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Prevalence of Supranormal Pulmonary Function Testing Values Between a Military and Non-Military Cohort

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ABSTRACT

Purpose: The study objective was to determine differences in the proportion of supranormal pulmonary function tests (PFTs) between active duty military personnel and a similar non-active duty population. Given the emphasis on cardiovascular fitness in the military, it has been hypothesized that regular exercise in this cohort leads to an increased proportion of supranormal PFTs. We hypothesized a comparison of PFTs would identify no differences in the ratio of supranormal to normal PFTs between the active duty and non-active duty populations.

Methods: A retrospective chart review was conducted of all pulmonary function testing studies at Brooke Army Medical Center from 2006-2011. Studies were included with either a forced vital capacity or forced expiratory volume at one second >110% predicted with both values greater than 100% predicted. A comparative analysis was performed for patients between the ages 18 to 50 based on active duty status. Further analysis was performed on all ages to determine the distribution of supranormal findings in the entire study population.

Results: A total of 16,600 interpreted pulmonary function tests were queried. Of those, 4303 (31.6%) were active duty patients and 9306 (68.4%) were non-active duty patients. From all the PFTs reviewed, a total of 912 (6.7%) were identified as supranormal. When further analyzed, 381 (9.4%) of active duty age 18-50 were supranormal, 175 (12.4%) of non-active duty patients ages 18-50 were supranormal, and 356 (4.7%) of non-active duty patients age greater than 50 were supranormal.

Conclusion: This study revealed no significant difference in the proportion of supranormal to normal PFTs in an active duty versus non-active duty population of the same age range. Based on these findings, no assumption should be made that supranormal PFTs are more common in

military personnel. Interpretation of normal PFTs in active duty personnel undergoing evaluation should not differ from any typical patient.

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ABBREVIATIONS

AD	Active duty
EIB	Exercise-induced bronchospasm
PFT	Pulmonary function testing
FVC	Forced vital capacity
FEV_1	Forced expiratory volume at one second
NHANES	National Health and Nutrition Examination Survey
TLC	Total lung capacity
RV	Residual volume
DLCO	Diffusing capacity for carbon monoxide

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INTRODUCTION

Dyspnea is a frequently evaluated complaint among the active duty (AD) population of the United States military. In part, military personnel may be referred for clinical evaluation due to their inability to meet the physical requirements of military service and specifically, the standards for a timed physical fitness run. While asthma and exercise-induced bronchospasm (EIB) are often the cause of exertional symptoms, many initial clinical evaluations based on pulmonary function testing (PFT) and chest imaging are negative. Twenty-five percent of AD military personnel with complaints of exertional dyspnea had a negative comprehensive evaluation[1]. Given the recent emphasis on post-deployment respiratory symptoms and the possible relationship with environmental exposures such as sand storms and burn pits, many military personnel being evaluated for respiratory symptoms are found have to normal baseline PFT[2, 3]. Some clinicians have theorized that the AD military population, with a high level of emphasis on regular physical fitness when compared to their non-AD counterparts, has a larger proportion of supranormal PFT values. This has lead to a supposition that a "normal" spirometry in an AD service member presenting with dyspnea actually reflects a decrement in function and underlying lung disease[3]. While spirometry reference equations such as NHANES III establish both an upper and lower limit for normal, the upper limit of normal is not routinely calculated on spirometry reports. How does a clinician interpret spirometry in those patients either referred for a baseline study due to military occupational exposures or in those symptomatic individuals presenting with cough, dyspnea, or other respiratory complaints other than with established population guidelines?

Intense aerobic training does have a direct impact on overall cardiovascular function, muscle strength and endurance, and hematologic indices[4]. However, data is inconclusive regarding the change in lung function in high level aerobic performers. Studies comparing athletes and individuals in high-performance professions to untrained control groups provide little evidence that high demand of lung function changes the underlying PFT values[5]. The results of these studies led many investigators to question whether the minor increases found in lung function found in conditioned versus non-conditioned subjects were induced by training or present prior to training. Conversely, several studies of elite athletes for the diagnosis of EIB have noted elevated baseline values in this population[6, 7]. Given the current lack of evidence supporting the correlation between increased levels of fitness and supranormal PFT in elite athletes, the suggestion that the military population would be comprised of more supranormal PFT values than the general population has not been investigated. Although many members of the military achieve and maintain a high level of physical fitness, the average military member is not a highly conditioned elite athlete. We hypothesized that a comparison of PFT data from both AD military and non-AD beneficiaries would not demonstrate an increase in supranormal values more prevalent in military personnel.

