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ACCURACY AND PREDICTIVE CAPABILITY OF BODY MASS INDEX IN EVALUATION OF OBESITY AND BODY FATNESS LEVEL IN POLICE OFFICERS

[1]Filip Kukić[1], [2]J. Jay Dawes, [3]Jillian Joyce, [1]Aleksandar Čvorović, [4]Milivoj Dopsaj

[1]Police Sports Education Centre, Abu Dhabi Police, Abu Dhabi United Arab Emirates

[2]School of Kinesiology, Applied Health and Recreation Oklahoma State University, Stillwater, OK, USA

[3]Department of Nutritional Sciences, Oklahoma State University, Stillwater, OK, USA

[4]Department for Diagnosis and Analysis in Sport Faculty of Sport and Physical Education, University of Belgrade, Serbia Institute of Sport, Tourism and Service South Ural State University, Chelyabinsk, Russia

Abstract: This study evaluated the accuracy and predictive value of body mass index (BMI) in evaluation of obesity and body fatness. Data on BMI and percent body fat (PBF) were collected on 953 male police officers who were allocated into age groups: 20-29 years, 30-39 years, and 40-49 years. BMI > 30.0 kg/m^2 and PBF > 25% were classified as obese, and those with lower values were classified as non-obese. Chi-square was used to evaluate the accuracy in classification in obese and non-obese when officers' BMI was matched to PBF. Pearson's correlation and linear regression analyses determined the prediction value of BMI. Chi-square revealed significant difference in obesity prevalence when evaluated by BMI and PBF, with classification accuracy of 44.5%-71.8%, depending on age. BMI had moderate prediction value of body fatness. If the assessment of PBF is not attainable, BMI needs to be used carefully as it is likely to underestimate obesity among police officers.

Keywords: law enforcement, tactical athletes, body composition, occupational health.

INTRODUCTION

Police officers have some of the most physically demanding occupations within society (Anderson et al., 2001; Dawes et al., 2018). To this end, to ensure that

1 Corresponding author: filip.kukic@gmail.com

police officers are physically capable of performing all occupational requirements safely and successfully, physical fitness assessments are typically a mandatory part of the recruitment process (Anderson et al., 2001; Maupin et al., 2018). However, once a cadet graduates training academy there is generally an increase in the administrative duties required to do the job of an officer. Subsequently, these tasks increase the amount of sedentary time at work, which may contribute to a loss in physical fitness over time (Green & Gates, 2014). This, coupled with shift work and a lowered amount of leisure-time activity may lead to increased body fatness (Ćopić et al., 2020; Vuković et al., 2020). Consequently, it contributes to the prevalence of obesity among police officers (Sorensen et al., 2000; Boyce et al., 2008; Kukić & Dopsaj, 2016; Dawes et al., 2019;).

Obesity represents one of the leading public health problems in the world (WHO, 2017), which has been associated with coronary heart disease, hypertension, diabetes mellitus, lower quality of life and sleeping problems (Violanti et al., 2006; Charles et al., 2008; Alghamdi et al., 2017). Moreover, increased body fatness has been negatively associated with physical performance (Dawes et al., 2016), and is a significant predictor of health-related and occupational performance-related physical fitness outcomes (Kukic et al., 2018; Kukić et al., 2020). Considering this, police agencies have been working on development of assessments, treatments and prevention policies to address the negative changes in obesity related to work that is more sedentary and life habits of police officers. Body mass index (BMI) has been used extensively to assess the general health and anthropometric status within law enforcement populations (Dawes et al., 2016; Čvorović et al., 2018a; Ćopić et al., 2020). In general, BMI represents the ratio of body mass relative to body size, but without giving specific information on the body composition (Rothman, 2008; Provencher et al., 2018). The validity of its utilization relies on consistent associations with biological and socioeconomic factors such as age, sex, education, occupation, and income (Sorensen et al., 2000; Ball et al., 2002; Boyce et al., 2008; Kukic et al., 2019;). In that regard, the World Health Organization and American College Sports Medicine use standard values of BMI for the evaluation of nutritional status (WHO, 2017; Riebe et al., 2018). Moreover, BMI is a very simple, time and cost effective method of gaining a general knowledge of an officer's health status. This is of high importance for police agencies that may already be pressed for time based on other duties and responsibilities. For example, Dawes et al. (2019) reported acceptable accuracy of self-report BMI on a sample of police officers. Therefore, multiple studies on police officers have used self-reported data to evaluate obesity rate (Dopsaj & Vuković, 2015; Kukić & Dopsaj, 2016; Alghamdi et al., 2017). However, considering that obesity primarily means an increased body mass (BM) due to body fatness, a more precise measure of obesity should theoretically include a more direct assessment of body fat mass (BFM).

