Accuracy of body mass index in volunteer firefighters

J. Ode, J. Knous, R. Schlaff, J. Hemenway, J. Peterson and J. Lowry

Department of Kinesiology, College of Health and Human Services, Saginaw Valley State University, University Center, MI 48710, USA

Correspondence to: J. Ode, Department of Kinesiology, College of Health and Human Services, Saginaw Valley State University, 7400 Bay Road, University Center, MI 48710, USA. Tel: 989 964 7331; fax: 989 964 4024; e-mail: jjode@svsu.edu

Background
Obesity is prevalent among career firefighters and may contribute to heart attacks, a leading cause of on-duty fatalities. The US National Fire Protection Association estimates that 800,000 of 1.1 million firefighters are volunteers. Body mass index (BMI) is commonly used to assess obesity, but little is known about its accuracy in volunteer firefighters, in whom muscle mass may be higher, given firefighting’s physical demands, reducing its accuracy in identifying obesity.

Aims
To evaluate the accuracy of BMI in identifying obese volunteer firefighters.

Methods
Height, weight and body composition were measured in 73 male volunteer firefighters (mean age 40 ± 12). The proportions with BMI ≥ 25 kg/m², ≥30 kg/m² and percent fat ≤ 20th percentile were determined. Using the age-specific 20th percentile for percent fat (Cooper Clinic) as the criterion for being over-fat, the accuracy of BMI was assessed using sensitivity and specificity calculations.

Results
The means ± standard deviation of BMI and percent fat were 32 ± 6 and 25 ± 5, respectively. The proportions with a BMI ≥ 25 and ≥30 were 90% and 60%, respectively. Fifty-one percent had a percent fat ≤ 20th percentile. The measure BMI ≥ 25 had a perfect sensitivity (1.0) and low specificity (0.19) and BMI ≥ 30 had a high sensitivity (0.89) and moderate specificity (0.69).

Conclusions
Although BMI ≥ 30 accurately predicted being over-fat, it misclassified large and lean firefighters. Although BMI should be used cautiously, it can identify over-fat firefighters at risk of cardiovascular disease, and its measurement is cost-effective and simple.

Key words
Body mass index, obesity, percent fat, volunteer firefighters.

Introduction
Heart attacks are the leading cause of fatalities on-duty in US firefighters, and the Centers for Disease Control and Prevention report that heart disease is responsible for 45% of on-duty fatalities in firefighters [1]. Although physical stress and overexertion contribute to the high prevalence of heart attacks, a recent systematic review indicated a high prevalence of cardiovascular disease (CVD) risk factors in firefighters [2], which may contribute to heart attack mortality rates. Obesity, a prevalent CVD risk factor among US adults [3], may contribute to the CVD-related events in firefighters. Previous studies indicate the mean body mass index (BMI) among career (i.e. paid, professional) firefighters consistently falls within the overweight or obese category [4–14]. Fewer studies that have assessed body composition have found an average percent fat between 14 and 25% [5,7,9,11,15,16].

According to the National Fire Protection Association, there are 1.1 million firefighters in the USA of whom 756,400 (69%) are classified as volunteers [17]. This increased reliance on volunteers, and the impact of obesity on CVD-related events illustrates a need to evaluate obesity within this sample. Previous research has primarily focused on career firefighters [4–9,12], and only three studies have evaluated obesity in volunteers [9,18,19]. Similar to the results in career firefighters, these studies indicate overweight prevalence rates higher than that in the general US population [9,18,19]. Furthermore, the study by Poston et al. [9], the only one to assess body composition, found the average percent fat was 26% in volunteer firefighters. Given the increased reliance of volunteer firefighters and the limited knowledge about the
obesity problem in this population, additional data are needed to evaluate obesity in this group.

Another emerging issue is that despite the increase in obesity, fewer overweight individuals perceive themselves as overweight [20]. This has been demonstrated in male career firefighters. Baur et al. [15] found that 67% of overweight firefighters perceive themselves as normal weight, while 8% of obese firefighters perceive themselves as obese. Therefore, male firefighters often perceive their BMI classification status to be lower than their measured classification, making it important to identify obesity in this population objectively.

Given the importance of objectively measured height and weight when calculating BMI, it is imperative to examine its accuracy in identifying excess body fat. Obesity classification often uses BMI as a surrogate for percent fat; adults with BMI ≥ 30 are considered to have elevated percent fat and are at increased risk for developing CVD. Published estimates for classifying obesity in men (aged 20–59 years) according to percent fat range from 23–28% [21]. However, the BMI classification system and percent fat cut-off point for obesity were developed using general adult populations, making it possible that these classifications are not accurate in specific populations such as firefighters. Firefighting is a physically demanding job that requires muscular strength, so BMI may be an inaccurate measure of percent fat given the elevated muscle mass required for the profession. A recent study sample of career firefighters [9,22] evaluated the accuracy of BMI as a measure of over-fat. The authors limited the evaluation of the accuracy of BMI to career firefighters with percent fat < 25 and found that 12% of those classified as overweight by BMI had a percent fat < 18 [22]. These results are consistent with athletic populations as BMI also misclassifies a large percent of athletes due to elevated muscle mass [23]. To our best knowledge, this is the only study that has examined the accuracy of BMI in firefighters, and additional information is needed on volunteers and firefighters with elevated percent fat.

