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Use of Human Body Morphology as an Indication of Physical Fitness: Implications for Police Officers

Uso de la Morfología del Cuerpo Humano como una Indicación de la Condición Física: Implicancias en Oficiales de Policía

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SUMMARY: Research with police officers (POs) suggests an association between body composition, physical performance and health. The aim of the study was to investigate the associations between body composition and measures of physical fitness, and their use to predict estimated physical fitness score (EPFS). The sample included 163 male POs (age = 31.61 ± 4.79 years, height = 172.97 ± 6.09 cm, body mass = 77.53 ± 11.66 kg). Eight body composition variables: body mass index (BMI), body fat mass index (BFMI), percent of body fat (PBF), percent skeletal muscle mass (PSMM), index of hypokinezia (IH), skeletal muscle mass index (SMMI), protein mass index (PMI), and fat-free mass index (FFMI); and four physical fitness measures: a 3.2 km run, a 2-minute push-up, 2-minute sit-up and estimated physical fitness score (EPFS) were correlated, followed by the regression analysis for causal relationship between body composition and EPFS. Running 3.2 km test correlated to BMI, PBF, PSMM, BFMI, and SMMI ($r = 0.274, 0.250, -0.234, 0.311$, $p<0.01$, respectively); 2-minute push-up correlated to PBF, PSMM, BFMI, SMMI, PMI, IH, and FFMI ($r = -0.413, 0.436, -0.375, 0.221, 0.231$, $-0.411, 0.261$, $p<0.01$, respectively); 2-minute sit-up correlated to PBF, PSMM, BFMI, and IH ($r = -0.237, 0.250, -0.236, -0.218$, $p<0.01$, respectively); and EPFS correlated to BMI, FFMI, PBF, PSMM, BFMI, and IH ($r = -0.200, 0.168$, $p<0.05$, and $r = -0.369, 0.378, 0.376$, -0.317, $p <0.01$, respectively). Two models of predictions were extracted: 1) PBF, BFMI, PMI and FFMI ($R^2 = 0.250$, $p<0.001$); 2) PBF, BFMI and PMI ($R^2 = 0.244$, $p<0.001$). Obtained prediction models may be a promising screening method of a POs' fitness, when conducting the physical tests is not possible or safe (obese and injured POs or bad weather conditions).

KEY WORDS: Assessment; Anthropometrics; Physical performance; Law enforcement officers.

INTRODUCTION

Tasks performed by police officers (PO) can involve chasing fleeing suspects on foot, grappling, wrestling and fighting with uncooperative belligerents, carrying injured or unconscious people, and manual handling tasks (Pryor *et al*., 2012), often while wearing and carrying external loads (Orr & Pope, 2017). Based on the nature of these tasks and task requirements it is evident that physical fitness is of importance if PO are to perform these job sufficiently and effectively, and with a reduced risk of injury (Anderson & Plecas, 2000; Dopsaj *et al*., 2007; Guffey *et al*., 2013). However, in some police units, the majority of police work is sedentary in nature (e.g. deskwork, sitting in a parked car, etc.) (Garbarino & Magnavita, 2015), which in long term might lead to a 10 – 32 % drop in PO's physical performan-

ce and increase of body fat mass (BFM) due to lack of physical activity and exercise (Lagestad *et al*., 2014; Orr *et al*., 2017).

Increased levels of BM and BFM can create a greater physiological burden when performing occupational tasks, negatively affecting stamina and even reducing aerobic performance (Dawes *et al*., 2014, 2016; Garbarino & Mangavita; Mitrovic´ *et al*., 2015). Research by Dawes *et al*. (2014) found that BFM and estimated percentage body fat (PBF) were significantly ($p \leq 0.001$) and negatively correlated 1-repetition maximum bench press, 1-minute push-ups, 1-minute sit-ups, vertical jump height, 1.5-mile run, and maximal voluntary oxygen consumption.

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Additionally, Mitrovic *et al*. conducted a study on Serbian Special Forces, and discovered that PO with normal BMI ≤ 24.99 kg/m^2 had significantly better 3000m run performance compared to obese PO with BMI ≥ 30 kg/m^2 (p = 0.021). Likewise, in a load carriage study on military population, Ricciardi *et al*. (2007) observed that even when participants were wearing a relatively light load of 10 kg, which is very common in police officers (Orr & Pope), the amount of body fat negatively correlated (r = -0.88; p < 0.001) with physical task performance, a reduced aerobic capacity and load carriage task performance ability (p = 0.01) in male and female participants with increased levels of body fat.

