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Blood Carbon Monoxide Levels in Persons 3-74 Years of Age: United States, 1976-80[a]

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Air pollution is an often-cited environmental hazard in many cities of the United States. One major component of air pollution is carbon monoxide, an odorless colorless gas that is a product of incomplete combustion. It is one of the pollutants subject to control by the Environmental Protection Agency (EPA) under the Clean Air Act. National Ambient Air Quality Standards established by EPA allow a carbon monoxide concentration of 9 parts per million. At this concentration, 8 hours of exposure would generally result in blood carbon monoxide levels in humans greater than 1.5 percent.

Industrial plants, electric generating plants, and automobile exhausts are sources of carbon monoxide in outdoor air. In homes, gas stoves or furnaces produce this gas. Tobacco smokers are regularly exposed to higher levels of carbon monoxide than almost all nonsmokers.

The health effects of exposure to carbon monoxide are not fully known. However, research findings in selected population groups indicate that carbon monoxide acts as an added stress factor to precipitate cardiac symptomatology or episodes in persons with hearts already compromised by coronary disease.[1,2] Additionally, excessive levels of carbon monoxide in the blood have been found by some investigators to impair certain perceptual and motor functions.[1] However, further assessment of the possible deleterious health effects of exposure to carbon monoxide has been handicapped by the lack of data for the United States population on the body burden resulting from exposure. This report presents the initial findings from such data—the first estimates of blood carbon monoxide levels ever obtained on a representative sample of the U.S. population. These findings should also be pertinent in consideration of national legislation such as revision of the Clean Air Act and local ordinances to curb air pollution.

Carbon monoxide is unique among air pollutants in that the degree of body burden from exposure to this gas can be directly determined by measuring the percent of carboxyhemoglobin (the compound formed from hemoglobin on exposure to carbon monoxide) in the blood. Blood carboxyhemoglobin (COHb) levels were measured on a cross-sectional national probability sample of persons representative of the U.S. civilian noninstitutionalized population 3-74 years of age in the second National Health and Nutrition Examination Survey (NHANES II) conducted from February 1976 to February 1980. NHANES II is the fifth in a series of National Health Examination Surveys conducted since 1960 by the National Center for Health Statistics. These programs, described in previous publications,[3-8] are designed to collect a broad range of morbidity data on chronic illness and related health information. The primary emphasis has been placed on obtaining those kinds of data that can be optimally collected through standardized, direct physical examination, tests, and measurements. Dietary intake and food consumption information also are collected to be used in the analysis of the interrelationships between nutrition and health status measures.

Examinations were conducted in specially equipped Mobile Examination Centers (MEC's), which visited 64 locations selected from 1,924 primary sampling units (PSU's) into which the entire United States is divided. Each PSU is a standard metropolitan statistical area (SMSA), a county, or a group of two or three contiguous counties. The entire sample consisted of 27,801 persons ages 6 months-74 years. Of these, 20,322 persons were examined—a

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sample response rate of 73.1 percent. The findings below are based on data from a probability half-sample of 11,368 persons ages 3-74 years selected to receive the test for levels of carbon monoxide. Of these 11,368 persons, 9,365 came in for examination, and acceptable COHb blood samples were obtained for 8,411, giving an item nonresponse rate of 10.2 percent for this test.

This report presents national estimates of the distribution of carbon monoxide levels in the blood of persons ages 3-74 years in the United States by age, smoking status, race, urbanization status of residence, annual family income, and season of the year. These findings will be described and analyzed further in a report in the *Vital and Health Statistics* series (in preparation).

In this report the relative contributions of the four principal sources of carbon monoxide (smoking, ambient or outdoor exposures, occupational exposures, and indoor exposures) to COHb levels are examined. Of these, smoking is the most significant and widespread, although in special circumstances each of the other contributors assumes some importance.

Sources of data

Sample collection and COHb determination

At the Mobile Examination Center, venipuncture blood samples were drawn by the nurse. For the carboxyhemoglobin assessments, which were performed on a subset of examinees ages 3-74 years, at least 1 ml of whole blood was placed into a 2-ml Vacutainer and refrigerated until a weekly shipment was made to the laboratory at the University of Pittsburgh. The specimens were kept cool, but not frozen, in transit.

Carboxyhemoglobin and methemoglobin (metHb) level measurements were made by the spectrophotometric method of Small et al.[9] This method utilizes the difference in light absorption spectra among oxyhemoglobin, carboxyhemoglobin, and methemoglobin to identify and quantify the proportions of these compounds in the blood. From blood diluted about 1 to 70 in dilute ammonia, absorbance measurements are made in the Soret region (390-435 nm) at four wavelengths with a 1-mm light path; the equipment employed was a Gilford Model 240 spectrophotometer, with corrections applied to compensate for nonlinearity of the phototube. A series of simultaneous equations is used to determine the percents of carboxyhemoglobin and methemoglobin and, by difference, the percent of oxyhemoglobin. Measurements have been shown to be accurate and reliable at all levels of carbon monoxide saturation, including saturation from 0 to 5 percent COHb (see Technical notes), the range found to be least reliable when monitored with other rapid techniques.

Simultaneous measurement of methemoglobin level facilitates a determination of the condition of the blood sample, because an excessively high methemoglobin level indicates that the sample is partially decomposed. In this report, acceptable samples were defined as having methemoglobin levels of 5 percent or less.

Questionnaire and demographic data

Age was defined as age at last birthday at the time of the household interview. Race was determined by interviewer observation during the interview. The interviewer categorized respondents as "white," "black," or "other." Data on other races are not presented separately in this report but are included in the "all races" category. Income was defined as reported total family income during the 12 months preceding the interview.

Based on a preliminary analysis, two season categories were defined. The first category includes data for all persons in the sample examined during May through September; the second category includes data for all persons in the sample examined during November through March. October and April were transition months, and inclusion of data for persons in the sample examined during these months with those in the season categories they preceded had an insignificant effect on the overall means. Consequently, these data were excluded from the seasonal analysis.

Smoking status was derived from questionnaire data collected on all respondents ages 12-74 years. Never-smokers were defined as persons who had smoked fewer than 100 cigarettes in their lifetimes and were not current smokers. Ex-smokers were persons who had smoked more than 100 cigarettes but were not current smokers; ex-cigar and ex-pipe smokers were not identified separately but were included in the never-, ex-, or current smoker category, depending on their cigarette smoking status. Current smokers were persons reporting that they were current cigarette, cigar, or pipe smokers.

Results

In all the following analyses, the primary statistics of interest are the mean COHb levels for the population subgroup or the proportion of the subgroup with blood COHb levels greater than 1.5 or 2.0 percent. The sample sizes for most of the defined subgroups were large enough to provide national estimates that are not subject to excessive sampling variability. Unless otherwise noted, statistical significance was determined at the 5-percent level, as described in the Technical notes. The tables at the end of the text also present population frequency distributions for COHb (from which can be determined the proportion of the population with COHb levels greater than critical points other than the 1.5 or 2.0 percent used in this report) and selected percentiles.

Carboxyhemoglobin concentration by smoking status and age group

Table 1 and figure 1 show the mean percent of carboxyhemoglobin concentration in blood among the U.S. population ages 3-74 years by smoking status and age. Children in the age group 3-11 years were assumed to have never smoked, although among the 1.2 percent of the population with COHb levels greater than 2 percent in this age group, a few smokers may have been present. For healthy nonsmokers, 2 percent is well above the sum of COHb arising from endogenous metabolism and from minimal exposures to ambient CO. For this reason, values greater than 2 percent were considered to be the result of unusual exposures. About 1 percent of the children under 5 years of age had COHb levels greater than 2 percent, and it is likely that most of these cases represent exposures to sources other than smoking.

Among never-smokers age 12 years and over, 3.6 percent had COHb levels greater than 2 percent (figure 2). The difference between age groups of never-smokers may be due to occupational exposures of the older group to environments with high ambient CO levels (such as those experienced by garage mechanics or taxi drivers).

The ex-smoking population show 5.5 percent with COHb levels greater than 2 percent, compared with 3.6 percent for never-smokers age 12 years and over. The higher proportion with COHb levels over 2 percent accounts for the higher mean and standard deviation for ex-smokers than for never-smokers, because the two medians are nearly identical (0.77 percent COHb versus 0.74 percent COHb, respectively). The excess may be accounted for in part or wholly the inclusion in the ex-smoking group of smokers

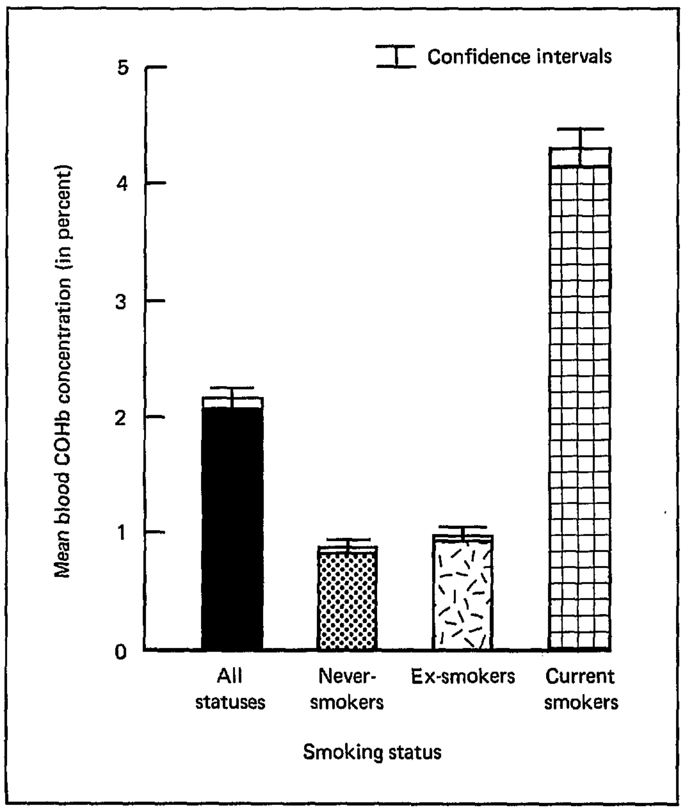

Figure 1. Mean blood COHb concentration for persons 12-74 years of age, by smoking status: United States, 1976-80