Given the high prevalence of on-duty heart attacks and obesity in firefighters, it is important to evaluate whether BMI is an accurate measure of percent fat. Furthermore, there is limited knowledge regarding obesity in volunteer firefighters. Therefore, the purpose of this study was to evaluate the accuracy of BMI in identifying obese volunteer firefighters.

**Methods**

The fire department used in the analysis serves ~40 000 people in a residential/commercial community, uses 90 volunteer firefighters and receives ~800 calls annually. Volunteer firefighters attending a department meeting were invited to participate in the study. All data were anonymized after the completion of testing, and the study was approved as exempt by the Institutional Review Board.

Measures were completed at a local fire station during a monthly department meeting. Subjects wore athletic clothing without shoes for all measurements. Standing height was measured to the nearest 0.1 cm using a calibrated portable stadiometer (QuickMedical, Issaquah, WA, USA). Body mass was measured to the nearest 0.01 kg using a calibrated electronic scale (HRM USA INC., Warminster, PA, USA). BMI was calculated as body mass in kilograms divided by the square of the height in meters (kg/m²). Percent fat was predicted via a three-site skinfold formula for males (chest, triceps, and subscapular skinfold sites) and the Siri Equation. All measurements were taken by one trained member of the research team in triplicate on the right side of the body with the subject standing. Calibrated Lange skinfold calipers were used for all measurements (Beta Technology, Santa Cruz, CA, USA). The accuracy of estimating percent fat from skinfolds is ±3.5% [24].

Based on the Expert Panel on the Identification, Evaluation, and Treatment of Overweight and Obesity in Adults [25], overweight is defined as a BMI ≥ 25 and obesity as BMI ≥ 30. Using Cooper Clinic data reported in the American College of Sports Medicine Guidelines for Exercise Testing and Prescription [21], the 20th percentile was defined as poor for percent fat. The exact percent fat values for the 20th percentile were 23.1, 24.9, 26.6, 27.8, 28.4 and 27.6% for age groups 20–29, 30–39, 40–49, 50–59, 60–69 and 70–79, respectively. These age-based percent fat cut-off points reported for the 20th percentile were used to define over-fat in this study.

The descriptive data (mean ± standard deviation) were reported for height, weight, BMI and percent fat. The proportions of study participants meeting the criteria for overweight (BMI ≥ 25), obesity (BMI ≥ 30) and percent fat (percent fat ≤ 20th percentile) were determined. The correlation between BMI and percent fat was assessed using Pearson correlation coefficients. An alpha level of 0.05 was used to determine statistical significance.

The accuracy of BMI as a measure of over-fat was evaluated using sensitivity/specificity analyses. The first sensitivity/specificity analysis used cut-off points of BMI ≥ 25 to categorize subjects as normal weight or overweight and a percent fat ≤ 20th percentile to categorize all subjects as over-fat or normal fat. Study participants were classified as true positive (TP), i.e. overweight and over-fat; false positive (FP), i.e. overweight and normal fat; true negative (TN), i.e. normal weight and normal fat or false negative (FN), i.e. normal weight and over-fat. The second sensitivity/specificity analysis used cut-off points of BMI ≥ 30 to categorize subjects as normal weight or obese and a percent fat ≤ 20th percentile to categorize all subjects as over-fat or normal fat. Study participants were classified as TP, i.e. obese and over-fat; FP, i.e. obese and normal fat; TN, i.e. normal weight and normal fat and FN, i.e. normal weight and over-fat. To determine the accuracy of BMI as a measure of over-fat the sensitivity, specificity and predictive values of BMI were calculated [26]. In this study, we
report the sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and the 95% confidence interval for both BMI ≥ 25 and BMI ≥ 30.

Results

Of the 90 volunteer firefighters, 77 were recruited and participated in the assessment. We excluded three female firefighters and one male whose body weight exceeded the maximal limit of our scale, resulting in a final sample size of 73. Descriptive data (mean ± standard deviation) for height, weight, BMI and percent fat are shown in Table 1. The prevalence rates of overweight and obesity are shown in Table 2. The correlation coefficient between BMI and percent fat was 0.74 (P < 0.001).