Conversely, estimated lean body mass has been found to significantly and positively (p ≤ 0.001) correlate with 1 repeat maximum bench press, 1-minute push-ups, and vertical jump performances (Dawes *et al*., 2014). Furthermore, skeletal muscle mass (SMM) has been shown to be positively associated with military specific task performance (consisting of rushes with changing of direction, crawling, sprinting, jumping, lifting and caring), whilst soldiers wore their combat load, including leather boots, body armor, helmet and 3kg assault rifle replica (Pihlainen *et al*., 2018). When considering a specific task common to police officers, research on load-carriage has found the importance of LBM, as the carrier's load gets heavier (Lyons, *et al*., 2005).

On this basis, the question is raised as to whether other body composition variables may be associated with fitness measures; potentially to a greater degree and whether the use of different indices may be more precise and, as such, better predictors of physical fitness measures. Thus, the aims of this study were to investigate the associations between novel index values of body composition and common policing measures of physical fitness, and to investigate the possibility of predicting a PO's physical fitness by using these indices. This information may be useful to identify potential deficits in fitness when the ability to perform a full fitness testing battery is not practical or feasible, or as a non-invasive physical fitness monitoring tool.

MATERIAL AND METHOD

This study was of an applied non-experimental cross-sectional research design conducted through a combination of laboratory and field tests and using a random sample of available PO. A body composition analysis was conducted, and indexes of body composition measures were calculated (Table I). Further, three physical tests were conducted (a 3.2 km run, a 2-minute push-up and 2-minute sit-up assessment) and their scores were converted into a one estimated physical

fitness score (EPFS). Finally, body composition indexes were correlated with the physical fitness measures, followed by a regression analysis.

Subjects. The sample included 163 male POs (mean age = 31.61 ± 4.79 years, mean body height (BH) = 172.97 ± 6.09 cm, mean BM = 77.53 ± 11.66 kg and mean BMI = 25.86 ± 3.26 kg/m2). The assessment of physical abilities was conducted as part of departmental process, however all POs as well as trainers that conducted measurements were informed about the aim of the data collection and POs' body composition was measured only if they agreed to be the part of the study. The research was carried out in accordance with the conditions of declaration of Helsinki, recommendations guiding physicians in biomedical research involving human subjects (Christie, 2000), and with the ethical approval number 484-2 of the ethical board of the Faculty of Sport and Physical Education, University of Belgrade.

Testing. Body composition measurement procedures were conducted using multi-channel bioelectric impedance (InBody 720: Biospace Co. Ltd, Seoul, Korea), which was shown to be very reliable with an ICC = 0.97 (Aandstad *et al*., 2014). The assessment was conducted as previously reported in details (Dopsaj *et al*., 2017), whereby all participants fasted the night before the measurements being taken (starting at 6am). Further, participants were wearing sports shorts and T-shirt, were barefoot, and had all metal, plastic, and magnetic accessories removed, stood on the device and on the metal spots designated for their feet. The outcome measures from this device, that were relevant to this study where BM, FM, SMM, and protein mass (PM), which were later used to calculate 8 body composition index measures in a similar manner as in the study of Dopsaj *et al*. (2017).

The procedure for the 3.2 km run has been reported in previous literature (Kukic´ & Maamari, 2017). After a 10-minute warmup routine, and five minutes of passive rest, the 3.2 km run was conducted (starting at 07:00). The participants were instructed to run the test in the quickest time possible, and they were briefed about the time needed to pass the test. They had to run two laps at the fixed 1.1 km running track and one shorter lap of 1 km to complete the distance.

There was a 20-minute rest between the run test and the push-up test. After the rest period, participants were briefed regarding the requirements for the two-minute push-ups (and sit-ups) tests. Participants were allowed to have a maximum of 4-points (feet and palms) of contact with the ground and were required to hold their body straight and firm (straight line from toes to the head). Hands widths were personal preferences, with general advice to be around one palm width wider than the shoulder width. The starting position

was with arms fully extended. One push-up repetition was recorded when the participant's elbow joint crossed the position of 90 degrees of flexion so that the upper arm was parallel to the ground before returning to the straight arm position. If any part of the body except feet or palms touched the ground, the test was stopped and number of the accurate push-ups until that point was taken as the result of the test.

