Weighing in on Type 2 Diabetes in the Military

Characteristics of U.S. military personnel at entry who develop type 2 diabetes

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OBJECTIVES — Current incidence trends in type 2 diabetes portend a significant public health burden and have largely been attributed to similar trends in overweight and physical inactivity. Medical surveillance of the U.S. military indicates that the incidence of all types of diabetes is similar to that in the civilian population (1.9 vs. 1.6 cases per 1,000 person-years) despite weight and fitness standards. Differences in the common determinants of diabetes have not been studied in the military population, which may provide novel clues to the increasing incidence of diabetes in the U.S.

RESEARCH DESIGN AND METHODS — A case-control study, 4-to-1 matched for age, sex, entry date, time in service, and service component (e.g., Army, Navy), was used to describe the association of race/ethnicity, socioeconomic status, and BMI and blood pressure at entry into military service with the subsequent development of type 2 diabetes.

RESULTS — Increased BMI (adjusted odds ratio, 3.0 for the ≥30 kg/m² vs. ≤20 kg/m² categories and 2.0 for the 25.0–29.9 kg/m² category, compared with the reference category), African-American (adjusted odds ratio, 2.0) and Hispanic origin (adjusted odds ratio, 1.6) compared with white race and rank (adjusted odds ratio for junior enlisted versus officers, 4.1) were all associated with type 2 diabetes.

CONCLUSIONS — Individuals with type 2 diabetes in the U.S. military have risk factors similar to the general U.S. population. Because diabetes is a preventable disease, it is of concern that it is occurring in this population of younger and presumably more fit individuals. This has significant implications for the prevention of diabetes in both military and civilian populations.

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A table elsewhere in this issue shows conventional and Système International (SI) units and conversion factors for many substances.
1,000 person-years for the U.S. Marines (R. Paris, unpublished data).

Because the incidence of type 2 diabetes is expected to be lower among active, younger individuals, epidemiologic information from the military may provide important clues to the increasing prevalence of this disease among young adults and may aid in identification of risk factors for prevention among members of the armed forces. Therefore, we sought to determine whether type 2 diabetes was associated with BMI, blood pressure, and other data from physical examination records that were obtained upon entering the military.

**RESEARCH DESIGN AND METHODS**— Our study population was composed of members of the U.S. military on active-duty status between January 1997 and August 2000. We selected case and control subjects from a surveillance database that maintains information on all inpatient and outpatient records of military personnel. To obtain data on recruit characteristics such as height, weight, education, and blood pressure at entry, we merged our surveillance data with information on these individuals from the Defense Manpower Data Center, which manages all data from the Military Entrance Processing Command obtained on recruits from July 1970 (11). A total of 500 individuals with an initial diagnosis of type 2 diabetes by *International Classification of Diseases, 9th Revision, Clinical Modification* (ICD-9-CM) code between January 1997 and August 2000 were selected at random. Only individuals whose records included coding for type 2 diabetes (i.e., ICD-9-CM codes 250.00, 250.02, 250.40, 250.42, 250.50, 250.52, 250.60, 250.62, 250.70, 250.72, 250.90, and 250.92) were used as case subjects. Because ICD-9-CM codes ending in “1” or “3” denote type 1 diabetes and those ending in “0” and “2” denote type 2 diabetes, it is possible that some cases could be misclassified as type 2 diabetics if the fifth digit were not specified. To remove this possible misclassification of type 1 diabetes, we analyzed two subsets of the data, one consisting of those cases coded 250.02 only (42% of cases) and the other consisting of cases with the code ending in “2,” which gave results similar to our final multivariable model using the full data set (data not shown). A sample of 150 cases were screened for available records at our local medical treatment facility (Walter Reed Army Medical Center, Washington, DC). Of the 150 cases, records were available for 58 individuals, and data from 1997 to August 2000 were available for 29 individuals. A total of 22 cases (76%) included laboratory evidence of diabetes, and 16 of 29 individuals (55%) were taking medication for diabetes. A total of 11 of these 16 individuals were taking oral hypoglycemics (with or without insulin) and 5 were on an insulin regimen only.