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METHODS

This study was conducted as a retrospective review of Department of Defense electronic medical records after obtaining written approval from the local Institutional Review Board. The electronic database repository for all PFT studies conducted at Brooke Army Medical Center was queried from years 2006 to 2011. All studies were performed on a VMax-22 spirometer (SensorMedics, CareFusion, San Diego, CA) which was calibrated on daily basis as per manufacturer recommendations. Individual spirometry exams were reviewed and those with an elevated FVC or FEV_1 greater than 110% of predicted (based on National Health and Nutrition Examination Survey (NHANES) III reference values) were identified.[8] To qualify for inclusion in this study, both the FEV_1 and FVC were required to be greater than 100% predicted. Spirometry reports from our laboratory do not calculate the upper limit of normal based on confidence intervals and the percent predicted was used as a surrogate to compare populations. Studies that did not meet American Thoracic Society guidelines for acceptability and repeatability were excluded from further analysis. Specific note was also made for patients with either FEV_1 or FVC greater than 120% predicted. The percentage of percent predicted values (110% and 120%) that were above the calculated 95^{th} confidence interval (CI)based on NHANES III upper limit of normal for FEV_1 and FVC was also determined for the included studies. From these studies, the following information was obtained: 1) Patient demographics (age, gender, ethnicity, and height); 2) Patient military status (AD, retired, or military dependant; 3) Spirometry results (actual, predicted and percent predicted) to include FEV_1, FVC, FEV_1/FVC ratio, and 4) if performed, total lung capacity (TLC), residual volume (RV), and diffusing capacity for carbon monoxide (DLCO).

Results were divided into three groups of patients for analysis; 1) AD military from ages 18-50, 2) non-AD patients from ages 18-50, and 3) military retirees or dependants from ages 51-

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90. The percentage of studies meeting the inclusion criteria were calculated by dividing from the overall number of studies performed based on diagnostic procedure codes obtained for the pulmonary clinic during the study years. Values were calculated for AD and non-AD patients by groups and age ranges.

Statistical analysis was performed using commercially available software (SPSS, version 16 and SAS version 9.3). Statistical comparison of the three groups was done with a one-way analysis of variance for the following variables, FVC (% predicted), FEV_1 (% predicted), and FEV_1/FVC (actual). Post hoc analysis was performed if the primary analysis failed to reach significance. Additional analysis included differences between groups based on RV (% predicted), TLC (% predicted) and DLCO (% predicted) values. Direct comparison of the 18-50 AD and non-AD groups was performed using a paired t-test assuming equal variance. A final analysis was also performed to evaluate for any differences in PFT values based on gender or ethnicity. To compare the actual FEV_1 and FVC for the AD and non-AD across ages 18-50, a z-score was calculated for all patients. The z-score was calculated by taking each patient's absolute FEV_1 and FVC measures, subtracting the mean and dividing by the standard deviation, with respect to their gender and age group (18-20, 21-30, 31-40, 41-50). The z-scores were then compared between the AD and non-AD using a t-test for both the FEV_1 and FVC measures.

RESULTS

A total of 16,600 pulmonary function tests performed at Brooke Army Medical Center between 2006 and 2011 were queried in this study. Of those, 32% were identified as active duty patients and the remaining 68% were non-active duty patients, either military retirees or dependent family members. Further division of the non-active duty patients identified by age groups, 18 to 50 years, and 51 to 90 years identified the percentages as 11% and 57% respectively. The number and percentage of supranormal spirometry values for each group and the total cohort is shown in Table 1. For the total cohort, 912 (5.5%) were found to have supranormal values at the 110% predicted value and 248 (1.5%) had either FEV_1 or FVC greater than 120% predicted. The highest percentage of supranormal values at 9.7% was found to be in the 18-50 non-AD group. The remaining demographic information is also shown in Table 1. Notably, the overall gender distribution was 40% and 60% female but the active duty group had a higher percentage of males at 57%. The percentage of military retirees (vs. dependents) in the 50-90 age group was 41%.