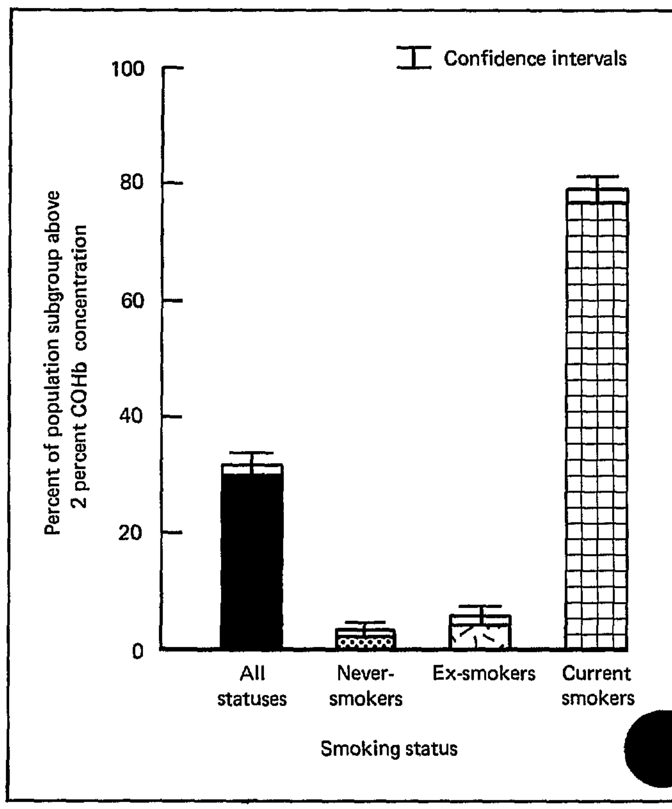

Figure 2. Percent of sample above 2 percent COHb concentration for persons 12-74 years of age, by smoking status: United States, 1976-80

who incorrectly reported a history of having stopped smoking. Incorrect reporting appears to be a particular problem among older teenagers.

The expected effect of smoking on COHb levels was shown clearly (figure 3), but it is of interest that 9.1 percent of the current smokers had COHb levels of 1 percent or less—within the usual range for never-smokers. While the prohibition against smoking in the examination unit may have resulted in lower COHb levels for some smokers, especially for those examined in the morning, this group with low values clearly cannot be inhaling much of their own cigarette smoke. Analysis by smoking level, which is not shown in this report, indicated that light smokers (1-5 cigarettes per day) contributed many of these low values.

The smoking population showed a mean COHb level of more than 4 percent; for never-smokers, the mean was less than 1 percent. The standard error for the smoking group was more than three times as large as that for the never-smoking group. The large variability of COHb levels for the smoking group, along with the relative insensitivity of this group to an incremental change in the environmental burden of CO when compared with the never-smoking group, made it necessary to limit subsequent analyses of demographic and environmental factors to the never-smoking subjects. For the one-third of the age 12 or over population that smokes, the subtle effects of environmental sources of CO are overwhelmed by the massive impact of smoking.

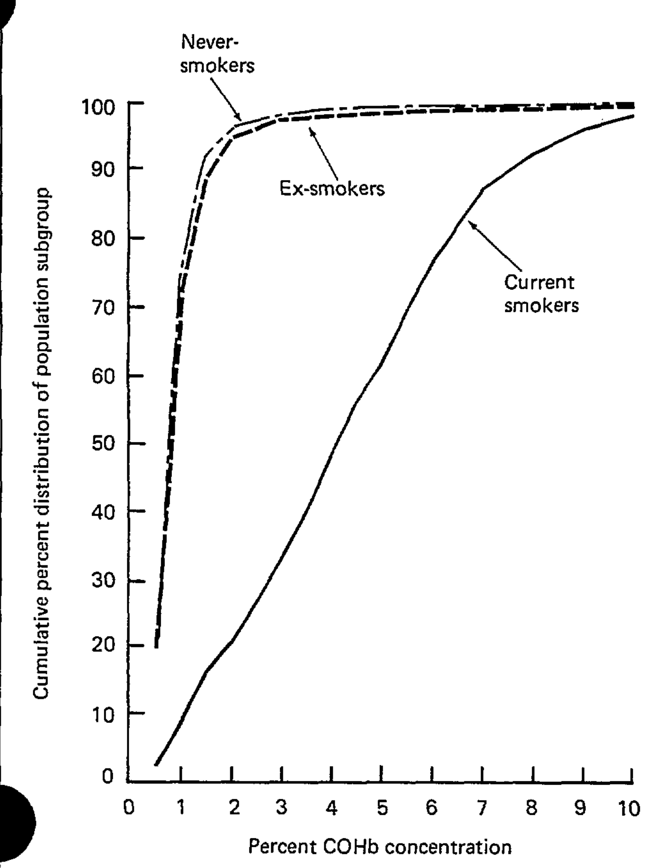

Figure 3. Cumulative distribution of percent COHb concentration for persons 12-74 years of age, by smoking status: United States, 1976-80

COHb concentrations for never-smokers by race and urbanization

The COHb levels for persons in the never-smoked category are shown in table 2 and figure 4 by urbanization, age, and race. The four urbanization classes used, based primarily on the population of the standard metropolitan statistical area (SMSA) in which the individuals resided, were: (1) population over 1,000,000, central city; (2) population over 1,000,000, not in the central city; (3) population under 1,000,000; and (4) rural. In some subsets, the numbers of subjects were small (especially among black persons), but the numbers are generally sufficient to permit reliable comparisons.

Several conclusions are apparent from table 2. First, among children ages 3-11 years, the mean COHb level is statistically significantly higher for those in large cities than for those in smaller cities and rural areas (mean difference of 0.27, $P < 0.01$). Central city children especially show higher values, with a mean difference of 0.19 percent COHb between those in the central city and those not in the central city; a further mean difference of less than 0.10 percent COHb was found between children living in the large cities but outside the central city and those in the smaller SMSA's or rural areas. These differences, however, are not physiologically significant and are in the reported range of variation of endogenous COHb production.[10] The proportion of the population with COHb levels greater than 2 percent does not vary systematically with degree of urbanization. These observations are very similar to those reported by Kahn et al. in their study of St. Louis, Mo., adults.[11] There is little indication that white and black children differ in mean COHb to any significant extent, although black children are observed to have slightly higher values in general.

Second, the urban-rural gradient is somewhat greater for adult never-smokers than for children, although it is still small (a mean difference of about 0.4 percent COHb). Confounding by occupational exposures to CO among adults may contribute to the larger urban-rural gradient.

Black adults were observed to have consistently higher COHb levels than white adults. This probably also is explained by greater likelihood of occupational exposure among black adults. Among white adults in the central city of SMSA's with over 1,000,000 population, 5.7 percent had COHb levels greater than 2 percent; the corresponding figure for black adults was 8.6 percent.

