Obesity in the UK Armed Forces: Risk Factors

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ABSTRACT Objective: To assess the risk factors of obesity in terms of body mass index (BMI) and waist circumference in the UK Armed Forces. Methods: A quota sample from all UK services, of 2,448 men and 311 women aged 17–55 years. Results: The risk ratios for those with a BMI ≥27.5kg/m^2 and waist circumference ≥94 cm in men were 0.21 (95% confidence interval [CI], 0.13–0.34) for non-whites compared to whites, 0.55 (95% CI, 0.38–0.78) for commissioned officers compared to lower ranks, and 0.13 (95% CI, 0.06–0.31) for Royal Marines compared to the Army, but increased with age, 58.2 (95% CI, 19.6–172.7). Risk ratios were usually nonsignificant between service-demographic factors for BMI ≥27.5 kg/m^2 and waist circumference < 94 cm. Conclusions: The risk of obesity is highest in the Army and Royal Navy, whites, lower ranks, and older ages. BMI and waist circumference should be used together as measures of obesity.

INTRODUCTION

The socio-demographic risk factors for obesity are well known in the general population,[1,2] but less so in the military population. It would be expected that an emphasis on fitness to fulfill military duties in a predominantly mobile young population would decrease the risk of obesity in the Armed Forces.[3] The fact that the Armed Forces over recruit from more disadvantaged sections of the population might decrease this effect[4] as obesity is more common in lower social classes, especially in women.[2]

Studies of U.S. service personnel report that obesity based on a body mass index (BMI) of 30 kg/m^2 or over more than doubled from 1995 to 2005.[5] Over the last 10 years, U.S. service personnel receiving a clinical diagnosis of being overweight has increased in all age groups.[6] Obesity is now estimated to be 12.4% in the U.S. Armed Forces.[5] This is a cause for concern because obesity is an exclusion factor for a military occupation in the United States, with maximum allowable weight requirements for different branches of the service corresponding to BMI of 25.9 to 29.9 kg/m^2.[7–9] We report about the prevalence of obesity in the UK services in a companion article.[10]

There is little information on obesity in the UK Armed Forces and the risk factors that would modulate its prevalence. The available information in those presenting for national service in Portugal, Israel, and Germany have shown an association between level of education and obesity, but these studies were carried out in populations with a low prevalence of obesity.[11–13] The military circumstances of serving personnel are different from those conscripted for National Service because all volunteer militaries will differ substantially from those based on universal conscription. In the UK Armed Forces, the entry guidelines for BMI and waist circumference were modified in February 2008. Acceptable BMI ranges from 18 to 28 kg/m^2 for both sexes from age 18, but the maximum may be 32 kg/m^2 for males and 30 kg/m^2 for females with additional tests of waist circumference and fitness. Waist circumference must be less than 94 cm in males and 80 cm in women. BMI requirement in those less than 18 years is more stringent with the maximum being 27 kg/m^2.[14]

A drawback to the assessment of obesity based on BMI in the military is that its increase may correspond to an increase of fat-free mass, but not fat mass.[3,15] Thus, it is possible that an individual is large, but not obese. The lack of specificity of BMI in the military may be problematic because muscle mass may be a greater component of BMI in the military than in the general population. BMI and waist circumference are the only 2 feasible measures to assess obesity in population studies and in clinical settings in the Armed Forces. We have recently demonstrated that the level of agreement between BMI and waist circumference in Army personnel is high for values representing overt obesity, but agreement decreases for decreasing values of BMI and waist circumference.[16] Although waist circumference has recently been preferred over BMI as an assessment of obesity,[17] both perform equally well in their association with known outcomes of obesity such as blood pressure and insulin-mediated glucose uptake.[18,19]

The aim of this study was to assess the level of association between service-demographic risk factors and obesity, as assessed by BMI and waist circumference, stratified by sex. Of particular interest is whether the pattern of risk factors was consistent in relation to those with only high BMI and those who had high BMI and high waist circumference.

METHODS AND PROCEDURES

Sampling

The study was approved by the QinetiQ ethics committee and also by the Ministry of Defence Research Ethics Committee. Service personnel were briefed about the study and asked to give signed consent.