The PFT values for each group are shown in Table 2. Eighty-nine percent of studies with an FVC value greater than 120% also exceeded the 95^{th} CI, while only 32% exceeded the 95^{th} CI at 110% predicted. For FEV_1 values greater than 120% and 110% predicted, the percentage of studies above the 95^{th} CI were 78% and 26% respectively. When all three groups were analyzed and found to have a normal distribution, a significant difference for FEV_1 (% predicted) is shown which can be accounted for the higher FEV_1 in the 50-90 year group. Further subset analysis using a paired t-test showed no statistical difference between the 18-50 AD and non-AD group for FEV_1 (% predicted) ($p = 0.927$). The differences seen in FEV_1 account for the significant difference seen in FEV_1/FVC across all three groups; no difference exists between the 18-50 AD and non-AD groups ($p = 0.736$) when directly compared. Analysis of TLC, RV, and DLCO as shown in Table 2 also showed a significant difference for TLC ($p < 0.005$) and DLCO ($p < 0.005$) which can be accounted for by the decrease in both values in 51-90 age group.

To further define the distribution of PFT values within this cohort, z scores were calculated for the AD group (18-50) and the non-AD group (18-50) by gender and across age ranges. Results are shown in Table 3 and demonstrate statistical differences in actual FEV_1 and FVC values between the AD and non-AD groups ($p < 0.001$). However, when calculated using z scores, there is normal distribution of both FEV_1 and FVC with p values of 0.15 and 0.36 respectively.

Distribution of the supranormal values was further analyzed by year of study and age ranges. Figure 1 shows the distribution of supranormal PFTs based on year of study. There are percentages of PFTs completed in 2006 and 2007 but the non-AD population consistently had higher percentage than AD for all years. The distribution of supranormal PFTS by age range is shown in Figure 2. A higher percentage of PFTs with supranormal values is seen in the 18-20 group but are evenly distributed between AD and non-AD persons. This is a consistent finding for the 20, 30 and 40 year age groups with 7.6%, 7.2%, and 7.1% of all patients were supranormal with decreasing percentages in older age groups. Distribution by ethnicity is shown in Figure 3 where similar percentages for Caucasians, African-Americans, and Hispanics are shown for all three groups.

Notably, the non-AD population included more female than male studies, 86% female vs. 14% male, in the non-AD group ages 18-50 and 65% female to 35% male in the non-AD group ages 51-100. The AD population noted a higher percentage of male patients (57% male to 43% female). Analysis for differences in PFT values (FVC, FEV_1, and FEV_1/FVC) for both males and females between groups demonstrated significance for FEV_1 and FEV_1/FVC ($p < 0.001$). Post-hoc analysis again yielded no significant difference when the gender-based AD 18-50 group was compared to the non-AD 18-50 groups for both FEV_1 and FVC.

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DISCUSSION

Minimal information has been previously published on the frequency or significance of supranormal PFTs in the pulmonary literature. Understandably, if elevated values are found during the performance of spirometry in a symptomatic patient, this finding is not typically indicative of a disease process and reassures the clinician that an obstructive or restrictive process is not present. Based on current population studies and spirometric reference values (e.g., NHANES III), the derivation of expected normal values should be closer to 100% predicted due to normal population distributions. However, knowing the baseline spirometric value of any given patient can be important in determining the presence or absence of pulmonary disease, as it can identify individual changes in pulmonary function over time. Especially in a younger, more fit population; does a normal spirometry in the presence of symptoms represent active pulmonary disease? This study has begun to answer several questions on supranormal PFT values. First, it was a common finding across all age ranges in our population and did not favor a specific age group where more comprehensive reference values may be lacking. Secondly, differentiating between active duty personnel and their non-active counterparts did not demonstrate an increased frequency of supranormal PFT values. Based on this study, we have reservations about automatically defining the AD military population as having supranormal values on PFTs.