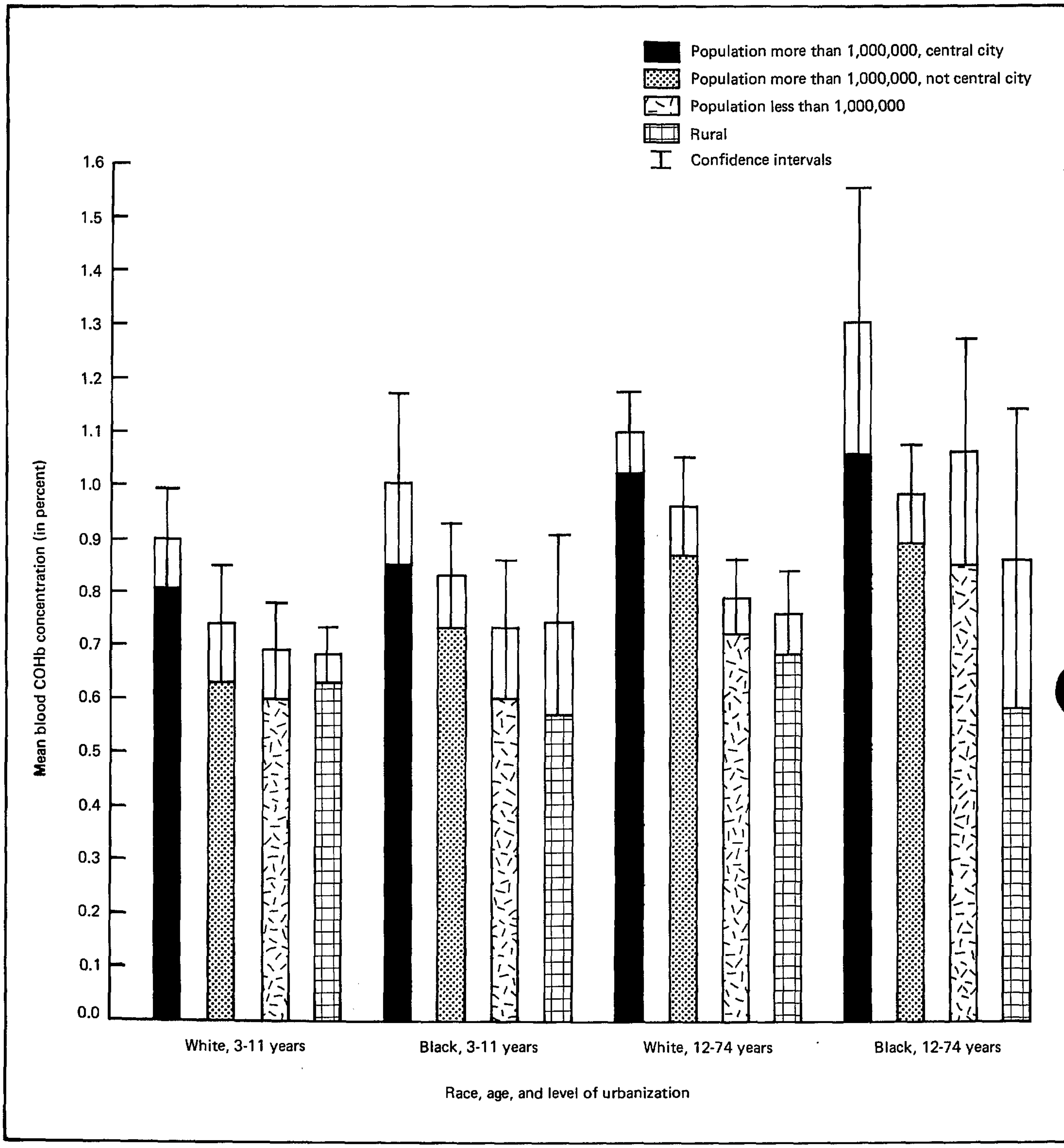

Figure 4. Mean blood COHb concentration for never-smokers 3-74 years of age by race, age, and level of urbanization: United States, 1976-80

The conclusions drawn above mask, to a large extent, the variability observed among locations. Although the design for NHANES II does not provide samples representative of the individual selected SMSA's, an examination of the proportion of the population with COHb levels greater than 1.5 percent[b] by sample PSU reveals striking differences, even within a single urbanization class. For instance, in the selected locations in SMSA's over 1 million population, this measure varies from a minimum of 2.4 percent to a maximum of 47.3 percent. This location-by-location variability will be examined in more detail in a subsequent report.

In summary, analysis of carboxyhemoglobin by degree of urbanization shows an urban-rural gradient for children and adults. The results for adults also may be affected by occupational exposures, apparently to a greater extent among black persons.

COHb concentrations for never-smokers by season and urbanization

Table 3 and figures 5 and 6 show the results for adult never-smokers and children by the season during which the blood was drawn. The urban-rural comparisons mentioned above are retained. As described in the Technical notes, itineraries of MEC's were designed to sample examinees in the more northern parts of the United States in the summer and in the more southern parts of the United States in the winter, thus mitigating the effects of the severest winter weather on COHb levels. Thus this sample does not provide precisely representative U.S. seasonal estimates.

Table 3 shows there is a significant effect of season on COHb concentration; values found during the summer months were about 0.3 percent COHb lower than those found in the winter for children and adults. The mean values are reflections primarily of the proportion of persons studied who had a COHb concentration more than 2 percent, and the seasonal difference may be ascribed largely to the fraction of persons with these higher values. The increased proportion of high COHb values observed in the winter months probably arises from indoor sources of CO, which are more important in winter, when homes are closed. Outdoor sources, especially in the urbanized areas, also may contribute to high COHb levels because of higher CO emissions in winter.

Indoor sources can include gas stoves, furnaces and other appliances, as well as possible effects of passive smoking. Separate analyses of NHANES data not presented in this report indicate that subjects living in dwellings in which the primary heating system was unvented space heaters (n=208) had significantly higher mean COHb levels than subjects reporting electric heating (1.06 percent COHb versus 0.74 percent COHb). These results support the hypothesis that subjects using unvented or portable space heaters are more likely to have a significant indoor exposure to CO, a reasonable conclusion given present knowledge regarding the likelihood of CO release from these units into living space.

One indication of the possible contribution of indoor sources is the significantly higher proportion of never-smokers with COHb concentrations greater than 2 percent found in the winter months ($P<0.01$). For children aged 3-11 years, 2.9 percent had levels more than 2 percent COHb in November through March, compared with none in the summer; for adults, 5.4 percent had levels greater than 2 percent COHb in the winter, compared with 1.6 percent in the summer.

The urban-rural gradient persists and is similar for both seasons, at least for children, which confirms the likelihood that this gradient is derived primarily from exposure to ambient (outdoor) sources of CO. There may be a slight additional seasonal effect on adults in large urban central cities, but this effect does not appear to be large. The urban-rural difference could be due to greater occupational exposures in winter for persons in urban areas.

COHb concentrations for never-smokers by income and urbanization

Blood carboxyhemoglobin levels among the never-smoking group were analyzed by family income classification. Table 4 and figure 7 show the results of this evaluation by urbanization category. In general, the results showed that individuals in the lowest family income category (less than $10,000) had somewhat higher COHb levels than those in other income groups. However, the effect of family income was greatest and most clear for children ages 3-11 years. In terms of the percent of the population of children with COHb levels greater than 2 percent, there were 2.7 percent in the lowest income category, 0.9 percent in the middle income category, and none in the highest income category, when all urbanization categories were combined.

This income effect was observed in all four urbanization classes. In every category, the mean COHb level for children ages 3-11 years was highest for those in families whose income was less than $10,000, and the mean COHb level tended to decrease as income category increased. This trend was attributed primarily to indoor sources of CO because the other sources of CO either were eliminated (as in the case of smoking and occupational sources) or held constant (as in the case of outdoor sources) in this

[b]1.5 percent is used here as the upper limit for COHb in the absence of ambient sources of CO (see section titled "Discussion").

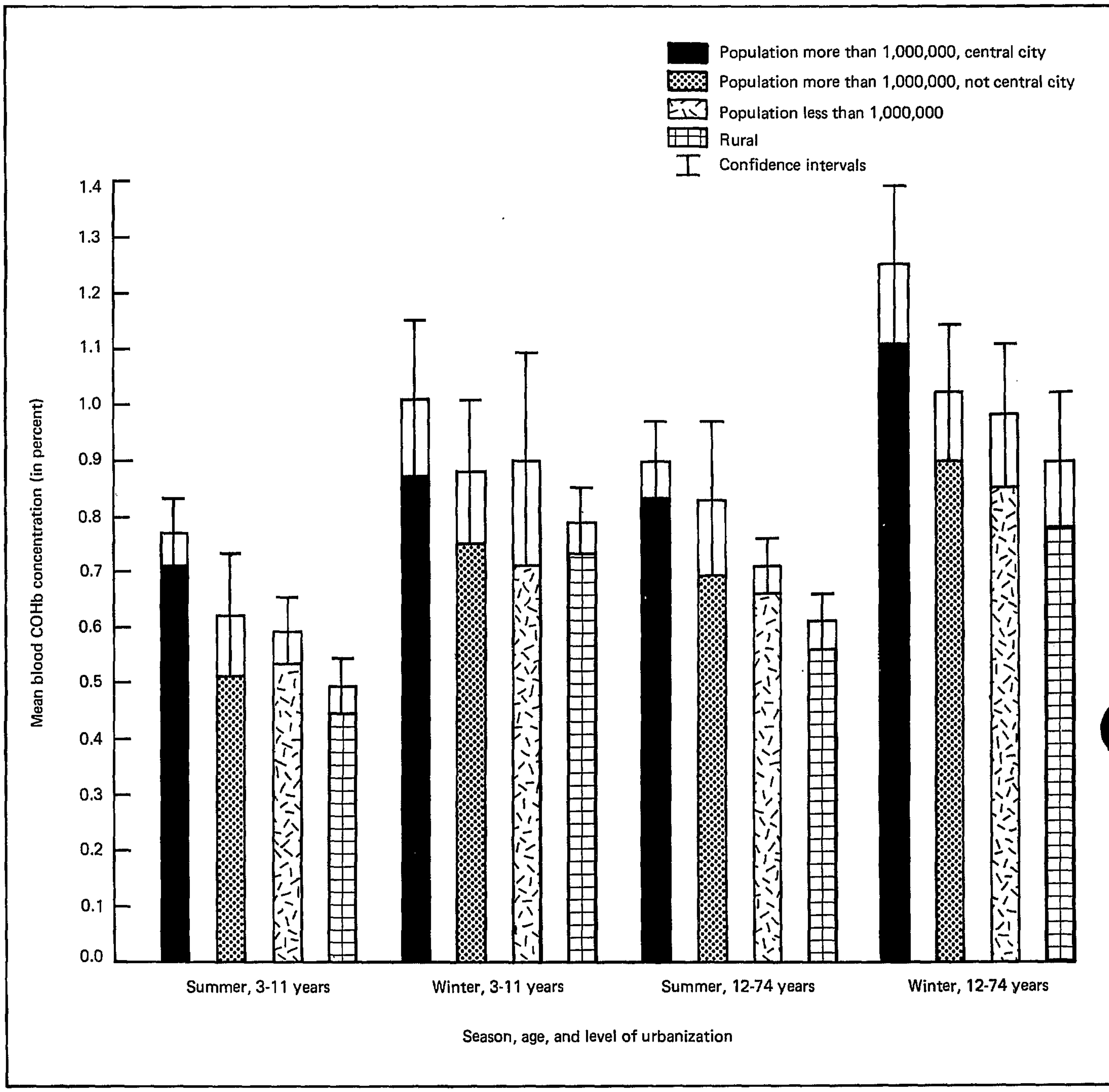

Figure 5. Mean blood CHOb concentration for never-smokers 3-74 years of age, by season of sample collection, age, and level of urbanization: United States, 1976-80