The relative amount of body fatness (BFM) (percent of body fat [PBF]) explains how much fat tissue constitutes the given body mass of an individual. Moreover, PBF can also be sued to indicate the relative amount of lean muscle mass (percent of skeletal muscle mass [PSMM]) an individual possesses. These are basically contrasting tissues of human body (active and ballast), meaning that an increase in PBF will yield a decrease in PSMM and vice versa (Kukic et al., 2018, Kukic et al., 2019). These changes in PBF and PSMM may cause changes in BMI, depending on the size of change in the amount of muscle and fat tissue (Čvorović et al., 2018b; Kukic et al., 2019). Typically, a BMI greater than 30 kg/m^2 (Kukić et al., 2018) has been determined as "obese" in the literature (WHO, 2017; Riebe et al., 2018). However, a police officer may possess a relatively low PBF (i.e., 11%) and high PSMM (i.e., 52%), that may result in a false-positive obesity classification. Considering this, BMI as a screening tool of nutritional status could not detect these specific differences and variations in body composition that would precisely and accurately classify officers as obese or non-obese.

Some of the major issues that surround the collection of body composition data in law enforcement agencies relates to cost, time, and accuracy (Lukaski, 1993; Laskey, 1996). During the last two decades, the use of bioelectric impedance analysis (BIA) has gained popularity as the results obtained from this method have improved (Janssen et al., 2000; Dopsaj & Dimitrijević, 2013; Aandstad et al., 2014; de Abreu et al., 2020). BIA has been shown to provide an accurate, valid and reliable method of assessing body composition in field conditions, even when hydration was altered (Kemble et al., 2010; Aandstad et al., 2014; de Abreu et al., 2020). This is of importance for law enforcement agencies because it is often difficult to control the time of the testing and whether police officers took some fluid or not prior to the measurement being taken. It is of note, however, that the accuracy may vary between BIA machines and calculations used by software (Aandstad et al., 2014). Thus, if a law enforcement agency or physical conditioning specialists decide to use the BIA for body composition assessment, they should select those with research grade accuracy, validity, and reliability. It would provide more purposeful practical application and possibility of comparing the results to official public data that are typically assessed via valid and accurate method.

Although several studies have investigated the prevalence of obesity using BMI (i.e., BMI > 30 kg/m^2) in police officers (Sorensen et al., 2000; Kukić & Dopsaj, 2016; Alghamdi et al., 2017; Heinrich et al., 2020), few have assessed the PBF (i.e., PBF > 25%) in order to precisely classify officers' health status (Boyce et al., 2008; Kukić & Dopsaj, 2016; Heinrich et al., 2020). Considering that BMI does not provide precise information about body composition, it is questionable if the obesity prevalence obtained from the BMI provides the real obesity prevalence. Accordingly, the question arises to whether the difference in obesity prevalence significantly differs when it is evaluated by BMI and PBF separately or combined, and whether BMI can be used to estimate PBF in police officers. Therefore, the aims of this study were to determine if the BMI misclassifies the obesity rate of officers when compared to PBF; and to determine the prediction values of BMI in estimation of PBF.