The joint American Thoracic Society/European Respiratory Society recommendations on PFT testing and interpretation were published in 2005 and made several important changes[9]. The primary change included incorporation of variances in the published reference equations from a higher percentage of minority populations[8]. Secondly, interpretation was changed to incorporate 95% confidence intervals to define the lower limit of normal. There are multiple factors that can influence the performance of spirometry and primarily are related to patient effort and ability to consistently reproduce the forced expiratory maneuver. Incorrect height and age may drastically alter the predicted value and thus incorrectly the percent predicted may be in the normal or supranormal range. While both the upper and lower limit of normal for most reference equations is established, generally there is no clinical use of the upper limit of normal in the interpretation of spirometry. It is presumed that a patient being evaluated for pulmonary disease with normal values for FEV_1, FVC, and FEV_1/FVC would not have significant disease. In many instances, the evaluation for the presence of pulmonary abnormalities may end with a normal spirometry. In those evaluations where there is concern for occupational disease, serial PFTs are used to detect significant clinical change. However, as the discussion in the American Thoracic Society guidelines adequately points out, there is vast difference in the evaluation of healthy subjects and patients with disease or symptoms. Applying the same concept of “normal” based solely on PFT findings would be inappropriate and the interpretation very much depends on the clinical question being asked[10].

Early investigations suggested an increase in lung function during adolescence especially noted in those individuals with high levels of activity[11, 12]. One particular group with supranormal values are competitive swimmers due to their particular type of exercise. An Australian study of eight swimmers compared to eight runners showed a higher FEV_1 and FVC in the swimmer group that was primarily related to an increase in chest wall width[13]. This confirmed earlier findings in several other small studies of swimmers[14, 15].

Given the hypothesis that highly athletic individuals have supranormal PFT values, the published literature on PFTs in competitive athletes should provide ample information. Six published articles were identified that measured resting spirometry values in long distance

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runners (both marathon and triathlon participants)[16-21]. These studies primarily described the effect of running on PFT values and provided baseline spirometric values in small groups of highly trained athletes. Table 4 provides the demographic information along with actual and predicted values for FEV_1 and FVC. From this group of 67 athletes with a mean age of 27, the mean FVC was 102.7% and FEV_1 was 101.6%. None of the mean values from these six studies reached the 110% cutoff as defined in our study, although this group was younger (27 vs. 31) than our AD population.

As our study is retrospective in nature, there are several limitations to the data provided. Because the spirometers in our laboratory do not identify values outside the 95th percentile for the upper limit of normal, we had to establish a cutoff for review based on percent predicted which showed a modest correlation with 90th and 95th confidence intervals. Others factors such as the indication for spirometry and smoking history were not listed on the PFT report and we were unable to distinguish between symptomatic and asymptomatic individuals. Interpretation of spirometry is limited without other pertinent clinical information such as symptoms or underlying lung disease. Further potential biases include the comparison of AD military with dependents and retirees. We assumed an overall improved fitness for the AD group but did not have any direct measurements. Also, while the repeatability of the values within a given test is required by PFT standards, we were unable to determine in our cohort if the supranormal values could be repeated over time. Finally, there are limited large population studies with PFT reference values against which we can compare our data.

Another consideration that has been discussed is the role of spirometric screening for all military service members. Spirometry is currently not used as a screening tool in asymptomatic individuals prior to enlistment or commissioning into the United States Armed Forces. Current guidelines do not recommend "screening" for common lung diseases in the general population and limit surveillance to those individuals with potential occupational exposures. There is a multitude of confounding factors surrounding this issue to include cost, manpower, quality control, and timing of screening spirometry that make such a proposition difficult to accomplish. The main reasons not to perform screening spirometry include 1) the limited utility of a screening test in an asymptomatic population, 2) the very small likelihood of developing future respiratory disease in this population, and 3) the burden of evaluating abnormal baseline tests that may affect military careers.