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QinetiQ carried out a study during 2006–2007 for the Ministry of Defence with the purpose to provide up-to-date anthropometric data that could be used to inform acquisition of equipment and clothing.[20] Data collection was conducted over a 27 working-week period between April 2006 and October 2007. A quota sample design was used to ensure that information on most groups of the UK Armed Forces would be available. The proposed target was to collect information on 4,500 service personnel with at least 1,000 from each service with the outstanding balance from the Army. Women were oversampled for the overall ratio men to women to be 3:1 (the ratio in the UK Armed Forces is 10:1).[20] This corresponded to 3.6% of the Royal Navy, 13.5% of the Royal Marines, 1.5% of the Army, and 2.1% of the Royal Air Force (RAF).[21] A further consideration was to sample 200 Gurkhas as it is an ethnic minority with a large contingent in the UK Armed Forces. The study strategy was to obtain a large quantity of information for each of the specified groups. Quota sampling, by the groups specified, fulfilled the requirement to have sufficient information for each service, women, and Ghurkas. The UK Armed Forces were at an unprecedented level of activity during the duration of the survey in 2007, which meant that the total sample assessed in the study was 2,470 instead of the planned 4,500 because a large percentage of the personnel selected for the study were away from their bases during the visits. The planned male:female ratio of 3:1 was not fully reached and the final ratio studied was 7:1. The final percentage assessed by service was 1.9% of the Royal Navy, 2.4% of the Royal Marines, 1.1% of the Army, and 1.4% of the RAF.

Data Collection

Information on sex, age, service, ethnic origin, and rank were collected via a self-administered questionnaire. All measurements were taken with males wearing light briefs only and females wearing a sports bra and pants. A latex skull cap was fitted before scanning because hair impeded a good scanning image. Height was measured with the subject standing erect, looking straight ahead as the vertical distance from the floor to the top at vertex delimited by a straight headpiece. Body mass was assessed with the subject standing erect, looking straight ahead on the platform of an electronic digital scale. Waist circumference was measured using a three-dimensional whole body light scanner (Textile Clothing Technology Corporation [TC]^2, Cary, NC). This was carried out by projecting a shining light onto the body, the reflection of which was used as data points to build a three-dimensional picture of the body. The measurement was taken at the mid point between lower rib and iliac crest. There was a high correlation between the waist circumference scanning measurements and waist circumference measurements taken with a tape in 212 subjects ($R^2 = 0.99$).

Statistical analysis

As we looked for equivalent thresholds of obesity for both BMI and waist circumference, we used a BMI of 27.5 kg/m^2 and waist circumference of 94 cm in men and 84 cm in women. A BMI of 25 kg/m^2 would have identified too many service personnel, 50% of the sample, while a threshold of 30 kg/m^2 would have identified only 13% (Table I). We decided to use these thresholds based on the National Institute for Health and Clinical Excellence recommendations for waist circumference in men,[22] but we increased the threshold from 80 to 84 cm in women to identify 23.6% of our sample. This resulted in a comparable prevalence of obesity to that reported for men. Analyses were carried out using logistic and multinomial logistic regressions.[23] Logistic regressions were used to assess the association between service-demographic factors and obesity assessed as high BMI or high waist circumference. Multinomial logistic regression is an extension of multiple logistic regression analysis for assessing the combined effects of 2 outcomes, in our study, BMI and waist circumference. By using this method, we assessed whether the service-demographic factors had a similar pattern of associations with those who have a high BMI, those who have a high waist circumference, and those who have both a high BMI and a high waist circumference. The small number of women was insufficient to allow us to carry out multinomial logistic regression. Statistical significance was set at 0.05. We also assessed the goodness of fit of our models.[24] Analyses were performed using the statistical software package STATA (Stata Corporation, College Station, TX).

RESULTS

Table I shows the distributions of the variables in our study. The mean age for men in our sample was 28.3 years (SD = 7.6) compared to 30 years of the total UK Armed Forces. The 12% of commissioned officers in men was slightly below the 16% of the total UK Armed Forces. Age was presented as a 10-year interval (age/10) to make odds ratios (ORs) more interpretable. The ethnic distribution reflects the predominantly white ethnicity of the services, with the Gurkhas making the largest non-white male contribution to the Armed Forces.

The distributions of BMI and waist circumference by sex showed that 30.5% of men and 27.1% of women had a BMI greater than 27.4 kg/m^2, and 23.5% of men had a waist circumference greater than 93.9 cm and 23.6% of women had a waist circumference greater than 83.9 cm (Table I). 13.5% of men and women had a BMI of 30 kg/m^2 or greater (Table I).