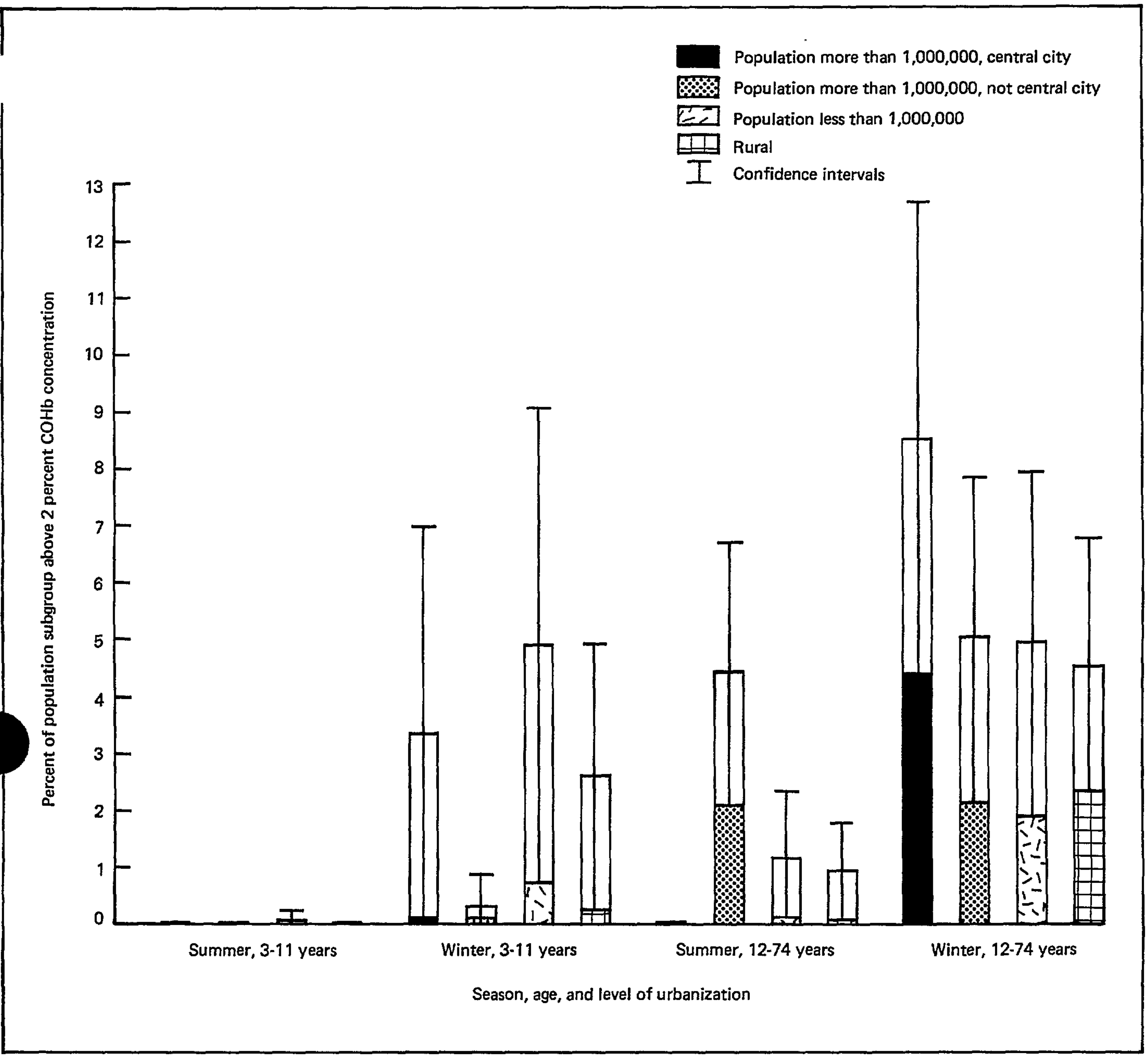

Figure 6. Percent of sample above 2 percent COHb for never-smokers 3-74 years of age, by season of sample collection, age, and level of urbanization: United States, 1976-80

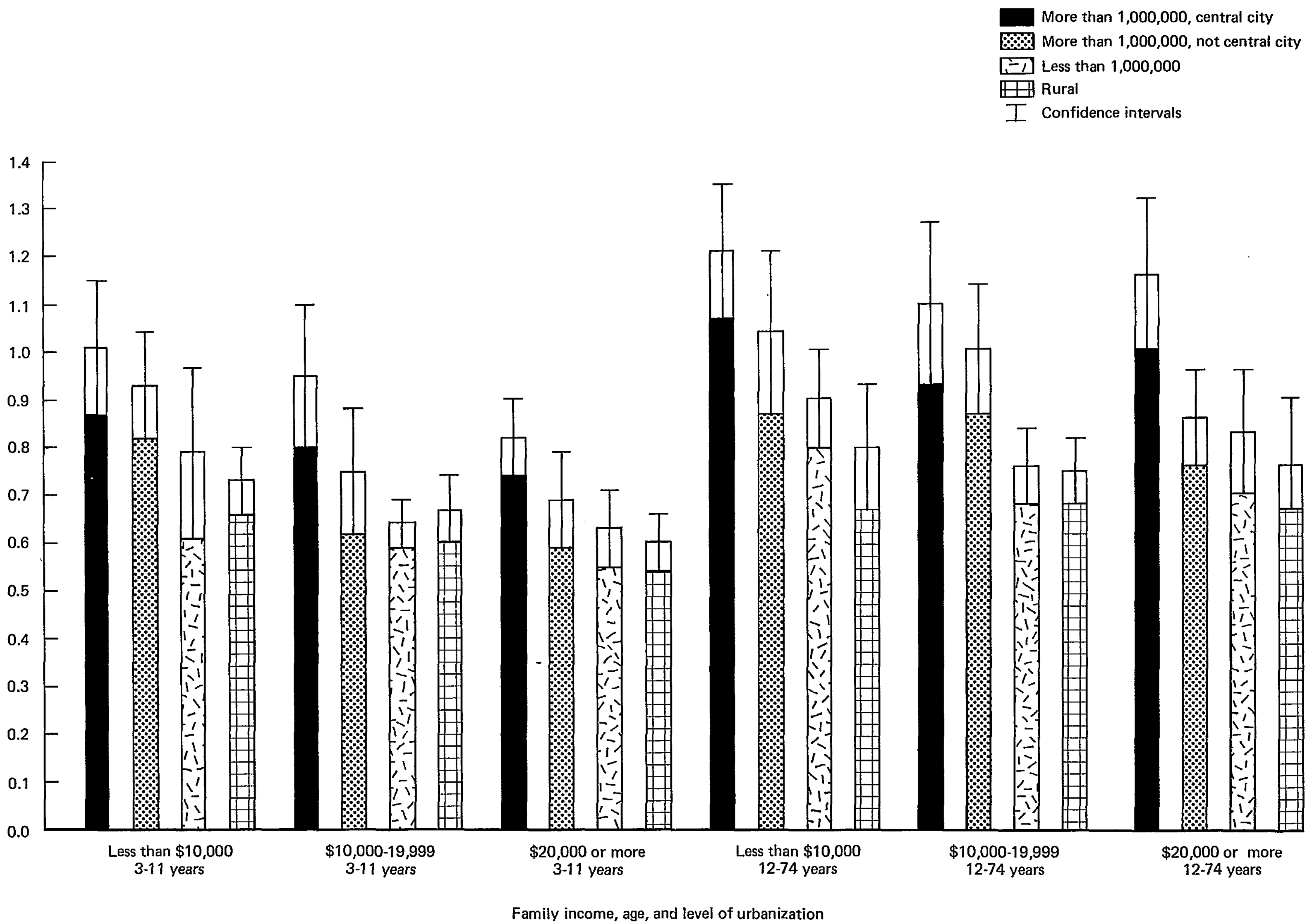

Figure 7. Mean blood COHb concentration for never-smokers 3-74 years of age, ily income, age, and level of urbanization: United States, 1976-80

analysis. The observed income effect suggests that economic status is a major factor in the likelihood of significant exposure to CO in the home environment.

For adults, the differences of COHb level by income category were not striking, despite the fact that in their case occupational exposures may have contributed to higher levels that were found. Although the mean COHb level for subjects in the lowest income group was highest in every urbanization category, none of the differences was statistically significant. These results are similar to those of Kahn et al.,[11] who also were not able to substantiate a relationship between family income and COHb level among adults.

Discussion

Clearly, smoking constitutes the greatest source of exposure to carbon monoxide; the mean COHb level for smokers was more than four times the level for never-smokers, and the smoking effect completely overwhelmed the much more subtle contributions of indoor and ambient sources. In addition, adults who reported a history as ex-smokers may include some current smokers, and some adult never-smokers may have COHb levels more than 2 percent as a result of occupational exposures to CO.

The only population subgroup not subject to the possible confounding effects of smoking or occupational exposures is children ages 3-11. Their results were used to assess the contribution of indoor or ambient CO. The results of children in this age group (mean COHb of 0.73 percent) indicate that, on the average, exposures to ambient CO have been well below the current ambient standard of nine parts per million, an air concentration at which 8 hours of exposure generally would result in a COHb level more than 1.5 percent.[1]

Although a mean difference of 0.27 percent COHb was found between central cities and rural areas, most urban areas showed little evidence of ambient exposures leading to blood COHb levels greater than 1.5 percent. Nevertheless, in some large metropolitan areas, substantial elevations of CO in blood were observed. Moreover, by chance, no sampling locations were in cities at high altitudes, where outdoor CO emissions are likely to be more important than at sea level.[12]

The analysis of the seasonal changes in COHb levels in children indicates that in winter, especially in central city urban areas, a significant fraction is exposed to CO, causing levels of COHb in excess of 2 percent. This CO exposure probably is explained by indoor sources, such as improperly adjusted or vented heating or cooking units. Some contribution from outdoor sources or passive smoking (inhalation of ambient tobacco smoke products) also may be present.