A total of 2,000 control subjects were selected at random and matched on a 4-to-1 basis by the following characteristics: age within 1 year, sex, branch of service (i.e., Army, Navy, Air Force, Marines), date of entry into the military within the same month, and active duty at the time the matched case received an initial diagnosis of diabetes (to control for time in military service). Control subjects did not have a diagnosis of diabetes or diabetes-related complications at the time of selection. Race/ethnicity was analyzed by three categories: non-Hispanic whites, African-Americans, and Hispanic/other, which included people of Hispanic origin and all others who did not report being of Caucasian or African-American descent (e.g., Asians, Pacific Islanders). Rank was categorized into three classes: junior enlisted (service grades E0–E4), senior enlisted (service grades E5–E9), and officers (grades O1–O10, WO1–WO5). Rank is often used as a surrogate for socioeconomic status in epidemiologic studies of military populations and was hypothesized to be associated with diabetes in this study (12–14). This study was reviewed and approved by the Human Use Committee at the Walter Reed Army Institute of Research.

**Statistical analysis**— We estimated that our sample size required ~500 case subjects and 2,000 control subjects to reject our null hypothesis of no difference in the highest compared with the lowest quartile of BMI, which was the variable of primary interest. In the first phase of analysis, we performed bivariate and descriptive statistical tests to look for confounding and effect modification of diabetes and variables known to be associated with diabetes: BMI, race/ethnicity, and rank (as a proxy for socioeconomic status), using contingency tables, analysis of variance, Student’s *t* tests, and other exploratory data methods. We performed analyses of continuous variables by dividing BMI, systolic blood pressure, and diastolic blood pressure into quartile distributions and compared the highest and lowest of these distributions. In addition, we used a modification of the classification system for overweight and obesity based on measurement of BMI as recommended by the National Heart, Lung, and Blood Institute (15). We classified BMI into four categories: lean (<20), normal (20–24.9), overweight (25–29.9), and obese (≥30 kg/m²). This categorization provided better interpretation and fit in regression models and is reported in **results**. We used multivariable, stepwise, conditional logistic regression analysis to estimate relative risk (using odds ratios) of the association of variables of interest and then adjusted for potential confounding covariates identified in our exploratory analysis. We excluded persons with missing data from the multivariate analysis (n = 454). We performed model checking using the Hosmer-Lemeshow χ² goodness-of-fit test and applied the principle of conditional error to evaluate the most parsimonious model (16). We performed all analyses with Stata statistical software, (version 6.0; Stata, College Station, TX).

**RESULTS**— Our final data set contained 419 observations for case subjects and 1,627 observations for control subjects; 454 observations were excluded due to missing data (P = 0.71; Fisher’s exact test for difference in missing data for case versus control subjects). The mean age at diagnosis of personnel with type 2 diabetes was 35.3 years (range 18–55); these individuals had served an average of 13.6 years in the military. Of the case subjects, 86% were men, which is representative of the military population. Only 36 of our case subjects had been diagnosed with diabetes as inpatients. In bivariate analysis, diabetes was associated with a higher BMI (mean 24.0 vs. 23.1, P < 0.0001), lower rank, and minority status but not blood pressure (Table 1). There were no significant differences in BMI at entrance into military service between African-Americans (mean 23.1, SD 3.1), Hispanics (mean 23.7, SD 3.2), and whites (mean 23.3 kg/m², SD 3.0) (P = 0.07, one-way analysis of variance). Also, there were no significant differences in BMI between rank at the time of diagnosis.
(or matching for controls) and BMI at entry into the military; the mean was 23.2 (2.8) for officers, 23.5 (3.4) for junior enlisted, and 23.2 kg/m² (3.0) for senior enlisted (P = 0.11, Mann-Whitney U test).

In multiple logistic regression analysis, BMI, rank, and race/ethnicity were associated with type 2 diabetes (Table 2). The association with BMI increased by category: for comparison of overweight and lean categories, the odds ratio was 2.0 (95% CI 1.4–3.0), and for comparison of obese and lean categories, the odds ratio was 3.0 (95% CI 1.4–6.4). In a survival analysis of individuals in whom diabetes developed, persons classified as obese or overweight by BMI measurements had fewer years of military service than those with normal or lean BMI at entry into the military (P < 0.0001 by log-rank test).