Table II shows the pattern of associations using multiple logistic regressions in men and women. The risk of obesity greatly increased with age in both sexes, but especially for men. A quadratic term for age was statistically significant in men, indicating sudden increase in obesity with age, which continued to increase in older ages, but at a lower rate. In women, the association between age and obesity was linear. Commissioned officers had a lower risk of obesity in both sexes. Non-white men and those in the RAF and the Royal Marines were less likely to be obese.

Table III shows the results of the multinomial logistic regression only in men. The effect size of age on "obesity" was greatest in the group with high BMI and high waist

TABLE I. Descriptive Characteristics of the Sample, Stratified by Gender

Variable	Men (n = 2,148)[a], N (%) or m [95% CI]	Women (n = 311)[a], N (%) or m [95% CI]
Age (Years)	28.3 [28.0–28.7]	26.4 [25.7–27.0]
Ethnicity		
White Caucasian	1,870 (87.1)	289 (92.9)
Asian	20 (1.0)	5 (1.6)
Gurkhas	188 (87.5)	0
Black African or Caribbean	60 (2.8)	9 (2.9)
Other Non-White	9 (0.4)	8 (2.6)
Service		
Naval Service	454 (21.1)	91 (29.3)
Royal Marines	181 (8.4)	0
Army	1,003 (46.7)	84 (27.0)
RAF	510 (23.7)	136 (43.7)
Rank		
Non-Commissioned	1,897 (88.3)	266 (85.5)
Officer	251 (11.7)	45 (14.5)
BMI (Units)	26.1 [25.9–26.3]	25.3 [24.9–25.8]
BMI		
Normal Range	905 (42.1)	169 (54.3)
25 to 27.4	588 (27.4)	58 (18.7)
27.5 to 29.9	366 (17.0)	44 (14.2)
Obese (30 or Over)	289 (13.5)	40 (12.9)
Waist Circumference (cm)	87.7 [87.2–88.1]	78.2 [77.3–79.2]
Waist Circumference		
Normal Range (Up to 93.9 cm Men and 79.9 cm Women)	1,582 (76.4)	194 (62.6)
Risk of Obesity (males 94 to 101.9 cm men and 80 to 87.9 cm women)	307 (14.8)	77 (34.8)
Women (80 to 83.9cm)	N/A	43 (13.8)
Women (84 to 87.9cm)	N/A	34 (11.0)
Obese (Males 102 or Over; Women 88 or Over)	181 (8.7)	39 (12.6)

N, Number of Observations; %, Prevalence for Categorical Variables; m, Mean for Continuous Variables; N/A, Not Appropriate. [a]Numbers may not equal totals because of missing data.

TABLE II. Multiple Logistic Regression of Socio-demographic Predictors of High BMI (27.5 or Over) and High Waist Circumference (94 cm or Over Men and 84 cm or Over Women). Each Estimate Adjusted for the Other Factors in the Analysis

	High BMI or High Waist Circumference	
Predictors[a]	Men (754/2,148), OR (95% CI)	Women (97/311), OR (95% CI)
Age (as a 10-year Interval)	24.29 (9.91–59.53)***	2.02 (1.33–3.07)**
Age (as a 10-year Interval), Quadratic Term[b]	0.70 (0.61–0.81)***	Not Needed
Services		
Naval Service	0.98 (0.76–1.26)	0.98 (0.51–1.87)
Royal Marines	0.41 (0.26–0.63)***	Not Available
RAF	0.66 (0.51–0.85)**	0.68 (0.37–1.26)
Rank		
Officer	0.59 (0.44–0.80)**	0.39 (0.17–0.88)*
Ethnicity		
Gurkhas	0.49 (0.29–0.83)**	Not Available
Other Non-whites	0.36 (0.24–0.53)***	1.22 (0.48–3.09)

[a]Reference groups lowest 10 years, Army, lower ranks, whites. [b]A quadratic term was significant in men, but not in women. *$p < 0.05$. **$p < 0.01$. ***$p < 0.0001$.

circumference, but the 95% confidence interval (CI) of the linear term was wide in the 3 groups. Men in the RAF were less likely to be obese than men in the Army, regardless of outcome group; Royal Marines and non-whites were markedly less likely to be obese in the group with high BMI and high waist circumference. Commissioned officers were less likely to be obese if the outcome was high waist circumference or if the outcome was high BMI and high waist circumference.