The evidence of possible elevated indoor exposures to CO may be significant. If the results for children are extrapolated to the entire U.S. population, the fact that 2 percent or more may be exposed during the winter to indoor sources of CO in excess of the outdoor ambient standard (nine parts per million) emerges as a potential public health problem.

These observations differ from those reported by Stewart et al.,[13] who measured COHb in blood samples obtained from blood donor centers in several communities in the United States. These investigators found that for all urban and rural communities, a significant fraction of samples obtained from nonsmokers showed levels of COHb greater than 1.5 percent. Although NHANES II found similar evidence of exposure to outdoor CO in a few urban location in general, the values observed in this study were nc indicative of physiologically important exposures from outdoor sources. The results presented in this report are consistent with measurements made on nonsmoking controls by other investigators in various regions of the country.[1,11,14,15]

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Table 1. Percent carboxyhemoglobin by age and smoking status—sample sizes, weighted population estimates, means, standard deviations, standard errors, selected percentiles, and cumulative frequency distributions: United States, 1976-80

Smoking status and age[1]	*n*[2]	*N*[3]	*Mean*	*Standard deviation*	*Standard error*	*Percentiles*			
						50th	*75th*	*90th*	*95th*
All smoking statuses			Percent COHb						
3-74 years	9,365	195,877	1.94	2.236	0.037	0.91	2.38	5.49	6.83
3-11 years	2,055	30,066	0.73	0.502	0.019	0.67	0.87	1.12	1.42
12-74 years	7,310	165,812	2.16	2.358	0.044	1.01	3.17	5.79	7.05
Never-smokers									
3-74 years	5,459	106,042	0.83	0.671	0.021	0.72	0.97	1.33	1.65
3-11 years	2,055	30,066	0.73	0.502	0.019	0.67	0.87	1.12	1.42
12-74 years	3,404	75,976	0.87	0.726	0.025	0.74	1.01	1.38	1.77
Ex-smokers									
12-74 years	1,366	28,655	0.97	0.999	0.031	0.77	1.04	1.58	2.08
Current smokers									
12-74 years	2,533	61,015	4.30	2.553	0.072	4.15	5.89	7.56	8.68

[1]Smoking histories are unavailable for children less than 12 years of age.
[2]n = unweighted sample size.
[3]N = population estimate in thousands.

Table 1. Percent carboxyhemoglobin by age and smoking status—sample sizes, weighted population estimates, means, standard deviations, standard errors, selected percentiles, and cumulative frequency distributions: United States, 1976-80—Con.

Percent COHb															
≤ 0.50	≤ 1.00	≤ 1.50	≤ 2.00	≤ 2.50	≤ 3.00	≤ 3.50	≤ 4.00	≤ 4.50	≤ 5.00	≤ 5.50	≤ 6.00	≤ 7.00	≤ 8.00	≤ 9.00	≤ 10.00
Cumulative percent distribution of population															
16.4	55.3	68.4	72.9	75.6	78.0	80.6	83.1	85.5	87.6	90.0	92.4	95.6	97.4	98.7	99.4
28.6	84.7	95.9	98.8	98.9	99.5	99.5	99.7	99.7	99.7	99.8	100.0	100.0	100.0	100.0	100.0
14.2	49.9	63.4	68.2	71.4	74.1	77.2	80.1	82.9	85.4	88.3	91.0	94.8	96.9	98.4	99.2
23.7	77.3	93.2	97.0	98.0	98.6	99.1	99.3	99.4	99.5	99.6	99.8	99.9	99.9	99.9	100.0
28.6	84.7	95.9	98.8	98.9	99.5	99.5	99.7	99.7	99.7	99.8	100.0	100.0	100.0	100.0	100.0
21.8	74.4	92.2	96.4	97.7	98.3	98.9	99.2	99.3	99.4	99.5	99.7	99.8	99.8	99.9	100.0
19.8	72.1	88.6	94.5	96.2	97.6	98.0	98.1	98.4	98.5	98.8	99.0	99.2	99.4	99.8	99.9
2.1	9.1	15.7	20.8	27.1	33.1	40.4	47.9	55.4	61.9	69.4	76.5	86.6	92.0	95.9	98.0

Table 2. Percent carboxyhemoglobin for never-smokers by age, race, and urbanization status—sample sizes, weighted population estimates, means, standard deviations, standard errors, selected percentiles, and cumulative frequency distributions: United States, 1976-80

Urbanization level, race, and age of never-smokers[1]	*n*[2]	*N*[3]	*Mean*	*Standard deviation*	*Standard error*	*Percentiles*				*Percent COHb*						
						50th	*75th*	*90th*	*95th*	*≤ 1.00*	*≤ 1.25*	*≤ 1.50*	*≤ 1.75*	*≤ 2.00*	*≤ 2.25*	*≤ 2.50*
All urbanization levels																
All races[4]				Percent COHb						Cumulative percent distribution of population						
3-74 years	5,459	106,042	0.83	0.671	0.021	0.72	0.97	1.33	1.65	77.3	88.4	93.2	95.7	97.0	97.5	98.0
3-11 years	2,055	30,066	0.73	0.502	0.019	0.67	0.87	1.12	1.42	84.7	93.0	95.9	97.7	98.8	98.9	98.9
12-74 years	3,404	75,976	0.87	0.726	0.025	0.74	1.01	1.38	1.77	74.4	86.6	92.2	94.9	96.4	97.0	97.7
White																
3-74 years	4,512	89,322	0.80	0.645	0.021	0.70	0.94	1.26	1.58	79.8	89.9	94.0	96.2	97.1	97.5	98.1
3-11 years	1,628	24,563	0.71	0.504	0.021	0.65	0.85	1.09	1.40	86.2	93.6	96.0	97.8	98.8	98.9	99.0
12-74 years	2,884	64,759	0.84	0.690	0.024	0.72	0.98	1.32	1.68	77.3	88.5	93.2	95.6	96.5	97.0	97.8
Black																
3-74 years	818	13,389	1.02	0.890	0.065	0.84	1.17	1.59	1.93	64.2	78.1	87.5	92.0	95.9	96.6	96.9
3-11 years	373	4,515	0.82	0.548	0.048	0.76	0.95	1.33	1.57	77.1	88.2	94.7	96.4	98.2	98.3	98.3
12-74 years	445	8,875	1.12	1.012	0.079	0.91	1.31	1.77	2.03	57.7	72.9	83.9	89.7	94.7	95.7	96.1
Population more than 1,000,000, central city																
All races																
3-74 years	629	12,151	1.11	0.691	0.045	1.02	1.31	1.69	2.02	49.5	71.2	83.6	91.0	94.8	96.0	97.1
3-11 years	231	3,099	0.95	0.480	0.047	0.87	1.11	1.51	1.76	66.2	80.6	89.5	95.0	98.3	98.3	98.3
12-74 years	398	9,052	1.17	0.746	0.051	1.07	1.36	1.78	2.22	43.7	68.0	81.5	89.6	93.6	95.2	96.7
White																
3-74 years	324	7,088	1.05	0.608	0.032	0.96	1.25	1.58	1.98	53.7	75.8	86.2	93.8	95.4	96.6	98.2
3-11 years	104	1,702	0.90	0.446	0.045	0.82	1.04	1.47	1.73	73.8	85.3	90.2	96.8	98.5	98.5	98.5
12-74 years	220	5,386	1.10	0.653	0.039	1.07	1.29	1.60	2.18	47.4	72.7	84.9	92.9	94.3	96.0	98.1
Black																
3-74 years	275	4,383	1.22	0.872	0.108	1.08	1.44	1.88	2.63	44.1	63.6	77.8	85.8	93.2	94.3	94.8
3-11 years	117	1,241	1.01	0.566	0.083	0.92	1.33	1.57	1.95	54.2	71.7	87.3	91.9	97.7	97.7	97.7
12-74 years	158	3,142	1.31	0.963	0.129	1.11	1.51	1.94	3.20	40.2	60.4	74.0	83.4	91.4	93.0	93.6
Population more than 1,000,000, not central city																
All races																
3-74 years	719	18,207	0.91	0.701	0.040	0.80	1.09	1.46	1.74	69.3	83.3	90.8	95.1	96.2	97.3	98.2
3-11 years	262	5,074	0.76	0.430	0.051	0.74	0.97	1.21	1.45	78.1	90.9	95.9	99.0	99.9	99.9	99.9
12-74 years	457	13,133	0.96	0.777	0.043	0.83	1.15	1.55	2.02	65.9	80.4	88.8	93.6	94.8	96.3	97.6
White																
3-74 years	632	16,170	0.90	0.739	0.045	0.79	1.08	1.51	1.80	70.3	82.9	89.9	94.5	95.8	97.0	98.0
3-11 years	228	4,458	0.74	0.449	0.055	0.69	0.97	1.28	1.46	77.9	89.7	95.3	98.9	99.9	99.9	99.9
12-74 years	404	11,712	0.96	0.817	0.047	0.83	1.12	1.58	2.03	67.4	80.3	87.8	92.8	94.2	95.8	97.3
Black																
3-74 years	76	1,658	0.93	0.330	0.028	0.89	1.15	1.36	1.50	59.3	83.4	97.3	100.0	100.0	100.0	100.0
3-11 years	30	515	0.83	0.297	0.052	0.84	0.92	1.16	1.17	79.7	99.1	100.0	100.0	100.0	100.0	100.0
12-74 years	46	1,143	0.98	0.361	0.048	0.93	1.20	1.36	1.50	50.1	76.4	96.1	100.0	100.0	100.0	100.0

See footnotes at end of table.