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CONCLUSION

The assumption that AD military have elevated or supranormal PFT values by virtue of their active duty status is not supported by this study. There is fairly even distribution of supranormal values across all age groups and there is no predilection that more athletic AD military had increased values over their non-AD counterparts. While a prospective evaluation of a larger group of AD military is warranted, current practice standards should interpret PFTs according to published guidelines and not assume an underlying disease process in active duty military or elite athletes when PFTs are found to be within normal limits.

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LEGENDS

FIGURE 1: Graph depicting percentage of supranormal values divided by non-active duty (non-AD) and active duty (AD) per given year. Higher percentages are seen for each given year for the non-AD persons.

FIGURE 2: Bar graph depicting percentage of supranormal PFTS for each year group (by deciles) for both non-active duty (non-AD) and active duty (AD) persons. Higher percentages are seen in the 18-20 year group but remain consistent for the next 3 age deciles).

FIGURE 3: Bar graph depicting distribution of supranormal PFTS by ethnicity (Caucasian, African-American, or Hispanic) for the three study groups. Similar percentages are found for each ethnicity.

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TABLE 1: Patient Demographics

	Active Duty (18-50 yrs)	Non-Active Duty (18-50 yrs)	Non-Active Duty (50-90 yrs)	Total
N >110%	381 (7.3%)	175 (9.7%)	356 (3.7%)	912 (5.5%)
N > 120%	93 (1.7%)	43 (2.3%)	112 (1.2%)	248 (1.5%)
Gender (Male/Female)	219/162 (57%/43%)	25/150 (14%/86%)	124/232 (35%/65%)	368/544 (40%/60%)
Age (years)	31.6 ± 9.9	35.5 ± 10.8	65.5 ± 10.8	45.6 ± 19.1
Height (inches)	67.3 ± 4.5	65.0 ± 3.4	64.4 ± 3.8	65.7 ± 4.2

Demographics for overall group as distributed by patient groups (active duty vs. non-active duty)

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TABLE 2: Comparison of PFT Values for Active Duty and Non-Active Duty Groups

	AD 18-50	**Non-AD 18-50**	**Non-AD 50-90**	**All Patients**	**P value**
Spirometry	N = 381	N = 175	N = 356	N = 912	
FEV_1 (actual)	4.15 ± 0.83	3.49 ± 0.65	2.85 ± 0.78	3.52 ± 0.97	< 0.001
FEV_1 (% pred)	112.9 ± 8.3	112.8 ± 9.1	116.3 ± 10.8	114.2 ± 9.6	< 0.001
FVC (actual)	5.10 ± 1.03	4.31 ± .80	3.68 ± 0.99	4.40 ± 1.17	< 0.001
FVC (% pred)	115.3 ± 7.6	115.7 ± 9.6	114.4 ± 9.6	115.0 ± 8.8	.202
FEV_1/FVC	81.6 ± 5.0	81.0 ± 5.0	77.7 ± 6.0	80.0 ± 5.7	< 0.001
Full PFTs	N = 60	N = 24	N = 103	N = 187	
TLC (actual)	6.51 ± 1.25	5.29 ± 0.90	5.12 ± 0.87	5.70 ± 1.31	< 0.001
TLC (% pred)	110.6 ± 15.4	110.4 ± 14.1	103.9 ± 12.1	106.9 ± 14.1	< 0.005
RV (actual)	1.31 ± 0.76	1.24 ± 0.38	1.64 ± 0.57	1.48 ± 0.65	.001
RV (% pred)	80.7 ± 51.2	78.6 ± 24.8	79.2 ± 25.2	79.6 ± 35.0	0.956
DLCO (actual)	29.16 ± 6.47	23.08 ± 5.56	18.68 ± 5.47	22.61± 7.78	< 0.001
DLCO (% pred)	83.4 ± 14.4	82.7 ± 15.8	74.5 ± 16.7	78.4 ± 18.3	< 0.005