Fifteen minutes after all participants completed the push-up test, they proceeded with the maximal number of sit-ups in two minutes test, in accordance with a previously described procedure (Dawes *et al.*, 2014), whereby the only difference was that were arms crossed over the chest. The testers were standing on the participants' feet fixing their feet to the ground and checking the sit-up correctness.

Variables. Six for body composition variables, and three for physical performance were used. Body composition variables were presented as index variables relative to BH and BM. The rationale for developing index variables is based on the fact that BMI, PBF and percent of skeletal muscle mass can be misinterpreted given that BMI may remain the same even though at the same time the amount of fat in the body can increase, while muscle mass decreases (Demling & DeSanti, 2000; Kyle *et al.*, 2001). The general physical fitness, the EPFS, was calculated from the results scored in the 3.2 km run, push-ups and sit-ups tests. Calculations for all used variables are given in Table I.

Statistics. The basic descriptive statistics for means, standard deviations (SD), minimum (min) and maximum (max) values were calculated using Microsoft Excel. The EPFS was calculated using methods of mathematical modeling by applying the techniques of multidimensional scaling where physical fitness Z scores for each participant were identified and related to the centroid of their physical abilities (Dopsaj *et al.*, 2012). A factorial analysis was used to create a FACT_bod variable from RUN, PU and SU scores. The FACT_bod variable was further used to calculate the FACTscore. Since FACTscore represents the total score from all three tests and by doing so it estimates the general physical

fitness level and accordingly it was named EPFS. A Pearson's correlation product analysis was used to identify associations between the examined body composition variables and physical performance measures. The power of correlations were defined according to the study of Cohen (1992). To find the best prediction model for the EPFS, a backward multiple regression model was used with the level of significance set to $p < 0.05$. The mathematical modeling, correlations and regression analysis were conducted using the statistical package for social sciences (SPSS) (IBM, SPSS statistics, version 23).

RESULTS

The descriptive statistics for mean, standard deviation (SD), minimum and maximum values are shown in Table II.

Correlative analysis (r) revealed multiple associations between the body composition measures and physical fitness tests and EPFS. Four out of eight variables significantly correlated ($p < 0.01$) with RUN, among which BMI, PBF, and BFMI correlated positively and explained 27.4 %, 25 %, and 31.1 % of the common variance, while PSMM correlated negatively by explaining 23.4 % of the variance. Both, fat and muscle measures significantly correlated with executed number of PU. Considering the fat measures, PBF, BFMI, and IH were negatively associated with PU by explaining 41.3 % and 37.5 %, and 41.1 % of the common variance at the level of significance ($p < 0.01$). Conversely, PSMM, SMMI, PMI, and FFMI, were positively associated with PU, with the respective explanation of 43.6 %, 22.1 %, 23.1 % and 26.1 % of the common variance ($p < 0.01$). Furthermore, three fat measures and one muscle measure significantly correlated with the executed number of SU. PBF, BFMI, and IH explained 23.7 %, 23.6 % and 21.8 % of the common variance ($p < 0.01$), while PSMM explained 25 % of the common variance ($p < 0.01$). Finally, EPFS significantly negatively correlated with BMI ($p < 0.05$), PBF ($p < 0.01$), BFMI ($p < 0.01$) and IH ($p < 0.01$) by explaining 20 %, 36.9 %, 37.6 %, and 31.6 % of the common variance.

Table I. Calculations for indexed variables.

Variable	Calculation	Unit
BMI – Body Mass index	BM / BH^2	kg / m^2
BFMI – Body Fat Mass Index	BFM / BH^2	kg / m^2
PBF – Percent of Body Fat	$(BFM / BM) * 100$	%
PSMM – Percent Skeletal muscle Mass	$(SMM / BM) * 100$	%
IH – Index of Hypokinezia	PBF / BMI	$\% / kg \cdot m^{-2}$
SMMI – Skeletal Muscle Mass Index	SMM / BH^2	kg / m^2
PMI – Protein Mass Index	PM / BH^2	kg / m^2
FFMI – Fat-Free Mass Index	FFM / BH^2	kg / m^2
EPFS – Estimated Physical Fitness Score	Multidimensional scaling	Score Number

Conversely, PSMM and FFMI were positively associated to EPFS by explaining 37.8 % (p < 0.01) and 16.8 % (p < 0.05) of the common variance.