Table 2.—Percent carboxyhemoglobin for never-smokers by age, race, and urbanization status—sample sizes, weighted population estimates, means, standard deviations, standard errors, selected percentiles, and cumulative frequency distributions: United States, 1976-80—Con.

Urbanization level, race, and age of never-smokers[1]	*n*[2]	*N*[3]	*Mean*	*Standard deviation*	*Standard error*	*Percentiles*				*Percent COHb*						
						50th	*75th*	*90th*	*95th*	*≤ 1.00*	*≤ 1.25*	*≤ 1.50*	*≤ 1.75*	*≤ 2.00*	*≤ 2.25*	*≤ 2.50*
Population less than 1,000,000																
All races			Percent COHb							Cumulative percent distribution of population						
3-74 years	2,109	41,530	0.79	0.717	0.036	0.69	0.91	1.18	1.43	82.8	92.5	95.5	96.8	97.6	97.8	98.0
3-11 years	811	11,816	0.70	0.602	0.042	0.65	0.82	1.06	1.21	88.1	95.7	97.4	98.2	98.4	98.7	98.7
12-74 years	1,298	29,714	0.83	0.759	0.039	0.71	0.94	1.22	1.56	80.6	91.2	94.7	96.2	97.2	97.4	97.8
White																
3-74 years	1,654	33,691	0.76	0.659	0.034	0.68	0.89	1.11	1.34	84.4	93.8	96.3	97.2	97.7	97.8	98.1
3-11 years	599	9,071	0.69	0.618	0.047	0.63	0.81	1.03	1.21	89.0	95.8	97.4	98.2	98.5	98.8	98.8
12-74 years	1,055	24,620	0.79	0.678	0.037	0.69	0.92	1.13	1.36	82.6	93.0	95.9	96.9	97.4	97.5	97.8
Black																
3-74 years	383	5,883	0.94	1.071	0.087	0.76	0.97	1.49	1.92	77.5	85.5	90.8	93.9	96.2	96.8	97.1
3-11 years	182	2,214	0.73	0.623	0.068	0.67	0.81	1.10	1.35	87.1	94.6	96.7	97.6	97.6	97.9	97.9
12-74 years	201	3,669	1.06	1.259	0.108	0.82	1.10	1.59	1.98	71.8	80.0	87.2	91.7	95.3	96.1	96.6
Rural																
All races																
3-74 years	1,999	34,103	0.74	0.606	0.034	0.65	0.86	1.13	1.47	84.9	92.2	95.2	96.4	97.6	97.8	98.3
3-11 years	750	10,071	0.68	0.446	0.024	0.62	0.81	1.02	1.29	89.7	94.6	96.1	97.2	98.7	98.8	98.9
12-74 years	1,249	24,032	0.77	0.662	0.040	0.66	0.88	1.16	1.53	82.9	91.2	94.8	96.0	97.1	97.4	98.0
White																
3-74 years	1,899	32,321	0.74	0.610	0.035	0.65	0.85	1.12	1.44	85.4	92.5	95.4	96.5	97.6	97.7	98.2
3-11 years	696	9,325	0.68	0.455	0.027	0.62	0.80	1.02	1.29	89.7	94.8	96.0	97.2	98.6	98.7	98.8
12-74 years	1,203	22,995	0.76	0.664	0.041	0.66	0.88	1.15	1.49	83.6	91.5	95.1	96.2	97.1	97.3	98.0
Black																
3-74 years	84	1,465	0.82	0.640	0.106	0.74	0.98	1.48	1.77	76.6	85.5	92.4	93.4	97.8	98.7	98.7
3-11 years	44	544	0.74	0.419	0.085	0.72	0.94	1.28	1.28	86.8	89.7	98.3	98.3	100.0	100.0	100.0
12-74 years	40	920	0.86	0.762	0.143	0.74	1.08	1.69	1.77	70.5	83.1	88.9	90.5	96.5	97.9	97.9

[1]Smoking histories are unavailable for children less than 12 years of age.
[2]n = unweighted sample size.
[3]N = population estimate in thousands.
[4]Includes other racial groups in addition to white and black.

Table 3. Percent carboxyhemoglobin for never-smokers by age, season, and urbanization status—sample sizes, weighted population estimates, means, standard deviations, standard errors, selected percentiles, and cumulative frequency distributions: United States, 1976-80

Urbanization status, season, and age of never-smokers[1]	*n*[2]	*N*[3]	*Mean*	*Standard deviation*	*Standard error*	*Percentiles*				*Percent COHb*						
						50th	*75th*	*90th*	*95th*	*≤ 1.00*	*≤ 1.25*	*≤ 1.50*	*≤ 1.75*	*≤ 2.00*	*≤ 2.25*	*≤ 2.50*
All urbanization levels																
November-March					Percent COHb					Cumulative percent distribution of population						
3-74 years	2,105	43,285	0.96	0.787	0.033	0.80	1.09	1.55	1.94	69.4	82.4	89.0	92.8	95.3	96.1	97.0
3-11 years	795	12,421	0.87	0.655	0.034	0.75	0.97	1.39	1.76	77.3	87.3	91.8	94.9	97.1	97.3	97.4
12-74 years	1,310	30,865	1.00	0.835	0.037	0.83	1.14	1.59	2.07	66.1	80.5	87.9	91.9	94.6	95.6	96.9
May-September																
3-74 years	2,330	43,167	0.67	0.530	0.023	0.63	0.83	1.05	1.24	87.9	95.2	97.5	98.6	98.9	99.1	99.2
3-11 years	881	12,372	0.58	0.327	0.024	0.57	0.77	0.93	1.07	92.5	97.7	98.9	99.5	100.0	100.0	100.0
12-74 years	1,449	30,795	0.71	0.589	0.024	0.64	0.86	1.09	1.29	86.1	94.1	96.9	98.3	98.4	98.7	98.8
Population more than 1,000,000, central city																
November-March																
3-74 years	328	6,575	1.19	0.787	0.064	1.04	1.42	1.86	2.31	47.1	65.4	78.8	87.8	92.8	94.6	95.8
3-11 years	105	1,628	1.01	0.565	0.071	0.85	1.29	1.63	1.95	64.5	74.6	84.6	92.6	96.7	96.7	96.7
12-74 years	223	4,947	1.25	0.847	0.073	1.11	1.45	1.94	2.31	41.4	62.3	76.9	86.2	91.5	93.9	95.5
May-September																
3-74 years	165	2,879	0.86	0.377	0.029	0.82	1.11	1.28	1.52	65.4	86.4	94.4	99.0	100.0	100.0	100.0
3-11 years	76	844	0.77	0.369	0.030	0.78	0.92	1.11	1.34	80.6	94.5	96.5	96.5	100.0	100.0	100.0
12-74 years	89	2,034	0.90	0.379	0.034	0.85	1.15	1.29	1.52	59.1	83.0	93.5	100.0	100.0	100.0	100.0
Population more than 1,000,000, not central city																
November-March																
3-74 years	312	8,163	0.98	0.590	0.050	0.91	1.17	1.54	1.76	61.1	78.7	88.7	94.8	96.3	98.0	99.1
3-11 years	121	2,352	0.88	0.473	0.066	0.84	1.11	1.45	1.56	66.5	83.0	91.2	97.9	99.7	99.7	99.7
12-74 years	191	5,811	1.02	0.642	0.061	0.94	1.19	1.58	2.02	58.9	76.9	87.7	93.6	95.0	97.3	98.8
May-September																
3-74 years	289	7,145	0.78	0.826	0.066	0.68	0.89	1.20	1.58	82.9	90.7	94.6	96.6	96.8	97.5	98.0
3-11 years	102	1,938	0.62	0.350	0.058	0.65	0.84	0.99	1.07	90.2	99.0	100.0	100.0	100.0	100.0	100.0
12-74 years	187	5,207	0.83	0.936	0.070	0.70	0.93	1.42	1.59	80.1	87.6	92.6	95.3	95.6	96.6	97.3
Population less than 1,000,000																
November-March																
3-74 years	611	13,250	0.96	1.005	0.062	0.77	1.00	1.38	1.98	75.6	87.5	91.4	93.0	95.1	95.4	96.0
3-11 years	226	3,635	0.90	0.969	0.099	0.69	0.91	1.18	1.83	80.1	91.7	94.3	94.6	95.1	95.6	95.6
12-74 years	385	9,615	0.98	1.033	0.064	0.79	1.02	1.49	1.98	73.9	85.9	90.3	92.3	95.1	95.4	96.2
May-September																
3-74 years	1,075	20,147	0.67	0.460	0.027	0.64	0.84	1.04	1.20	88.8	96.1	98.1	98.9	99.1	99.3	99.4
3-11 years	435	6,220	0.59	0.343	0.032	0.59	0.76	0.94	1.11	92.4	96.9	98.4	99.7	99.9	100.0	100.0
12-74 years	640	13,927	0.71	0.499	0.026	0.65	0.86	1.07	1.22	87.1	95.7	97.9	98.6	98.8	99.0	99.1

See footnotes at end of table.

Table 3. Pe[illegible] carboxyhemoglobin for never-smokers by age, season, and urbanization status—sample sizes, weighted population estimates, means, standard deviations, standard errors, selected percentiles, and cumulative frequency distributions: United States, 1976-80—Con.

