	0.01	0.64 (0.46, 0.89)	0.008
Other jobs	1.00 (0.88, 1.15)	0.95	1.04 (0.84, 1.27)	0.73
Unemployed/retired	0.80 (0.55, 1.16)	0.24	0.52 (0.25, 1.10)	0.09
Not reported	0.46 (0.30, 0.69)	≤ 0.001	0.64 (0.39, 1.03)	0.07
WTC exposure arrival on September 11, 2001 vs. later	1.01 (0.92, 1.11)	0.79	0.92 (0.80, 1.06)	0.24
GERD certified	0.79 (0.71, 0.87)	≤ 0.001	0.29 (0.25, 0.34)	≤ 0.001
GERD follow-up (years)	1.13 (1.12, 1.15)	≤ 0.001	1.08 (1.07, 1.10)	≤ 0.001
≥ Visit 2 endoscopy or laryngoscopy	0.98 (0.89, 1.08)	0.68	0.65 (0.56, 0.77)	≤ 0.001
Bed head-elevation before resolution	0.70 (0.62, 0.79)	≤0.001	0.54 (0.42, 0.70)	≤ 0.001

(Continues)

TABLE 2 | (Continued)

	Intermittent GERD ($n = 18014$)		Resolved GERD ($n = 16656$)	
	AOR (95% CI)	***p***	**AOR (95% CI)**	***p***
Dietary modification before resolution	1.32 (1.17, 1.48)	≤ 0.001	0.89 (0.72, 1.08)	0.24
Proton pump inhibitors before resolution	0.44 (0.40, 0.49)	≤ 0.001	0.18 (0.15, 0.21)	≤ 0.001
Histamine-2 receptor antagonist before resolution	0.74 (0.67, 0.83)	≤ 0.001	0.38 (0.31, 0.47)	≤ 0.001
PBM antacid before resolution	1.04 (0.95, 1.15)	0.38	0.63 (0.54, 0.74)	≤ 0.001
Barrett's disease	0.76 (0.61, 0.94)	0.01	0.28 (0.13, 0.61)	≤ 0.001
Esophageal cancer certified	0.95 (0.21, 4.19)	0.94	NR[a]	NR[a]

Note: Analyses adjusted for age, race, Hispanic ethnicity, occupation, marital status on September 11, 2001, lifetime cigarette smoking status, body mass index, WTC exposure on or after September 11, 2001, Program GERD certification, GERD follow-up duration, pre-resolution endoscopy or laryngoscopy, bed head-elevation, dietary modification, and use of PPI, H2, or Program-approved antacids, Barrett's disease in GERD-certified members and Program certification for esophageal cancer.
Abbreviations: AOR = adjusted odds ratio, CI = confidence interval, GERD = Gastroesophageal reflux disease, NR = not reported, PBM = pharmacy benefits manager-listed antacid, WTC = World Trade Center.
[a] $n < 10$.

5 | Conclusion

The GRC's use of GERD services was consistent with clinical guidelines. Program members experiencing resolution may have had less severe GERD. Although only a modest proportion achieved resolution, earlier diagnosis and intervention might increase the likelihood of earlier therapeutic resolution.

Author Contributions

Christopher R. Dasaro: conceptualization, formal analysis, investigation, methodology, software, supervision, validation, visualization, roles/writing, writing – review and editing. **Ahmad Sabra:** conceptualization, formal analysis, investigation, methodology, software, validation, visualization, roles/writing, writing – review and editing. **Benjamin J. Luft:** funding acquisition, project administration, visualization, roles/writing, writing – review and editing. **Denise J. Harrison:** funding acquisition, project administration, visualization, roles/writing, writing – review and editing. **Iris G. Udasin:** funding acquisition, project administration, visualization, roles/writing, writing – review and editing. **Michael A. Crane:** funding acquisition, project administration, visualization, roles/writing, writing – review and editing. **Jacqueline M. Moline:** funding acquisition, project administration, visualization, roles/writing, writing – review and editing. **Winston Kwa:** methodology, writing – review and editing. **Henry S. Sacks:** methodology, writing – review and editing. **Andrew C. Todd:** funding acquisition, project administration, visualization, roles/writing, writing – review and editing. **Nancy L. Sloan:** conceptualization, formal analysis, investigation, methodology, project administration, software, supervision, validation, visualization, roles/writing, writing – review and editing. **Susan L. Teitelbaum:** conceptualization, funding acquisition, investigation, methodology, project administration, supervision, validation, visualization, roles/writing, writing – review and editing.

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Disclosure

The contents of this report are the sole responsibility of the authors and do not necessarily represent the official views of, nor an endorsement, by the National Institute for Occupational Safety and Health (NIOSH), the Centers for Disease Control and Prevention of the US Department of Health and Human Services (CDC/HHS), or the US Government.

Ethics Statement

This study follows the principles outlined in the Declaration of Helsinki 1975 as revised in 2013 and national and institutional committees' ethical standards on human experimentation. The World Trade Center (WTC) Health Program research has been approved by the institutional review boards of the WTC Health Program General Responder Data Center conducting the data analysis at the Icahn School of Medicine at Mount Sinai and the Clinical Centers of Excellence: Rutgers University Environmental and Occupational Health Sciences Institute; NYU School of Medicine; Icahn School of Medicine at Mount Sinai; Donald and Barbara Zucker School of Medicine at Hofstra/Northwell; Stony Brook University Department of Medicine). Written informed consent was obtained for all members included in the study.

Conflicts of Interest

The authors declare no conflicts of interest.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.