The multiple regression analysis extracted two best-fit models of prediction. The one with the smallest standard error of the estimate (SEE) included PBF, BFMI, PMI and FFMI ($R^2 = 0.250$, F[3,158] = 13.179, p < 0.001, SEE = 14.61). The another one was the simplest model of EPFS prediction and included PBF, BFMI, and PMI ($R^2 = 0.244$, F[3,159] = 17.152, p < 0.001, SEE = 14.62). The backward multiple regression analysis included 4 measures (4M model) as predictors in a first model while the second model included 3 measures (3M model) as the simplest best predictors of EPFS. Furthermore, analysis of variance showed that both models were significant, and that fat measures as well as muscle measures of body composition were significantly involved in predicting EPFS. Based on the regression analysis, two prediction formulas were formatted: 1) 4M model = - 69 + (4.602 • PBF) + (-16.481 • BFMI) + (25.572 • PMI) + (0.671 • FFMI); and 2) 3M model = -69.64 + (4.840 • PBF) + (-17.182 • BFMI) + (28.796 • PMI).

The regression's coefficients of determination suggest that body composition measures in 4M model (Fig. 1) explain 25 % of the variability in EPFS, where the majority of the variability (24.4 %) is determined by PBF, BFMI and PMI (Fig. 2).

DISCUSSION

The results of correlative analysis suggest that variability in physical fitness is significantly associated to body composition, where measures of body composition have a specific effect on performance of 3.2 km run, number of executed push-ups and sit-ups in 2 minutes as well as on EPFS calculated from these three tests. The multiple regression analysis established clear significant causal relationships between the measures of body composition and EPFS, defining two prediction models. Both models defined in what degree and which body composition measures are associated to variability in EPFS. Next to PBF, a widely used measure of body fatness, BFMI, PMI and FFMI entered the prediction model. Considering the calculations of each variable (Table I) within the models, it seems that PBF represents the volume of fatness, while BFMI, PMI and FFMI represent a longitudinal

Table II. Descriptive statistics for all variables.

| Variables	Mean	SD	Min	Max
Age	31.61	4.79	22.00	52.00
BH (cm)	172.97	6.09	156.00	190.00
BM (kg)	77.53	11.66	48.30	115.30
BMI (kg / m^2)	25.86	3.26	18.80	35.59
PBF (%)	23.59	6.59	8.03	37.37
PSMM (%)	43.13	3.93	34.77	52.36
BFMI (kg / m2)	6.23	2.24	1.70	11.80
SMMI (kg / m^2)	11.09	1.27	7.78	14.23
PMI (kg / m^2)	3.91	0.41	2.87	4.91
IH (% / kg•m^{-2})	0.91	0.22	0.35	1.51
FFMI (kg / m2)	19.64	2.31	12.33	25.65
RUN (sec)	1084.46	136.22	724.00	1509.00
PU (No)	35.09	13.86	0.00	65.00
SITUP (No)	41.19	11.05	11.00	80.00
EPFS	50.00	16.67	4.12	98.15
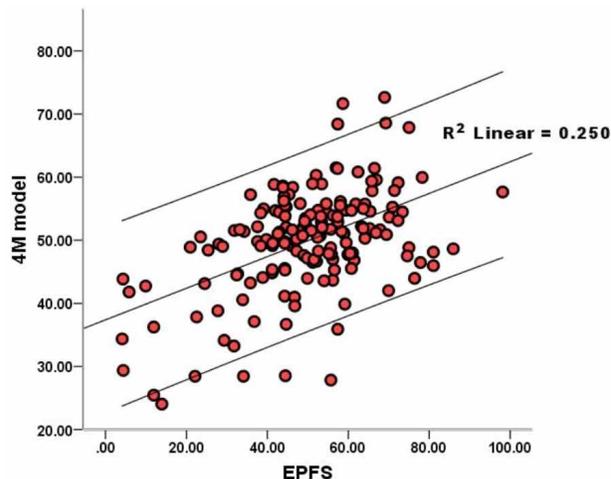
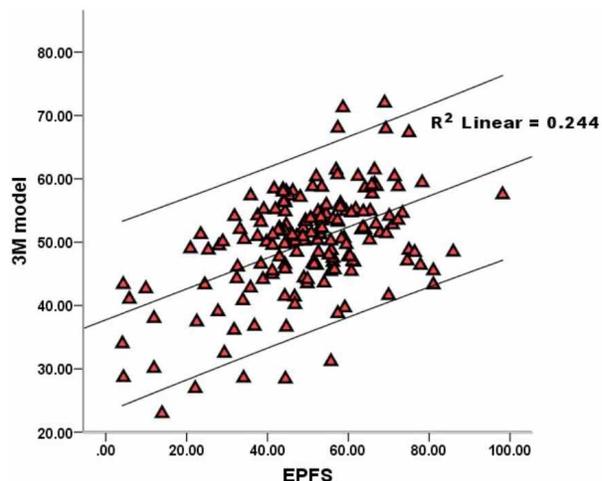Fig. 1. Scatterplot showing the regression line for the 4M model.