Accuracy of BMI was determined by assessing the proportion of FN and FP results when using the cut-off points of BMI ≥ 25 and BMI ≥ 30 (Figure 1). When using a cut-off point of BMI ≥ 25 29 firefighters (40% of total sample) were misclassified. All 29 of these misclassifications were FP. When using a cut-off point of BMI ≥ 30 15 firefighters (20% of total sample) were misclassified. Eleven misclassifications were FP (15% of total sample) and four (5%) FNs.

In order to provide a detailed assessment of the accuracy of BMI, Table 3 shows the sensitivity, specificity and predictive values for BMI ≥ 25 and BMI ≥ 30. The specificity of BMI ≥ 25 was very low (0.19; 0.08–0.37). Only 7 of 36 normal-fat firefighters were classified correctly by BMI ≥ 25. The high number of FP misclassifications resulted in a low PPV (0.56; 0.43–0.68). In contrast, there were no FNs when using a cut-off point of BMI ≥ 25, which resulted in a perfect sensitivity (1.0; 0.88–1.0) and NPV (1.0; 0.26–1.00). All 37 over-fat firefighters were classified correctly, while only seven with a BMI < 25 were normal fat. When assessing the accuracy of BMI ≥ 30, the total number and percentage of FP classifications were lower than those of BMI ≥ 25. The specificity of BMI ≥ 30 was significantly higher (0.69; 0.52–0.83) as 25 of 36 normal-fat firefighters were classified correctly by BMI ≥ 30. The PPV was also higher (0.75; 0.59–0.86) when using BMI ≥ 30. There were four FNs when using BMI ≥ 30. This resulted in a slightly lower sensitivity (0.89; 0.73–0.96) and NPV (0.86; 0.67–0.95) compared with BMI ≥ 25.

Discussion

Our findings illustrate that BMI ≥ 25 is not an accurate indicator of percent fat as it misclassifies nearly 80% of all normal-fat volunteer firefighters. In comparison, BMI ≥ 30 is more accurate, but it also misclassifies normal-fat volunteers. Although BMI ≥ 30 should be used with caution due to the misclassification of large lean volunteer firefighters, it accurately identifies over-fat individuals at risk for CVD and may be a cost effective and simple method to identify those at risk for CVD fatalities.

Strengths of this study include the approximately 85% participation rate among volunteer firefighters eligible to participate. Furthermore, BMI was calculated using objective measurements. A limitation to our study is the small sample size confined to Caucasian male firefighters from a small suburban fire department. Although this limits the extent to which our results can be generalized, the reliance on volunteer firefighters is greatest in smaller departments serving populations of fewer than 50 000 people, so this study may be applicable to the majority of US volunteer firefighters [17]. Another limitation is the use of skinfolds for estimating body composition. However, the error associated with skinfolds is ±3.5%, which is comparable to other two-compartment models [24]. To limit measurement error stringent methodological procedures were followed.

In order to provide a detailed assessment of BMI’s accuracy, we assessed the accuracy of both BMI ≥ 25 and BMI ≥ 30 as a measure of over-fat. Overall, BMI ≥ 25 was a poor measure of over-fat as 40% of the total sample was misclassified. Furthermore, 81% of normal-fat volunteer firefighters had a BMI ≥ 25. However, these results should be interpreted cautiously as only seven firefighters had a BMI < 25. We suggest not using this cut-off point due to the high prevalence of overweight in this population. In contrast, our study indicated that BMI ≥ 30 was a more accurate measure of over-fat than BMI ≥ 25, misclassifying 20% of the total sample. More specifically, the sensitivity of BMI ≥ 30 was 89%, illustrating that only 1 of every 10 overweight firefighters were misclassified as normal weight by BMI. This is substantially higher than the 36% sensitivity reported in the general US population [27] but lower than the 100% reported in athletes [23]. In contrast, the specificity in our sample

Table 1. Descriptive data for volunteer firefighters

<table>
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<tr>
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<th>n</th>
<th>Mean</th>
<th>±SD</th>
<th>Minimum</th>
<th>Maximum</th>
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<tbody>
<tr>
<td>Height (cm)</td>
<td>73</td>
<td>177.9</td>
<td>7.4</td>
<td>159.4</td>
<td>196.9</td>
</tr>
<tr>
<td>Weight (kg)</td>
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<td>102.4</td>
<td>23.5</td>
<td>57.9</td>
<td>191.1</td>
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<tr>
<td>Age (years)</td>
<td>73</td>
<td>39.9</td>
<td>12.2</td>
<td>20</td>
<td>69</td>
</tr>
<tr>
<td>Body mass index (kg/m²)</td>
<td>73</td>
<td>32.2</td>
<td>6.6</td>
<td>21.6</td>
<td>57.1</td>
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<tr>
<td>Body composition (% fat)</td>
<td>73</td>
<td>25%</td>
<td>6%</td>
<td>7%</td>
<td>35%</td>
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was 69%, illustrating that 3 of every 10 normal-fat volunteer firefighters are classified as overweight by BMI. This is lower than the 95% specificity reported in the general US population [27] but higher than the 25% reported in athletes [23]. This illustrates a possibility of misclassification among normal fat firefighters with elevated lean body mass, but not to the extent that has been reported in an athletic population. Overall, our results suggest that one should use BMI ≥ 30 cautiously when predicting percent fat in volunteer firefighters as one out of every five may be misclassified. However, BMI is more accurate in over-fat firefighters compared with those with normal fat.