METHODS

Experimental approach to the problem

This was an applied cross-sectional study conducted in laboratory setting to calculate the accuracy and predictive capacity of commonly used indicator of obesity. A large sample of police officers was randomly recruited from different police stations to complete the body composition assessment via bioelectric impedance analyser in a laboratory setting. From the result sheet, only age, BMI and PBF were extracted for the analysis. The distribution of police officers into obese and normal was compared between BMI and PBF to determine the misclassification rate. The ration for this lies in the fact that BMI has been often used as a regular indication of body status in tactical populations, while in contrast it was also found that BMI may misclassify people into obese or normal even though their PBF says differently. Moreover, the sample was divided into age categories because physical fitness and body composition of police officers are usually evaluated relative to age.

Subjects

The sample included 953 healthy male police officers who were assessed at the Faculty of Sport and Physical Education, University of Belgrade, Serbia. This data was collected from January 2018 to December 2019. Given that the number of tested officers above 49 years of age was very low, they were not included in this investigation (stated in study limitations). Standardized values for PBF have been divided into the following age groups: 20-29 years, 30-39 years, 40-49 years, and 50-59 years (Riebe et al., 2018). Accordingly, this study included only officers from 20-49 years, who were divided into three groups: 20-29 years (n = 535), 30-39 years (n = 319), and 40-49 years (n = 99). All data were collected and recorded in a manner that protected the anonymity of the subjects. The main characteristics of the whole sample were: age = 28.27 ± 8.07 years, body height (BH) = 177.93 ± 7.84 cm, BM = 85.46 ± 14.52 kg, and BMI = 26.95 ± 3.91 kg/m^2. The research was carried out in accordance with the declaration of Helsinki (Williams, 2008). Ethical approval number 484-2 was obtained from the Faculty of Sport and Physical Education, University of Belgrade, Serbia. Given the nature of information obtained and anonymity of data analysis, verbal consent was obtained from all individual participants prior to measurement being conducted. The data were fully anonymized prior to the analysis and participants were assured about anonymity.

Procedures

Body composition was assessed using an eight-channel multi-frequency bioimpedance analyser, InBody 720 (Biospace, Co., Ltd, Seoul, Korea), which had previously proved very reliable (ICC = 0.97). The assessment was conducted following standardized procedures previously reported in several studies on police officers (Kukić & Dopsaj, 2016; Kukić et al., 2019; Vuković et al., 2020). In short, the participants fasted for minimum five hours before the measurements were collected and were advised not to eat a large meal for dinner and not to exercise the day prior to the measurement. Body composition measurements were conducted between 8:00 am and 10:00 am, and the participants were required to stand still for about five minutes to maintain proper distribution of body fluids. Participants were wearing underwear, were barefoot, and had all metal, plastic, and magnetic accessories removed before standing on the device. The participants stood on the metal spots designated for their feet and held their hands on the designated metal spots on the handles. Their hands were positioned next to their body in a slight shoulder abduction, enough to disconnect upper arm from upper body. Body height was measured by measuring rod and entered into the InBody machine, while BM and BFM were taken from the results sheet and were used to calculate the BMI and PBF.

The BMI of 30.0 kg/m^2 and PBF of 25% were used as standardized values that define obesity in males (WHO, 2017; Riebe et al., 2018), according to which the data was divided into obese and normal. Police officers who had either BMI or PBF higher than these values were classified as obese, while those with lower values were classified as non-obese. These classifications were used to calculate and compare the prevalence of obesity according to BMI and PBF in each age-category and on a general level. In addition, BMI and PBF were matched so the prevalence could be calculated for those who had BMI > 30 kg/m^2 and PBF > 25%, BMI > 30 kg/m^2 and PBF < 25%, or BMI < 30 kg/m^2 and PBF < 25%, and BMI < 30 kg/m^2 and PBF > 25%.