In our final model, from which we present our adjusted estimates, we included only those covariates (rank, race/ethnicity, and BMI) that remained statistically significant and provided the best fit to the data by model testing. Rank had the strongest association with diabetes and increased in a dose-response manner. The odds ratio for junior enlisted (the lowest ranking members) was 4.1 (95% CI 1.9–9.3) compared with officers and 2.7 (95% CI 1.5–5.0) for senior enlisted compared with officers. Education level and scores on aptitude tests did not seem to be potentially confounding variables, because adjustment for these variables had little effect on the association between diabetes and rank (data not shown). Some of the association between rank and diabetes could also be due to differences between rank and minority status. There were significantly fewer African-American (53 or 10.7%) or other of African-Americans (424 or 85.7%) compared with whites of African-Americans only, the effect of rank persisted: the odds ratio (compared with officers) was 5.1 (95% CI 0.2–108.1) for junior enlisted and 2.4 (95% CI 0.4–15.6) for senior enlisted. Among whites, the odds ratio was 5.5 (95% CI 1.7–17.6) for junior enlisted and 3.3 (95% CI 1.5–7.9) for senior enlisted. Among Hispanic and other ethnicities, the odds ratio was 2.2 (95% CI 0.3–18.1) for junior enlisted and 1.2 (95% CI 0.1–12.0) for senior enlisted. Although some of the CIs include one (except for whites), the magnitude of association seems consistent. In addition, minorities had a higher risk of diabetes: adjusted for rank and BMI, the odds ratio was 2.0 (95% CI 1.6–2.6) for African-Americans and 1.6 (1.1–2.4) for Hispanic and other ethnicity groups combined.

There was no association between either systolic or diastolic blood pressure at entry and subsequent development of diabetes (data not shown). We found no difference between unadjusted and adjusted odds ratios for BMI and diabetes. It must be noted that our unadjusted values are “adjusted” by matching on sex, age, branch of military, and length of service.

CONCLUSIONS — Our results mirror those of other epidemiologic studies of type 2 diabetes, namely the well-recognized associations with BMI, race/ethnicity, and rank as a surrogate for socioeconomic status (8). The incidence rate for diabetes in the military in two prior analyses is the same or higher than that obtained from a similarly aged civilian population (6,10). Whether this is due to differences in case definition, bet-

<table>
<thead>
<tr>
<th>Variable</th>
<th>Case subjects (n = 419)</th>
<th>Matched control subjects (n = 627)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age at diagnosis (years)</td>
<td>35.3 (8.0)</td>
<td>35.2 (8.0)</td>
<td>NS</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>24.0 (3.3)</td>
<td>23.1 (2.9)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Systolic blood pressure (mmHg)</td>
<td>121.1 (13.8)</td>
<td>121.3 (13.2)</td>
<td>NS</td>
</tr>
<tr>
<td>Officer</td>
<td>60 (12)</td>
<td>435 (22)</td>
<td>Ref</td>
</tr>
<tr>
<td>Senior enlisted</td>
<td>333 (67)</td>
<td>1,180 (59)</td>
<td>&lt;0.001 *</td>
</tr>
<tr>
<td>Junior enlisted</td>
<td>107 (21)</td>
<td>385 (19)</td>
<td>&lt;0.001 *</td>
</tr>
<tr>
<td>White</td>
<td>262 (52)</td>
<td>1,401 (70)</td>
<td>Ref</td>
</tr>
<tr>
<td>African-American</td>
<td>175 (35)</td>
<td>438 (22)</td>
<td>&lt;0.001 *</td>
</tr>
<tr>
<td>Hispanic/others</td>
<td>62 (12)</td>
<td>156 (8)</td>
<td>&lt;0.001 *</td>
</tr>
<tr>
<td>Missing</td>
<td>81 (16)</td>
<td>373 (19)</td>
<td>NS*</td>
</tr>
</tbody>
</table>