Urbanization status, season, and age of never-smokers[1]	*n*[2]	*N*[3]	*Mean*	*Standard deviation*	*Standard error*	*Percentiles*				*Percent COHb*						
						50th	*75th*	*90th*	*95th*	*≤ 1.00*	*≤ 1.25*	*≤ 1.50*	*≤ 1.75*	*≤ 2.00*	*≤ 2.25*	*≤ 2.50*
Rural																
November-March			Percent COHb							Cumulative percent distribution of population						
3-74 years	854	15,298	0.86	0.703	0.051	0.73	0.95	1.41	1.84	77.9	87.4	91.5	93.7	96.1	96.4	97.3
3-11 years	343	4,806	0.79	0.528	0.032	0.71	0.88	1.23	1.76	84.9	90.3	92.7	94.6	97.4	97.5	97.8
12-74 years	511	10,492	0.90	0.772	0.062	0.74	1.01	1.45	1.86	74.7	86.1	91.0	93.3	95.5	95.8	97.1
May-September																
3-74 years	798	12,944	0.58	0.471	0.025	0.56	0.73	0.91	1.03	94.3	98.1	98.8	99.1	99.3	99.3	99.3
3-11 years	267	3,363	0.49	0.277	0.026	0.49	0.63	0.81	0.90	97.0	99.4	99.6	99.6	100.0	100.0	100.0
12-74 years	531	9,581	0.61	0.520	0.028	0.58	0.76	0.93	1.07	93.4	97.7	98.6	99.0	99.1	99.1	99.1

[1]Smoking histories are unavailable for children less than 12 years of age.
[2]n = unweighted sample size.
[3]N = population estimate in thousands.

Table 4. Percent carboxyhemoglobin for never-smokers by age, income, and urbanization status—sample sizes, weighted population estimates, means, standard deviations, standard errors, selected percentiles, and cumulative frequency distributions: United States, 1976-80

Urbanization status, age, and family income[1]	n^2	N^3	*Mean*	*Standard deviation*	*Standard error*	*Percentiles* 50th	75th	90th	95th	*Percent COHb* ≤ 1.00	≤ 1.25	≤ 1.50	≤ 1.75	≤ 2.00	≤ 2.25	≤ 2.50
All urbanization levels																
3-74 years			Percent COHb							Cumulative percent distribution of population						
Less than $10,000	2,153	36,114	0.91	0.799	0.031	0.76	1.03	1.41	1.85	73.5	85.3	91.5	94.2	95.9	96.7	97.2
$10,000-19,999	1,888	36,920	0.78	0.597	0.025	0.70	0.92	1.22	1.53	80.0	90.8	94.7	97.2	97.9	98.1	98.5
$20,000 or more	1,189	28,519	0.80	0.609	0.025	0.70	0.94	1.27	1.57	79.8	89.7	94.0	96.0	97.3	97.7	98.3
3-11 years																
Less than $10,000	795	10,025	0.81	0.695	0.041	0.71	0.92	1.31	1.71	79.3	89.0	92.8	95.5	97.3	97.6	97.7
$10,000-19,999	768	11,369	0.69	0.408	0.027	0.66	0.85	1.05	1.29	87.3	94.6	97.4	98.8	99.1	99.1	99.1
$20,000 or more	432	7,838	0.66	0.345	0.023	0.64	0.84	1.09	1.20	88.2	95.6	97.7	99.0	100.0	100.0	100.0
12-74 years																
Less than $10,000	1,358	26,089	0.94	0.839	0.035	0.78	1.07	1.45	1.93	71.2	83.8	90.9	93.6	95.4	96.3	97.0
$10,000-19,999	1,120	25,551	0.82	0.662	0.027	0.72	0.97	1.31	1.64	76.7	89.1	93.6	96.4	97.4	97.7	98.2
$20,000 or more	757	20,681	0.85	0.682	0.033	0.72	0.98	1.37	1.78	76.7	87.5	92.6	94.8	96.2	96.8	97.7
Population more than 1,000,000, central city																
3-74 years																
Less than $10,000	331	5,622	1.16	0.779	0.047	1.05	1.35	1.73	2.38	47.1	68.3	81.9	90.3	93.6	94.5	96.1
$10,000-19,999	152	3,017	1.06	0.689	0.081	0.97	1.21	1.50	1.83	51.8	79.5	90.5	94.6	96.6	96.6	96.6
$20,000 or more	108	2,834	1.05	0.544	0.066	0.94	1.32	1.72	2.14	55.4	70.3	81.7	90.4	94.9	98.0	99.6
3-11 years																
Less than $10,000	130	1,384	1.01	0.522	0.069	0.90	1.33	1.62	1.76	56.8	74.4	85.0	93.6	98.2	98.2	98.2
$10,000-19,999	54	726	0.95	0.508	0.074	0.87	1.04	1.33	1.51	71.9	83.4	94.7	96.1	96.1	96.1	96.1
$20,000 or more	38	912	0.82	0.409	0.042	0.79	0.95	1.35	1.61	77.3	87.7	93.0	97.3	100.0	100.0	100.0
12-74 years																
Less than $10,000	201	4,237	1.21	0.867	0.070	1.07	1.36	1.78	2.45	43.9	66.3	80.9	89.2	92.1	93.3	95.4
$10,000-19,999	98	2,291	1.10	0.736	0.087	1.07	1.22	1.52	1.83	45.5	78.3	89.2	94.1	96.7	96.7	96.7
$20,000 or more	70	1,921	1.16	0.570	0.083	1.08	1.45	1.86	2.18	45.0	62.0	76.3	87.1	92.4	97.1	99.4
Population more than 1,000,000, not central city																
3-74 years																
Less than $10,000	195	4,527	1.01	0.988	0.070	0.84	1.11	1.47	2.03	69.1	82.5	90.0	92.7	93.7	96.4	96.4
$10,000-19,999	239	5,790	0.91	0.654	0.058	0.82	1.17	1.54	1.72	66.2	79.4	89.4	95.6	97.0	97.6	98.2
$20,000 or more	249	6,957	0.81	0.498	0.046	0.78	1.04	1.36	1.53	72.6	88.1	94.0	96.8	97.9	98.4	99.5
3-11 years																
Less than $10,000	63	967	0.93	0.469	0.056	0.90	1.10	1.31	1.89	65.7	88.3	92.8	94.8	99.3	99.3	99.3
$10,000-19,999	107	2,057	0.75	0.433	0.064	0.75	0.98	1.29	1.44	77.7	88.6	95.5	100.0	100.0	100.0	100.0
$20,000 or more	84	1,822	0.69	0.407	0.051	0.67	0.92	1.13	1.45	82.8	93.7	97.5	100.0	100.0	100.0	100.0
12-74 years																
Less than $10,000	132	3,561	1.04	1.100	0.088	0.80	1.11	1.51	2.24	70.1	80.9	89.3	92.1	92.1	95.6	95.6
$10,000-19,999	132	3,732	1.00	0.742	0.069	0.90	1.26	1.69	1.97	59.8	74.3	86.0	93.2	95.4	96.2	97.2
$20,000 or more	165	5,135	0.86	0.523	0.049	0.83	1.05	1.41	1.66	69.0	86.1	92.7	95.6	97.1	97.9	99.3

See footnotes at end of table.

Table 4. Percent carboxyhemoglobin for never-smokers by age, income, and urbanization status—sample sizes, weighted population estimates, means, standard deviations, standard errors, selected percentiles, and cumulative frequency distributions: United States, 1976-80—Con.

Urbanization status, age, and family income[1]	*n*[2]	*N*[3]	*Mean*	*Standard deviation*	*Standard error*	*Percentiles*				*Percent COHb*						
						50th	*75th*	*90th*	*95th*	*≤ 1.00*	*≤ 1.25*	*≤ 1.50*	*≤ 1.75*	*≤ 2.00*	*≤ 2.25*	*≤ 2.50*
Population less than 1,000,000																
3-74 years			Percent COHb							Cumulative percent distribution of population						
Less than $10,000	872	14,791	0.87	0.866	0.052	0.73	0.96	1.31	1.71	79.7	89.3	94.0	95.2	96.1	96.6	96.9
$10,000-19,999	717	14,404	0.72	0.564	0.033	0.68	0.86	1.09	1.26	85.4	94.9	96.6	98.4	99.1	99.2	99.3
$20,000 or more	441	10,728	0.78	0.738	0.055	0.67	0.90	1.14	1.38	84.3	93.8	95.7	96.5	97.2	97.2	97.6
3-11 years																
Less than $10,000	331	4,291	0.79	0.918	0.092	0.67	0.84	1.10	1.57	85.1	92.2	94.7	96.2	96.2	96.8	96.8
$10,000-19,999	299	4,529	0.64	0.350	0.027	0.64	0.80	0.98	1.15	91.1	97.3	98.2	98.9	99.5	99.5	99.5
$20,000 or more	161	2,777	0.63	0.316	0.039	0.63	0.80	1.05	1.15	89.4	98.3	100.0	100.0	100.0	100.0	100.0
12-74 years																
Less than $10,000	541	10,500	0.90	0.860	0.053	0.76	0.98	1.34	1.81	77.5	88.2	93.7	94.8	96.1	96.6	96.9
$10,000-19,999	418	9,875	0.76	0.638	0.039	0.69	0.89	1.10	1.31	82.8	93.8	95.9	98.1	98.9	99.0	99.2
$20,000 or more	280	7,952	0.83	0.837	0.067	0.69	0.93	1.16	1.57	82.5	92.2	94.2	95.3	96.2	96.2	96.7
Rural																
3-74 years																
Less than $10,000	755	11,174	0.78	0.654	0.054	0.68	0.92	1.29	1.71	80.2	89.6	93.5	95.3	97.7	97.9	98.6
$10,000-19,999	779	13,689	0.73	0.602	0.032	0.65	0.84	1.07	1.36	86.3	93.8	95.9	97.1	97.4	97.6	98.2
$20,000 or more	390	7,994	0.72	0.580	0.031	0.63	0.82	1.08	1.39	88.8	92.7	96.1	96.5	97.7	97.7	97.9
3-11 years																
Less than $10,000	271	3,383	0.73	0.528	0.036	0.64	0.85	1.13	1.71	84.9	91.2	93.7	95.7	97.7	97.8	98.2
$10,000-19,999	308	4,057	0.67	0.450	0.036	0.63	0.80	0.98	1.06	90.7	96.6	97.9	98.6	98.8	98.8	98.8
$20,000 or more	148	2,322	0.60	0.327	0.028	0.60	0.74	0.88	0.92	95.3	97.1	97.1	97.7	100.0	100.0	100.0
12-74 years																
Less than $10,000	484	7,791	0.80	0.706	0.066	0.69	0.94	1.30	1.71	78.2	88.8	93.5	95.1	97.6	98.0	98.8
$10,000-19,999	471	9,632	0.75	0.657	0.035	0.66	0.86	1.14	1.47	84.4	92.6	95.1	96.6	96.8	97.1	97.9
$20,000 or more	242	5,673	0.76	0.663	0.046	0.65	0.87	1.17	1.42	86.1	90.8	95.6	96.1	96.7	96.7	97.0