Statistical analyses

The statistical analyses were conducted using Social Package for Social Sciences (IBM, SPSS statistics, version 23). The descriptive statistics for each age category were calculated including mean, standard deviation (SD), minimum (Min) and maximum (Max). Analysis of variance (ANOVA) was used to determine the differences in BM, BMI, and PBF between age groups. The age-adjusted prevalence of obesity according to both BMI and PBF were calculated using the frequency option in the SPSS. The prevalence of true positive, true negative, false positive and false negative classifications were identified using a cross tab, while the significance of the difference in prevalence distributions were analysed using Chi square analysis. Pearson's correlation coefficient and linear regression analysis were employed to determine the association and prediction value of BMI in predicting PBF. The significance level was set to $p < 0.05$. Cohen's effect size (*d*) was calculated to qualify the differences in BM, BMI, and PBF between the groups as small = 0.2, moderate = 0.6, large = 1.2 and very large = 2.0. The magnitude of correlations was defined as small 0.20–0.49, medium 0.50–0.79, and large ≥ 0.80; and the magnitude of regression R square (R^2) was defined as small 0.04–0.24, medium 0.25–0.63, and large ≥ 0.64 (Sullivan & Feinn, 2012).

RESULTS

Age-adjusted descriptive statistics for mean, SD, and range (Min and Max) are presented in Table 1. It could be observed that the BH was the same across age groups, while significant differences occurred in BM ($F = 23.709$, $p < 0.001$), BMI ($F = 41.140$, $p < 0.001$) and PBF ($F = 52.513$, $p < 0.01$). The ANOVA revealed that BM, BMI and PBF were significantly lower ($p < 0.001$) in the 20-29 year group than in the other two age groups whose BMI and PBF were not significantly different (Table 2). The differences were small between the 20-29 years group two other groups in BM and BMI, and moderate in PBF. Considering the descriptive analysis of prevalence of obese and non-obese police officers, the use of BMI for classification resulted in lower frequency of obese and higher frequency of non-obese officers compared to PBF in all age groups, as well as overall (Figure 1).

Table 1. *Descriptive statistics for age groups*

Variables	20-29 years (n = 535)	30-39 years (n = 319)	40-49 years (n = 99)
	Mean ± SD Min – Max	Mean ± SD Min – Max	Mean ± SD Min – Max
Age	22.17 ± 2.88 20.0 – 29.0	33.51 ± 2.62 30.0 – 39.0	44.32 ± 3.60 40.0 – 49.0
BH (cm)	178.33 ± 7.66 157.6 – 203.3	177.47 ± 8.05 161.2 – 206.2	177.24 ± 8.06 156.0 – 199.4
BM (kg)**	82.58 ± 13.83 48.0 – 144.7	88.70 ± 15.16 56.4 – 146.30	89.53 ± 15.04 60.0 – 131.2
BMI (kg/m²)**	25.97 ± 3.50 17.1 – 48.6	28.13 ± 4.18 18.6 – 44.3	28.39 ± 3.64 19.9 – 36.7
PBF (%)**	20.17 ± 7.83 3.0 – 51.0	25.57 ± 8.42 6.3 – 43.6	25.17 ± 6.69 5.9 – 40.2

BH – body height, BM – body mass, BMI – body mass index, PBF – percent of body fat, SD – Standard deviation.
**Significant at $p < 0.001$.

Table 2. *Bonferroni post hoc analysis for cross-group differences*

Variables	Age-group cross analysis		Diff.	Lower Bound	Upper Bound	*d*
BM (kg)	20-29	30-39	-5.93**	-8.35	-3.51	-0.41
		40-49	-8.61**	-12.98	-4.23	-0.58
	30-39	40-49	-2.67	-7.21	1.87	-0.17
BMI (kg/m²)	20-29	30-39	-2.16**	-2.80	-1.52	-0.56
		40-49	-2.42**	-3.40	-1.43	-0.65
	30-39	40-49	-0.26	-1.30	0.78	-0.06
PBF (%)	20-29	30-39	-5.39**	-6.74	-4.05	-0.66
		40-49	-5.00**	-7.08	-2.92	-0.67
	30-39	40-49	.39	-1.80	2.58	0.05

BM – body mass, BMI – body mass index, PBF – percent body fat, *d* – Cohen's effect size.
**Significant at $p < 0.001$.