One evident limitation in the firefighter literature is the lack of the assessment of percent fat as a measure of obesity. Previous studies assessing percent fat in career firefighters show varying results and report values between 13 and 25% [5,7,9,11,15,16]. The assessment of percent fat in volunteer firefighters is even more limited. To our knowledge, the work of Poston et al. [9] is the only previous study that assessed percent fat in volunteers. The authors found an average of 26.2% fat when using bioelectrical impedance analysis, which is similar to the 25% fat found in our sample. Although a standard percent fat has not been identified for optimal health, 25% is considered unhealthy for adult males from multiple sources [21,28,29]. Despite the high prevalence of overweight and obesity, multiple studies in career firefighters have reported average body fat percentages within the healthy range of 10–22% [5,7,11,16]. This suggests that firefighters may have a high lean body mass and lower percent fat. Therefore, using BMI as a measure for obesity may be of limited accuracy and an elevated BMI may not accurately assess obesity in firefighters because of the large percentage of FP results (high BMI, low percent fat). Our study supports this hypothesis as many lean volunteer firefighters were classified as obese by BMI. However, it is difficult to compare our results to previous research as only one study sample, using career firefighters, has assessed the accuracy of BMI [9,22] and reported that it is associated with significant errors in classification. This study excluded 34 subjects (11% of sample) with percent fat ≥ 25%, used a percent fat cut-off point (18%) and assessed only the accuracy of BMI ≥ 25 [22]. In contrast, given the high prevalence of percent fat ≥ 25% (51%) and BMI ≥ 25 (90%) in our study, we did not exclude anyone with high percent fat or limit the assessment to BMI ≥ 25. As a result, we found that BMI ≥ 30 is accurate in classifying over-fat firefighters as obese, which is critical when trying to identify firefighters at risk for CVD. However, these differences in study design limit the extent to which our results can be compared with this previous study. Furthermore, the higher prevalence of both percent fat ≥ 25% and BMI ≥ 25 in our sample of volunteers demonstrates the importance of assessing obesity in career and volunteer firefighters separately.

Given the limited amount of literature assessing percent fat in both career and volunteer firefighters, future studies should focus on large, diverse samples of volunteer firefighters in order to provide a more detailed and generalizable analysis of the possible obesity problem in this population. As a result of the common use of BMI as a screening tool for CVD risk, it is essential that future studies compare the accuracy of BMI in career and volunteer firefighters. Furthermore, future studies should consider assessing percent fat via laboratory measures to limit the potential error associated with field measures.

Obesity may be a significant contributor to the CVD-related on-duty fatalities in firefighters. This study

<table>
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<th>Table 2. Estimated percentage of obesity and over-fat in volunteer firefighters</th>
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<tr>
<td>BMI ≥ 25 kg/m²</td>
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<td>BMI ≥ 30 kg/m²</td>
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<td>Body composition (20th percentile)</td>
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<tr>
<th>FN=0</th>
<th>FP=29</th>
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<tr>
<td>TP=7</td>
<td>TN=25</td>
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<table>
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<tr>
<th>BMI≥25</th>
<th>BMI≥30</th>
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<tr>
<th>FP=11</th>
<th>TN=25</th>
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<tr>
<td>TP=33</td>
<td>FN=4</td>
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Figure 1. True positive, true negative, false positive and false negative rates for BMI ≥ 25 and BMI ≥ 30 in the assessment of over-fat.

<table>
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<tr>
<th>Table 3. Sensitivity (Se) and specificity (Sp) of BMI in measuring over-fat</th>
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<tr>
<td>Test</td>
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<tr>
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<tr>
<td>BMI ≥ 25 kg/m²</td>
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<td>BMI ≥ 30 kg/m²</td>
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CI, confidence interval.
provides insight into the strengths and limitations of the use of BMI as a measure of percent fat in volunteer firefighters.

**Key points**
- Body mass index ≥ 25 was a poor measure of overfat as 40% of the sample was misclassified.
- Body mass index ≥ 30 may effectively identify overfat volunteer firefighters at risk for cardiovascular disease.
- Body mass index ≥ 30 should however be used cautiously when assessing normal-fat volunteer firefighters.

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**Conflicts of interest**
None declared.

**References**