Data are means (SD) for continuous variables and n (%) for dichotomous variables. *Fisher’s exact test. NS, not significant, Ref, reference comparison group.
ter case ascertainment (overweight individuals in the military are referred for evaluation and there is universal medical coverage), or inadequate levels of physical activity and/or weight standards that are not enforced strictly is unclear and cannot be determined from the present study. What is unique, and perhaps surprising, is the population from which these results were obtained. Military personnel are presumably healthier and more physically active than the general U.S. population. Military personnel are required to maintain weight/height and fitness standards, which vary between services. In the U.S. Army, all personnel are mandated to participate in physical training programs year-round, maintain a minimum level of physical fitness, and undergo testing (sit-ups, push-ups, and 2-mile run) two times per year. Soldiers, without medical conditions that prohibit participation, who repeatedly fail the physical fitness test are barred from re-enlistment or separated from service. Special physical fitness programs are available in addition to body composition/weight control programs for those who are overweight. Interestingly, one recent survey found that levels of physical activity and prevalence of overweight among military members were similar to the general population. In this study, U.S. Navy and Air Force personnel were less likely to engage in physical activity (three or more times per week) than U.S. Army or Marine Corps personnel (17). This is one plausible hypothesis that may explain the differences in rates of diabetes between military services. Despite the lack of physical activity data, increased BMI at entry into military service during late adolescence and early adulthood is associated with diabetes, suggesting that adequate physical activity levels were either not achieved and/or not maintained in this population.

It is well recognized in epidemiologic studies that association does not imply causality. However, the associations described in this study are consistent with Hill’s criteria (18). Namely, the strength of the associations observed (odds ratios >2.0), evidence of a dose response (for both BMI and rank), coherency with other studies, and biologic plausibility. The biologic plausibility of overweight and obesity is well established, being largely mediated through the mechanism of insulin resistance (19). The existence of socioeconomic variation in disease occurrence strongly suggests environmental determinants of risk. It is unclear what this means in terms of actual exposures. For chronic diseases, this is believed to be explained in part by differences in risk factors that cluster with social class or socioeconomic status (except for access to medical care in this situation) (20,21). The effects of social class on diabetes may therefore be explained in part by the inverse gradient associated with BMI (22) and gains in BMI (23) and attendant insulin resistance, low birth weight (24,25), and nutrition (26,27).

Inferences from our study are limited for several reasons. Misclassification bias (of outcome) probably occurred, because our case definition relied on individual physicians and the criteria they used to diagnose diabetes. Only a small number of medical records were available for review; therefore, some of our cases may have had type 1 diabetes. However, it is likely that this misclassification was nondifferential and would tend to bias estimates toward the null (18). The possibility also exists that diabetes may have been present and undiagnosed at entry into the military, which may have occurred in a few cases, but is unlikely in the majority, because the mean number of years served was 13.6 at the time of diagnosis and any prevalent cases would probably have been detected earlier. Systematic (nonrandom) and nonsystematic error in measurement of certain variables, particularly blood pressure, height, and weight, probably occurred, because uniform quality-control measures do not exist throughout all military entrance processing stations, resulting in misclassification bias (of exposure). Again, this is most likely nondifferential bias because disease status was unknown at the time of measurement. The possibility of residual confounding exists in both measured and unmeasured risk factors such as family history, weight patterns, and exercise. Physical activity levels, although likely part of the causal pathway with diabetes and obesity (and thus not technically a confounder) were not assessed but would provide important information about the incidence of diabetes in this population (28). External validity, although less important, is limited by the demographics of our study population, because military personnel are younger, include more men (86%) than women, and include more African-Americans (~20%) than the general population but a similar number of Hispanic-Americans (29).

This study has important potential implications. For the U.S. military, it suggests that levels of acceptable body fat at entry, and perhaps during military service, may be too high (this standard may be waived when personnel are in critical shortage). For example, in the U.S. Army, acceptable body fat and weight levels increase with age for both men and women in conjunction with the risk of diabetes and allow higher acceptable levels of BMI compared with published U.S. guidelines (15,30). Considering the national trends of increased prevalence of obesity and diabetes, this may become problematic for military recruitment, retention, and readiness. Although not examined, physical activity levels likely played a role in the development of diabetes. It is possible that the activity levels required to meet fitness standards in the military are inadequate to prevent diabetes or that moderate to high levels of physical activity are inadequate to prevent diabetes in a younger population at higher risk. This and other alternative hypotheses, to include hereditary factors, occupational and environmental exposures, and other risk factors, must be explored. Investigation of diabetes in the military may provide a unique opportunity to study both the current epidemic of type 2 diabetes affecting young Americans and important information on the effectiveness of required weight control and exercise in the prevention of this disease in a burgeoning epidemic.

References

5. Headquarters Department of the Army:
Type 2 diabetes in the U.S. military