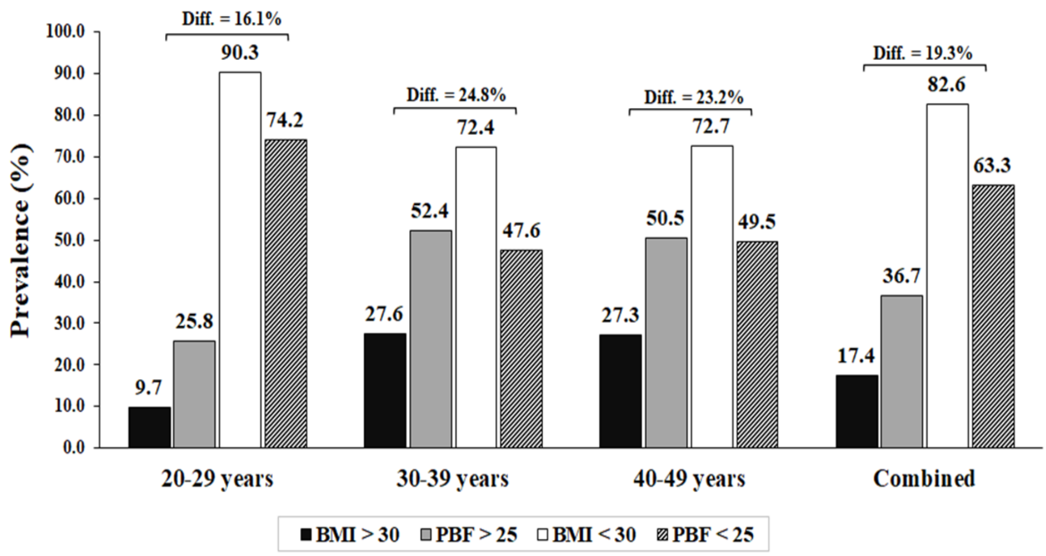
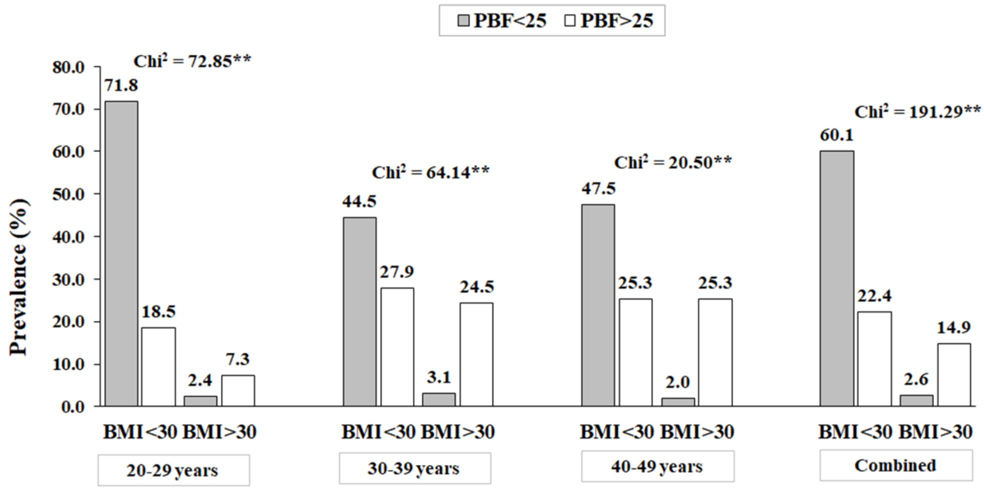