P values were calculated using one way analysis of variance

PFT – pulmonary function testing; FEV1 – forced expiratory volume at one second; Post-BD – post-bronchodilator; FVC – forced vital capacity; FEF25-75 – mid-expiratory flow; TLC – total lung capacity; RV – residual volume; DLCO – diffusing capacity for carbon monoxide

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TABLE 3: Z Score Analysis

	AD Status		
Variable	Non-AD	AD	P-value
Actual FEV_1			<0.001[2]
N	175	381	
Mean (SD)	3.49 (0.65)	4.15 (0.83)	
Median [IQR]	3.4 [2.99, 3.82]	4.01 [3.5, 4.83]	
Actual FVC			<0.001[2]
N	175	381	
Mean (SD)	4.31 (0.8)	5.1 (1.03)	
Median [IQR]	4.15 [3.71, 4.78]	4.89 [4.27, 5.91]	
FEV_1 Zscore			0.15[1]
N	175	381	
Mean (SD)	-0.09 (0.93)	0.04 (1.02)	
Median [IQR]	-0.18 [-0.72, 0.48]	0.07 [-0.65, 0.68]	
FVC Zscore			0.36[1]
N	175	381	
Mean (SD)	-0.06 (0.98)	0.03 (1)	
Median [IQR]	-0.14 [-0.79, 0.56]	-0.02 [-0.67, 0.74]	

Z score analysis of 18-50 year old cohort by AD status and standardized to age group (18-20, 21-30, 31-40, 41-50) and gender. [1]T-test; [2]Wilcoxon Rank sum FEV_1 – forced expiratory volume in one second; FVC – forced vital capacity; SD – standard deviation;; IQR – interquartile ratio.

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TABLE 4: Pulmonary Function Testing in Elite Athletes

	N	Age	Height	FVC (Actual)	FVC (Pred)	FVC (% Pred)	FEV_1 (Actual)	FEV_1 (Pred)	FEV_1 (% Pred)
Maron[16]	12	33	174	5.58	5.18	107.7%	NA	4.20	NA
Hill[17]	12	33	177	5.33	5.37	99.3%	4.36	4.35	100.2%
Bousanna[18]	12	22	176.5	5.62	5.50	102.2%	4.64	4.57	101.5%
Kippelen[19]	13	22	179	6.12	5.58	109.7%	4.95	4.64	106.7%
Ross[20]	9	32	179	5.73	5.44	105.3%	4.63	4.41	105.0%
Denguezli[21]	9	19	176	4.85	5.27	92.0%	4.18	4.43	94.4%
MEAN	67	27	176.9	5.54	5.39	102.7%	4.55	4.43	101.6%

Comparison of baseline spirometry values (FEV1 and FVC) in elite athletes (marathoners and triathletes); FEV1 – forced expiratory volume at one second; FVC – forced vital capacity

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FIGURE 1: Percentage of Supranormal PFTS by Year