[1]Smoking histories are unavailable for children less than 12 years of age.
[2]n = unweighted sample size.
[3]N = population estimate in thousands.

Technical notes

Sample design

The information presented in this report is based on data from the direct standardized physical examinations, tests, measurements, and questionnaires collected in the second National Health and Nutrition Examination Survey during 1976-80. The target population of NHANES II encompassed the civilian noninstitutionalized population of the United States, including Alaska and Hawaii, of persons 6 months through 74 years of age.

NHANES II utilized a multistage probability design that involved selection of PSU's, segments (clusters of households) within PSU's, households, eligible persons, and finally sample persons. The sample design provided for oversampling among persons 6 months-5 years, persons 60-74 years of age, and persons living in poverty areas. The U.S. Bureau of the Census, under contract to the National Center for Health Statistics, selected, according to rigorous specifications, the NHANES II sample of 27,801 persons. Of this total sample, 20,322 (73.1 percent) were examined. A half-sample of persons 3-74 years of age was assigned to receive the test for levels of carbon monoxide. Of the 11,368 persons originally selected in the sample to receive the carbon monoxide test, 9,365 came in for examination, and acceptable blood samples were analyzed for 8,411.

The data in this report are presented as population estimates. Examination findings for each sample person have been inflated by the reciprocal of the probability of selecting a person, adjusted for persons who were not examined, and poststratified so that final extimates closely approximate the independent U.S. Bureau of the Census estimates for the civilian noninstitutionalized population of the United States by race, sex, and age as of the midpoint of the study, March 1, 1978.

Adjustment for item nonresponse

Carboxyhemoglobin and methemoglobin values were imputed for the 954 cases with no or unacceptable samples. The procedure used has been described as a "hot deck" process, in which the acceptable values for a case that matches the missing case on a number of key criteria are imputed to the case with missing data. For this study, the criteria on which the cases were required to match were smoking status, age group, race, and location. (Although certain locations were visited twice, each visit was assigned a unique number, so that matching on examination location had the effect of adjusting for both season and degree of urbanization.) Comparison of imputed and nonimputed data revealed no substantial changes in detailed means.

Estimation of standard errors

Because the statistics presented in the text and detailed tables of this report are national estimates based on a sample, they differ somewhat from the figures that would have been obtained if the survey had been conducted on the complete population. In other words, the statistics are subject to sampling variability.

The standard errors presented in tables 1-4 are primarily a measure of sampling variability, but they also include the variation that arises in the measurement process, usually called measurement error. These standard errors were calculated using a Taylor Series linearization method.[16] This process approximates the variance of nonlinear (or linear) statistics, for example, means and proportions, using the first two terms of a Taylor Series expansion. If the higher order terms of the expansion are negligible and the sample is of a reasonable size for the domains of interest, then this approximation provides variance estimates as reliable as those from the pseudoreplication method adapted for use in the analyses of NHANES II data.[17] Estimates of standard errors are themselves subject to errors that may be large if the number of cases or PSU's on which the estimates are based is small.

Statistical significance was determined using *z*-tests when individual subgroup statistics were compared and using a modified chi-square technique when testing for effects. Both methods were modified to incorporate the complex NHANES II sample design.

Carboxyhemoglobin quality control

Three procedures were employed in the laboratory to ensure validity and reliability of the spectrophotometric method and to maintain the necessary quality control on the laboratory determinations: (1) duplicate determinations on "blind" and arbitrarily selected samples using a completely different method of measurement, (2) duplicate measurements on every sample, and (3) regular determinations using Small's method and comparisons with previous values on an independent group of nonsmoking subjects whose COHb levels would be expected to be very stable. The first procedure provided a measure of the validity of the spectrophotometric method and was essential to detect any baseline drift, a significant problem when measuring low COHb concentrations by spectrophotometry. The second and third procedures provided measures of precision and established the reliability of the final raw data.

The validity of the spectrophotometric method was verified by a comparison of results obtained by

Small's method with those obtained using the more accurate and precise (but prohibitively costly and time-consuming) gas chromatography method. At regular intervals, seven or eight samples selected to represent a range of COHb levels were sent to an independent laboratory (that of Dr. F. Lee Rodkey and Mr. R. Robertson of the Naval Medical Research Institute, Bethesda, Maryland) for COHb determinations using the reference standard methodology of gas chromatography.[18] The values obtained by gas chromatography were compared to those obtained by spectrophotometry, and the results were used to "fine-tune" the baseline adjustment on the spectrophotometric equipment.

At regular intervals, four or five "blind" samples were sent directly from the MEC's to both laboratories. About 200 comparisons resulted from this procedure, with a mean difference of 0.00 percent COHb and a standard deviation of 0.31 percent COHb. The correlation coefficient was 0.99.

The precision or reliability of the spectrophotometric method was confirmed through dual determinations on each sample. Theoretically, the standard deviation of repeated COHb measurements on a single sample by this method should be about 0.25 percent.[9] If measurements on a sample differed by more than 1 percent COHb (that is, by more than four standard deviations), the sample was rerun. The distribution of differences between duplicate determinations followed a Gaussian (normal) probability curve, with a standard deviation of approximately 0.25 percent.

Finally, samples were drawn regularly from a group of nonsmoking laboratory personnel as a test of the stability of the spectrophotometric method. After analysis, the COHb values were compared with previous values from the same person. Occasional high values (greater than 1.2 percent) were verified by the gas chromatography method and were found to occur on days when the ambient carbon monoxide level was high. Thus Small's method reliably detected increases in COHb of as low as 0.3 percent.

With the strict quality control on the spectrophotometric method, it was possible to reduce the baseline uncertainty of the method to ±0.1 percent COHb. This source of error is the only one contributing to the error of mean results obtained from groups of individuals; all other sources of error would average to zero. Thus for group comparisons, the method is considered to be accurate to ±0.1 percent COHb.

Limitations of data

Although the quality control and methodological verification previously described justify a high degree of confidence in the validity and precision of the results reported here, because of a number of factors the reader should be cautious not to "over-interpret" the data, particularly when comparing an individual subject's results with population distributions. Chief among these factors is the relative imprecision of a single measurement, estimated to be perhaps as much as 0.25 percent COHb on repeated measurements. For children, in particular, this variability may represent 25 or more percentile points. For the entire population, however, this measurement error was estimated to be no more than 0.10 percent COHb, so that cross-population comparisons should be only minimally affected.

Another possible confounding factor is the interaction between the seasonal effect noted in the results and the itineraries of the Mobile Examination Centers. To minimize the effects of adverse weather on response rates, MEC's traveled through the more northern parts of the United States in the summer and the more southern parts in the winter. Thus the effects of the severest winter weather on carbon monoxide levels are not represented in these data.

Several logistical factors also must be considered while interpreting these data. For instance, on rare occasions, an MEC was situated near major traffic arteries. These sites may have manifested ambient carbon monoxide levels that were atypically high for the given locale, but it is not possible to quantify this effect with the available data.

Another logistical factor with possible implications for the interpretation of these data was the shipping and handling of the samples. After collection, the samples were refrigerated until a sufficient number had accumulated for shipment (on ice) to the lab for analysis. In general, this procedure has not been identified as a factor that influences the resulting COHb test results. However, several shipments were lost; others were mishandled and arrived at the lab in an unanalyzable condition. Finally, some samples showed such high methemoglobin levels (greater than 5 percent) that the associated values for COHb were considered unreliable; the high metHb was evidence of sample deterioration. Of the 9,365 examined subjects who should have had values for COHb, acceptable samples were not available for 954 (10.2 percent). The distribution of these missing values did not show any race or sex bias, and the statistical weights for the remaining cases were adjusted to compensate for this item nonresponse as well as sample person nonresponse (see the section on Item nonresponse).

The definition and reporting of smoking status (see page 6) may have had some impact on the interpretation of results in this report. The remarkably high COHb values for a few of the ex-smokers leads to the suspicion that some incorrect reporting may have occurred in the history. In addition, the surprisingly low values for some current smokers indicate that their smoking levels (in cigarettes per day or amount inhaled) are so low that they have little or no effect on COHb levels.

Finally, the possibility exists that there is a relationship between the time of day of sample collection and the COHb level, particularly for current smokers. This relationship will be examined in the Series 11 paper in the *Vital and Health Statistics* series.

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