Figure 1. *The difference in age-adjusted frequency analysis of prevalence of obese and non-obese police officers according to the values above and below BMI of 30 kg/m² and PBF of 25%*

The results of the cross tab and Chi square analysis revealed significant ($p < 0.001$) differences in distribution of prevalence of obese and non-obese officers when the PBF was matched to their BMI (Figure 2). For the officers aged 20-29 years, whose BMI was below 30 kg/m², 384 were classified as true non-obese with PBF < 25%, while 99 were classified as false non-obese with PBF > 25%. For the officers with BMI > 30 kg/m², 13 were classified as false obese as their PBF was below 25% and 39 were classified true obese with PBF > 25%. For the officers aged 30-39 years with BMI < 30 kg/m², 142 were classified as true non-obese with PBF < 25%, while 89 were classified as false non-obese with PBF > 25%. For those of the same age group with BMI > 30 kg/m², 10 were classified as false obese as their PBF was below 25% and 78 were classified as true obese with PBF > 25%. For the officers aged 40-49 years with BMI < 30 kg/m², 44 were classified as true non-obese with PBF < 25%, while 28 were classified as false non-obese with PBF > 25%. For those of the same age group with BMI > 30 kg/m², two were classified as false obese as their PBF was below 25% and 25 were classified as true obese with PBF > 25%. Considering the combined sample, for the officers with BMI < 30 kg/m², 559 were classified as true non-obese with PBF < 25%, while 203 were classified as false non-obese with PBF > 25%. For those with BMI > 30 kg/m², 25 were classified as false obese as their PBF was below 25% and 136 were classified as true obese with PBF > 25%. Given that the differences in sample sizes of each age group, the absolute values were relativized to their sample size (Figure 2).



**Significant at $p < 0.001$

Figure 2. *The prevalence of true-non-obese, false-non-obese, true-obese, and false-obese (respectively representing the bars in the chart for each age group)*

The correlation analysis established a significant association of medium magnitude between BMI and PBF (r range = 0.654–0.699, $p < 0.001$), which was followed by significant moderate prediction values of BMI in estimating PBF (R^2 range = 0.428–0.488, $p < 0.001$). The results were similar across the groups, as well as for the combined sample.

DISCUSSION

The main findings of this study revealed that BMI and PBF differently classify police officers into obese and non-obese categories, with BMI underestimating the prevalence of obese officers. Accordingly, there was substantial misclassification as true obese, false obese, true non-obese and false non-obese, when the officers were sorted into obese and non-obese based on both parameters (BMI and PBF). This further reflected in moderate prediction values of BMI in estimating PBF. Therefore, BMI of 30 kg/m² is moderately valid in evaluation of obesity and body fatness among police officers as defined by PBF > 25%, and is likely to underestimate prevalence of obesity among officers.

Other previous studies investigating the difference in obesity prevalence of police officers, relative to BMI and PBF, revealed similar results to the current study (Kukić & Dopsaj, 2016; Heinrich et al., 2020). Kukic and Dopsaj (2016) conducted the structural analysis of body composition of 59 police officers (mean age = 31.53 years [19-49 years]) and found about 27% difference in obesity prevalence of officers when classified separately by BMI and PBF. According to BMI ≥ 30 kg/m², 22% of officers were classified as obese, while according to PBF > 25%, 49% were obese. This was about 3% higher difference than the results obtained for the 30-39 years group and about 8% higher than that of the combined sample of the current study. Although the sample of the present study is considerably larger and results could be considered more accurate, both studies clearly suggest the difference in classification of obese officers based on BMI and PBF, with BMI underestimating obesity prevalence. A recent study on 153 male Russian police officers reported 4.6% obesity prevalence based on BMI ≥ 30 kg/m^2 and 22.2% based on PBF > 25% (Heinrich et al., 2020). Although the overall obesity prevalence was lower in both parameters compared to the present study, the difference in prevalence was similar (17.6% vs. 19.1%), thus indicating that BMI tends to underestimate body fatness and thus obesity.