DISCUSSION

The risk of obesity markedly increases with age and in lower ranks for both men and women, white men compared to other

TABLE III. Multinomial Regression of Socio-demographic Predictors of High BMI (27.5 or Over) and High Waist Circumference (94 cm or Over) in Men. Adjusted for the Other Factors in the Analysis

Predictors[a]	Outcome, RRR (95% CI)		
	High BMI Only (n = 188)	High Waist Circumference Only (n = 99)	High BMI & Waist Circumference (n = 467)
Age (as a 10-year Interval)	20.29 (3.42–120.29)**	22.7 (3.44–150.44)**	58.16 (19.59–172.65)***
Age (as a 10-year Interval), Quadratic Term	0.65 (0.48–0.87)**	0.76 (0.58–1.00)	0.63 (0.53–0.74)***
Services			
Naval Service	1.22 (0.82–1.81)	0.67 (0.37–1.20)	0.96 (0.71–1.29)
Royal Marines	0.91 (0.53–1.56)	0.57 (0.22–1.52)	0.13 (0.06–0.31)***
RAF	0.51 (0.32–0.83)**	0.52 (0.29–0.93)*	0.73 (0.54–0.97)*
Rank			
Officer	0.83 (0.50–1.38)	0.49 (0.24–0.98)*	0.55 (0.38–0.78)**
Ethnicity			
Non-whites	0.72 (0.45–1.15)	0.71 (0.37–1.37)	0.21 (0.13–0.34)***

RRR, Relative Risk Ratios; n, number of observations. [a]Reference categories in the analyses lowest 10 years, Army, lower ranks, whites. *$p < 0.05$. **$p < 0.01$. ***$p < 0.0001$.

ethnic groups, and men in the Royal Navy and Army compared to men in the Royal Marines and the RAF. The multinomial analysis demonstrated that the risk of obesity in commissioned officers, non-white males, and Royal Marines greatly decreased when high BMI and high waist circumference were used to define obesity. This pattern of lower risk of obesity for officers, non-white males, and Royal Marines was not observed when high BMI but low waist circumference was the outcome.

The strategy in this study was to purposely look for equivalent thresholds of obesity in terms of prevalence for BMI and waist circumference in men and women. A BMI greater than 27.5 kg/m^2 and waist circumference greater than 94 cm in men and greater than 84 cm in women as cut offs gave similar percentage of "at least at risk" of obesity for each measure in both sexes.

The study demonstrated that obesity is common in the UK Armed Forces with a prevalence of 13%, but lower than in the age range 16 to 54 years of the general population with a prevalence that varies from 16 to 26%.[2] Friedl[3] has advised caution against a diagnosis of obesity based solely on BMI, as it could correspond to an increase in free-fat mass rather than fat mass. This was the rationale for using multinomial analyses, which we were only able to carry out in men, as the number of women in the study was small. As in our study, 71% of those with a high BMI had also a high waist circumference; there was some certainty that for the great majority high BMI would also entail an increase of fat mass. However, there was also a high prevalence (29%) of subjects who had a high BMI with a waist circumference below 94 cm. This would indicate that health staff in the military should base a diagnosis of obesity only after evaluating both BMI and waist circumference. This practice is further backed by the varying limits of agreement between BMI and waist circumference as shown in a previous study.[16] In that study, it was shown that the agreement between these measures increased with increasing values of BMI and waist circumference. Thus, a BMI greater than 30 kg/m^2 usually coincided with a waist circumference greater than 102 cm in men, but the agreement between these measures decreased in those with a BMI between 25 and 29.9 kg/m^2. The most remarkable finding in our study was that some groups such as commissioned officers, the Royal Marines, and non-white men are at much lower risk of having high BMI and high waist circumference compared to those having high BMI only. The most plausible explanation for such a difference is that those with high BMI not accompanied by high waist circumference may represent a group in which a large percentage has high free-fat mass but not excess fat mass.

The prevalence of obesity in our study is similar to the finding in the U.S. Armed Forces, although their estimates were based on reported height and body mass only,[4] which may underestimate the prevalence of obesity.[25–27] The low prevalence of obesity in other military-based studies of individuals presenting for compulsory military service is not comparable to our study as they correspond to obesity rates in 17 and 18 year olds, and obesity greatly increases with age.[11–13]

There is a large difference in the prevalence of obesity between the social classes in women, but it is less apparent in men in the general population.[2] We would have expected that in the UK Armed Forces, a predominantly male population, there would be only small differences in the prevalence of obesity by rank, a proxy measure of social status.[28] However, our study indicates that high BMI and high waist circumference were more common in other ranks than in commissioned officers.