Fig. 2. Scatterplot showing the regression line for the 3M model.

distribution of fat mass and muscle components of body composition. These findings suggest that both, transversal (PBF) and longitudinal measures of ballast mass (BFMI) and active mass (PMI and FFMI) are the best indicators of EPFS. By having a better insight in causality of interaction among investigated factors and better understanding of how they affect each other, it would be more likely that practical application of the results would also bear improvements in PO's physical fitness screening as well as in PO's physical preparation planning and programing.

This study showed that as the performance was more dependent on strength, the importance of PSMM tended to increase. For that reason, all measures of PO's muscularity (PSMM, SMMI, PMI and FFMI) significantly correlated to PU. Conversely, the negative association of PBF, BFMI and IH was highest in PU, RU and SU, respectively, suggesting that good quality of muscle mass may be very important for physical performance, especially knowing that PO tend to be fattier by time spent in service (Lagestad *et al*.). Moreover, studies have shown that BMI, PBF and PSMM can be misinterpreted (Kyle *et al*.; Rothman, 2008). Thus, the IH which significantly ($p < 0.01$) correlated to PU, SU and EPFS, was developed in order to define one measure that would indicate the body fat volume and how it is spread along the body and indirectly muscularity of the body. This measure would indicate a muscularity regardless of how fatty the PO is. Conversely, PMI, SMMI and FFMI were used to extract muscle quality regardless of the fat and muscle volume (PBF and PSMM).

The IH is based on a relationship between PBF and BMI and potentially might overcome the misinterpretation of PBF, BMI and PSMM. For instance, a PO's BMI may seem normal, even though their PBF is high (i.e., BMI = 24 kg/m2 and PBF = 25 %), which in turn would usually lead to underperformance on physical assessment, and accordingly their nutritional status should not be defined as normal. Moreover, IH could also distinguish the difference between the subjects with BMI above 25 kg/m2, based on either developed muscle mass or increased amounts of fat mass. This means that if two PO have the same BMI of 27 kg/m2 but one has 52 % of SMM and 12 % of BFM, while the other has 40 % of SMM and 24 % BFM, their potential for performance can be expected to be totally different. Thus, building the body composition indexes (IH) that more closely define these differences in relation to PO's physical performance could be a valuable tool for PO as well as for practitioners.

Compared to PMI, PSMM is more about the quantity of muscle mass in relation to body mass, while PMI is about the overall dry contractile mass, which is more important for policing jobs. For example, while a PO may have a normal PSMM it does not necessarily mean that the same person is not underweight (i.e., PSMM = 35 % and BMI < 18.5 kg/m2), which ultimately may also hinder physical performance. Conversely, a higher PBF may lead to lower PSMM, even though PMI may remain the same. For instance, if PO's BMI is 27 kg/m2 due to a greater amount of fat mass, or due to caring external loads (common in policing jobs), PSMM may seem lower, but the performance can still be acceptable because the quality of SMM, and hence PMI, is good. Therefore, in both cases PSMM and BMI may be misleading in regards to potential for performance.