In that regard, Heinrich et al. (2020) conducted cross box analysis followed by Chi square analysis to determine the misclassification rate of obesity when BMI was matched to PBF. They found that 2.5% of officers who were obese according to BMI (i.e., BMI ≥ 30 kg/m^2) were not obese according to their PBF (i.e., had PBF < 25%). The results from the present study provided the same results in misclassification of obese officers as false positives, ranging from 2.4-3.1% across the age groups and 2.7% for the combined sample. In contrast, 11.8% of officers who were not classified as obese according to BMI (i.e., BMI < 30 kg/m^2) were classified as obese according to PBF (i.e., PBF > 25%), which was a lower misclassification rate of false non-obese officers than in the present study (18.5-27.9%). Heinrich et al. (2020) reported that the overall accuracy of BMI-defined obesity was 78.4%, which was about

17.8% higher compared to the results obtained in the combined sample in the present study. Moreover, the present study revealed that the accuracy differed between age groups with the highest accuracy being in the 20-29 years age group and the lowest in 30-39 years. Considering this, obesity defined by BMI seems not to be accurate in evaluation of obesity as defined by increased body fatness in law enforcement populations.

The correlation and regression analysis coefficients showed moderate prediction value of BMI in estimating PBF, additionally reinforcing the lack of its ability (i.e., construct validity) to estimate the obesity in police officers. It is of note that the same correlation coefficient was obtained in the present study as it was in Heinrich at al. (2020), further suggesting cross-validation of this notion. Therefore, BMI should be used only as a crude measure of nutritional status in terms of defining to what degree body volume is increased in ratio to body size. For the accurate classification of obesity, police agencies should assess the PBF of police officers. Using BIA is a convenient and non-invasive method to obtain PBF. It provides information that could help planning exercise and nutrition interventions. As such, BIA could be used as a screening or self-screening tool that would provide timely information on changes in body composition, such as increase/decrease in body fat and skeletal muscle mass.

Limitations

Although this study clearly showed that BMI significantly misclassifies the officers into obese or non-obese categories, thereby being a moderately valid in estimating body fatness, a few limitations to this study should be pointed out.

The sample included only male police officers, which makes it applicable only to male officers. Further cross-country validation may be needed for higher external validity, even though the sample was large. Additionally, the sample of officers aged 40-49 years was relatively small, and the sample did not include older officers. Officers older than 49 years of age are a significant proportion of police agencies, and they should be included in the analysis as well, especially considering that BIA is safe while they often cannot do a physical test for various reasons.

Conclusions

On a general level, the accuracy of classification was 66%. However, the accuracy of BMI in evaluation of obesity rate may be altered by age, whereby the accuracy was the highest in the 20-29 years age group (71.8%), followed by 40-49 years age group (47.8%) and 30-39 years age group (44.5%). Moreover, BMI had moderate prediction value in evaluation of body fatness. Therefore, PBF should be used for the analysis of obesity and body fatness related to it for the most accurate results. If the assessment of PBF is not attainable, BMI needs to be used carefully and presented only in terms of ratio between the BM and BH, realizing that BMI is likely to underestimate obesity among police officers. However, this gap between BMI and PBF provides space for speculations, thereby making it difficult to draft health and performance policies that would serve officers, agencies and ultimately the public.

PRACTICAL APPLICATION

Considering the importance of body composition components to health and physical performance and the possible easiness of its assessment, police agencies may consider introducing body composition assessment as a screening tool. It would provide an agency with information on physical fitness of police officers, while both officers and strength and conditioning specialists would get the valuable information for planning officers' nutrition and physical activity.

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