It is of concern that obesity markedly increases with age in the Armed Forces because it implies that obesity for these service personnel started while serving in the Armed Forces. As we looked at the 10-year increase of obesity, we estimate that obesity becomes common from age 30 onwards. The problem is particularly serious in non-commissioned officers because obesity was lower in commissioned officers who are usually contracted to serve for a long period of time and because lower rank service personnel tend to exit the Armed Forces earlier if

they are not promoted. Obesity in non-commissioned officers may have a knock-on effect because they act as role models to younger personnel. Overall, obesity occurs despite military training to keep fit, perhaps reflecting a poor choice of food and excess energy intake compared to energy expenditure.

In this study, the problem is particularly serious in the Royal Navy and the Army as risk ratios were well above those found in the Royal Marines and RAF. A high prevalence of obesity in the U.S. Navy has previously been reported[5] and has been explained by the long time that personnel need to spend in the confined space of ships. However, the U.S. Army was not at a higher risk of obesity.[5] The problem may be compounded because in our multinomial analysis, the risk of obesity defined as high BMI and high waist circumference was low in Royal Marines, between 7 and 8 times lower, nearly 5 times less in non-white ethnic groups, and half as likely among commissioned officers. These large effect sizes were not observed in subjects with only high BMI. Thus, we could characterize personnel at high risk of obesity as more than 30 years old, white, non-commissioned officer, and more likely to be in the Royal Navy and the Army.

Strengths of this study included the large sample size, which included all services, ranks, and ethnic groups of regulars of the UK Armed Forces. It was based on measured body mass, height, and waist circumference rather than on reported measurements that may be subject to underreporting bias.[25–27] Risk factors were adjusted for the remaining factors in the analyses, and thus are likely to be genuine effects of factors in the analyses.

Weaknesses of this study included that the sample was not representative of all the UK Armed Forces and our results should be extrapolated with care. The selection of personnel was based on availability rather than on any particular characteristic associated with obesity. The studied sample was younger and had a lower percentage of commissioned officers than the total Armed Forces.[29] It may have been construed that a sample of 2,549 out of the aimed 4,500 men and women is a poor response rate. However, the study was carried out during 2006–2007, a period of great activity in Iraq and Afghanistan, which entailed that many of those in service were in the process of being deployed or carrying out activities in preparation for deployment. The study had insufficient numbers to be able to look at non-white ethnic groups separately, and it is possible that subtle differences in risk of obesity may exist between these sub-groups. The study was cross-sectional; thus, we have to be careful to infer causality. However, with the exception of age, the independent variables are highly stable in the Armed Forces because individuals who changed service in a 3-year period or were promoted from lower ranks to commissioned officer are low, 10 (0.1%) and 150 (1.9%), respectively.[30] In relation to age, the results would be more problematic if obese subjects were less likely to be recruited into the services now compared to say 10 years ago, an unlikely change in recruitment policy.

Obesity is a problem in the UK Armed Forces, and resources could be devoted to validate BMI and waist circumference with gold standards of fatness, such as dual X-ray absorptiometry, to appraise the sensitivity and specificity of BMI and waist circumference in UK service personnel. The U.S. Armed Forces has carried out a validity study and used a set of equations to diagnose obesity.[3,31] However, we would not recommend extending it to the UK Armed Forces without a proper validation in a UK sample because its implementation would entail the use of several measures and the equations do not provide 95% CI to assess the accuracy of these estimates. Another implication from our results is that the use of BMI as the sole tool to diagnose obesity in the Armed Forces is flawed and misdirects resources to modify BMI in service personnel who do not have excess fat. This may be more problematic in those with a BMI between 25.0 and 29.9 kg/m^2 than in those with a BMI greater than 29.9 kg/m^2.[16] The third major implication from our results is that the risk of obesity varies by age, rank, service, and ethnicity in the Armed Forces. Thus it would be possible to target resources according to risk. In conclusion, there is large variation in risk of obesity according to service-demographic factors in UK Armed Forces. BMI alone may over diagnose obesity in Royal Marines and commissioned officers. Age is a major risk factor of obesity in the Armed Forces. It is necessary to implement guidelines to prevent and manage obesity in the Armed Forces and to use both BMI and waist circumference to diagnose obesity in the military, especially in the BMI range of 25 to 29.9 kg/m^2.

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