This is supported by studies on load carriage, a military specific test and running 3 km (Lyons *et al*.; Mitrovic´ *et al*.; Pihlainen *et al*.). The regression analysis revealed that the LBM relative to fat and dead, or nonfunctional, mass was the strongest predictor among others as the load increased from 20 kg to 40 kg (Lyons *et al*.). The study on military specific performance showed moderate correlations between the SMM and a military specific test ($r = -0.47$), followed by the regression analysis that included SMM in best fit model of prediction, suggesting that higher skeletal muscle mass might improve the military specific test performance (Pihlainen *et al*.). Conversely, Mitrovic´ *et al*. investigated the association between the BMI and average running speed during 3km in specialist PO and found that PO with normal BMI levels were significantly faster than the PO classified as obese (mean difference = 0.364 m/s, $p = 0.021$). By using the regression analysis, authors established the significant link between BMI and running speed with $R^2 = 0.167$, and $p < 0.001$.

The findings of this study showed not only the significant correlation between body composition indexes and physical abilities and ultimately EPFS, but also the causal significant relationship between these two. It could be concluded that chosen body composition indexes could be the first indicators of variations in the level or type of PO's physical activity. Thus, the body composition-based prediction could be a useful and justifiable physical fitness prescreening and monitoring tool, when time does not permit for a more comprehensive assessment, especially having in sight the geographical position of some countries and possibility of high outside temperatures and humidity during the summer. Additionally, this information may provide a potential to mitigate potential fitness loss associated with the injury and to establish a greater understanding of the requirements to return the PO to optimal physical fitness.

ACKNOWLEDGEMENTS

RESUMEN: En este trabajo realizado con oficiales de policía (OP) se sugiere una asociación entre la composición corporal y el rendimiento físico y la salud. El objetivo del estudio fue investigar las asociaciones entre la composición corporal y las medidas de aptitud física, y su uso para predecir el puntaje de aptitud física estimado (PAFE). La muestra incluyó 163 OP masculinos (edad = 31,61 ± 4,79 años, altura = 172,97 ± 6,09 cm, masa corporal = 77,53 ± 11,66 kg). Se analizaron ocho variables de composición corporal: índice de masa corporal (IMC), índice de masa corporal grasa (IMCG), porcentaje de grasa corporal (PGC), porcentaje de masa muscular esquelética (PMME), índice de hipoquinezia (IH), índice de masa muscular esquelética (IMME), índice de masa proteica (IMP) e índice de masa libre de grasa (IMLG); y cuatro medidas de aptitud física: se correlacionaron una carrera de 3,2 km, una elevación de 2 minutos, una postura de 2 minutos y un puntaje de aptitud física estimada (PAFE), seguido del análisis de regresión para la relación causal entre la composición corporal y el PAFE. La prueba de ejecución de 3,2 km se correlacionó con el IMC, PGC, PMME, IMCG y IMME (r = 0,274, 0,250, -0,234, 0,311, p <0,01, respectivamente); Push-up de 2 minutos correlacionado con PGC, PMME, IMCG, IMME, PMI, IH y IMLG (r = -0,413, 0,436, -0,375, 0,221, 0,231, -0,411, 0,261, p <0,01, respectivamente); Sit-up de 2 minutos correlacionado con PGC, PMME, IMCG e IH (r = -0,237, 0,250, -0,236, -0,218, p <0,01, respectivamente); y EPFS correlacionado con IMC, IMLG, PGC , PMME, IGMC e IH (r = -0,200, 0,168, p <0,05, y r = -0,369, 0,378, 0,376, -0,317, p <0,01, respectivamente). Se extrajeron dos modelos de predicción: 1) PGC, IGMC, IMP y IMLG (R² = 0,250, p <0,001); 2) PGC, IGMC y IMP (R² = 0,244, p <0,00). Los modelos de predicción obtenidos pueden ser un método prometedor de detección de la condición física de los OP, cuando no es posible o seguro realizar las pruebas físicas (OP obesos y lesionados o condiciones climáticas adversas).

PALABRAS CLAVE: Evaluación; Antropometría; Desempeño físico; Agentes del orden.

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