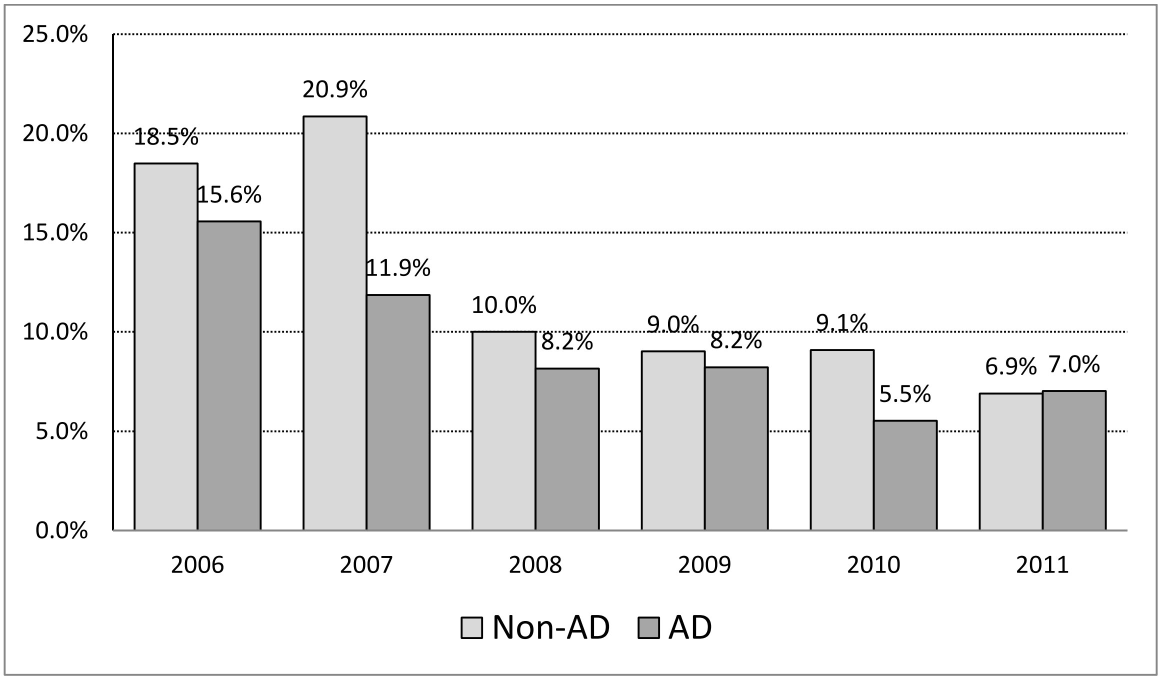

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FIGURE 2: Distribution by Age

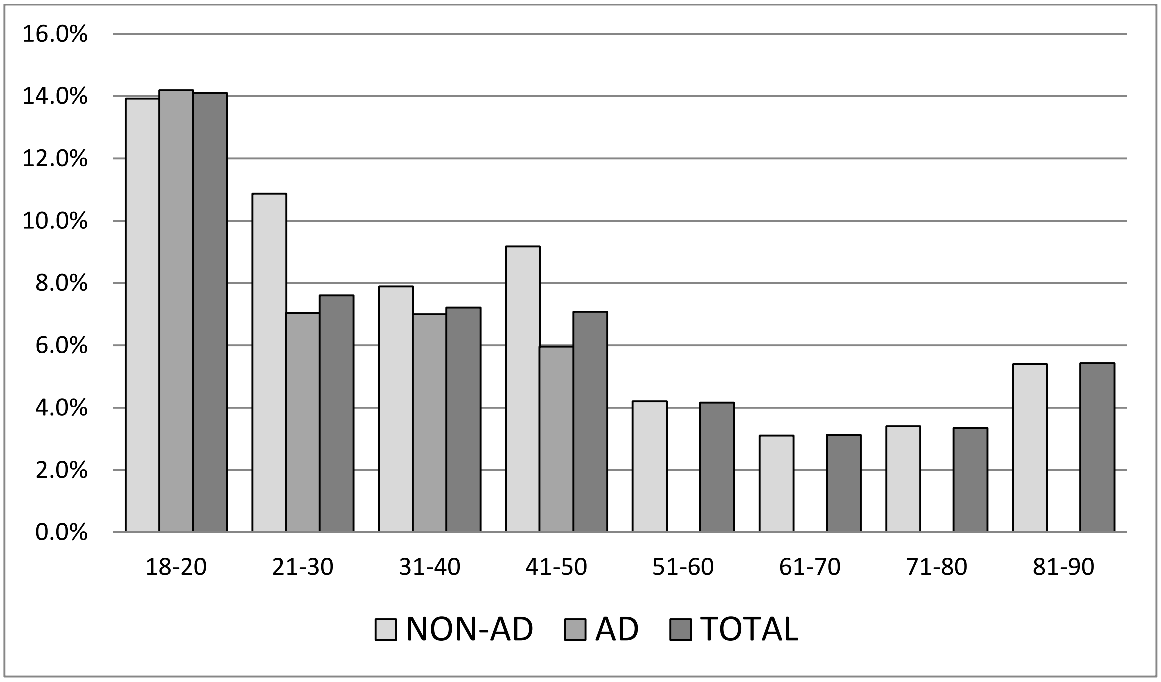

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FIGURE 3: Distribution by Ethnicity