

Age-dependent Model for Dynamics of Change in Body Composition Indicators in Professional Firefighters: Serbian Cross-Sectional Study

Modelo Dependiente de la Edad para la Dinámica de Cambio en los Indicadores de Composición Corporal en Bomberos Profesionales: Estudio Transversal Serbio

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SUMMARY: The aim of this study was to establish an age-related dynamic of change model for predicting changes in body composition indicators in professional firefighters. The study included a total sample of 145 subjects, comprising professional firefighters from Serbia (Age: 36.6 ± 7.6 yrs., Min – Max: 21.0 – 52.0 yrs.). Four basic variables were analysed: Body Mass - BM, Body Fat Mass - BFM, Skeletal Muscle Mass - SMM, and Visceral Fat Area - VFA, as well as five derived, or index, variables: Body Mass Index - BMI, Percentage of Body Fat - PBF, Percentage of Skeletal Muscle Mass - PSMM, Protein-Fat Index - PFI, and Index of Body - IBC Composition. The results showed a statistically significant dynamic of change as a function of age for eight of the examined variables, while only one (Skeletal Muscle Mass – SMM) was not statistically significant. The highest statistical significance in terms of dynamics of change as a function of age was found for the variable VFA ($F = 35.241$, $p = 000$) and the variable PSMM ($F = 31.398$, $p = 0.000$). Professional firefighters in Serbia fall into the category of people with normal nutritional indicators. However, due to a dominant increase in visceral fat (VFA) combined with a dominant decrease in the proportion of skeletal muscles in the body (PSMM), it can be concluded that they are exposed to a risk of developing various chronic diseases, while their working conditions, which promote certain negative lifestyle habits, also contribute to the observed increase in body fat components.

KEY WORDS: body composition; firefighters; body fat; linear regression.

INTRODUCTION

As one of the most demanding physical occupations, firefighting involves exposure to extreme heat environments that can affect both one's capacity to work and one's health. These thermal extremes may occur in outdoor or indoor settings and result from a combination of natural or artificial ambient conditions, the rate of metabolic heat generation from physical work, or workplace-specific processes (Cheung *et al.*, 2016). Due to working in these adverse conditions, firefighters have to wear bulky and heavy personal protective equipment (PPE), including self-contained breathing apparatus (SCBA), weighing more than 40 kg. This increases stress and creates difficulties, such as further increasing aerobic and anaerobic energy consumption, reduced mobility, and increased perception of effort while performing firefighting tasks (Phillips *et al.*, 2016).

It has been determined that there is a high prevalence of obesity and excessive weight amongst firefighters, which is characterised as a critical issue because, in addition to a higher risk of morbidity and mortality, excess body fat correlates with low fitness levels (Poston *et al.*, 2011). Obesity was also found to be highly prevalent among American firefighters (a prevalence of 24–35 %). This phenomenon is considered extremely negative as it reduces work performance efficiency and leads to an increased risk of injuries or a sudden heart attack while at work. Sudden cardiac events are the leading cause of duty-related deaths in the fire service, with coronary heart disease and cardiac structural changes (cardiomegaly and LVH) identified in over 80 % of cardiac cases (Mathias *et al.*, 2021).

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This study focusses on determining the relationship between age and the characteristic variables that define the body composition of firefighters. The aim is to define specific dynamic of change models for the examined variables of body composition in relation to the age of professional firefighters. This will provide quantitative standards as mathematical models to predict the examined phenomenon, thus representing an initial description of the state of this aspect of the firefighting system, specifically the dynamics of change in body composition as a function of age in professional firefighters.

MATERIAL AND METHOD

This was a non-experimental study with an applied scientific research character. Laboratory measurement was chosen (MIL, Faculty of Sport and Physical Education, University of Belgrade, Serbia) as the primary research technique, using a random sample of firefighters from the Republic of Serbia.

Subjects. The study involved a total sample of 145 subjects, comprising professional firefighters from Serbia (Age: 36.6 ± 7.6 yrs.). Participants were informed about the aim of the study and were selected randomly on a voluntary basis to participate in it. The research was conducted according to the Declaration of Helsinki (Christie, 2000) and with the permission of the Ethics Committee of the Faculty of Sport and Physical Education, University of Belgrade (02 No. 484-2).

Body Composition Measurement and Variables. Basic anthropometric parameters and body composition measurements were taken between 7.30 a.m. and 9.30 a.m. according to procedures described previously (Kukic *et al.*, 2018; Dopsaj *et al.*, 2020a; Rakic *et al.*, 2022). Body height was measured using an anthropometer (GPM, Swiss made), while body composition was assessed using the electrical multichannel bioimpedance method (BIA) with an InBody 720 device (Biospace Co., Ltd, Seoul, Korea) (Dopsaj *et al.*, 2023).

In addition to body height as a basic body longitudinal variable (BH, expressed in cm), the following 9 variables were used as a system of body composition indicators: four primary variables Body Mass - BM as the basic body volume variable, Body Fat Mass - BFM as the total amount of fat (ballast) tissue mass in the body, Skeletal Muscle Mass - SMM as the total amount of skeletal muscle (contractile) tissue mass in the body, all expressed in kg, and Visceral Fat Area - VFA, expressed in cm^2 ; five derived, or index, variables Body Mass Index - BMI, expressed in kg/m^2 , Percentage of Body Fat - PBF, and Percentage of Skeletal Muscle Mass - PSMM, expressed in %, Protein-Fat Index -

PFI, calculated as the relationship between proteins (in kg) and body fat mass (in kg), expressed in kg, and Index of Body Composition - IBC, calculated as the relationship between BMI and PBF, expressed in Index Units (Kukic *et al.*, 2018, 2020; Dopsaj *et al.*, 2020a).

Statistics. All raw data were analysed using basic descriptive statistical procedures, with the descriptive statistical parameters calculated as: Mean Mean Value - Mean, Standard Deviation - SD, Coefficient of Variation - cV (%), Minimum and Maximum value - MIN and Absolute Value of Standard Error of Measurement - MAX, SEM (aps.), and Relative Value of Standard Error of Measurement SEM (%). Linear regression analysis was used to calculate the linear relationship between the observed body composition variables, as a predictive variable, and age as a criterion variable. Thus, the regression coefficient presented a dynamic of change model for a particular variable over the observed period of time, i.e. one calendar year. All analyses were performed using Microsoft Office Excel 2007 and IBM SPSS v23.0 statistical software. P-values of less than 0.05 were considered statistically significant, for a 95 % level of probability (Hair *et al.*, 1998).

RESULTS

Table I shows the results of descriptive statistics for the analysed variables. Based on these, it can be concluded that the relative error value of the arithmetic mean ranges from only 0.30 % for BH to 6.09 % for PFI (Table I).

Figures 1 to 9 show the dynamics of change models, as defined regression dependencies, between the analysed individual body composition variables across different age groups in a cross-section of professional firefighters. The regression models showed that five variables exhibited mathematically positive dynamics of change, i.e. an increase in the nominal values of the variables as a function of age (Fig. 1 – BM; Fig. 2 – BMI; Fig. 3 – BF; Fig. 4 – PBF; Fig. 7 – VFA), three displayed a negative trend, i.e. a decrease in the nominal values of the variables as a function of age (Fig. 6 – PSMM; Fig. 8 – PFI; Fig. 9 – IBC), while no significant change with age was established for one variable (Fig. 5 – SMM).

Table II presents the results of the defined regression models for the analysed variables. Based on the results, it can be concluded that a statistically significant change as a function of age in professional firefighters was determined for eight of the examined variables, while only one (SMM) was not determined to be statistically significant. The highest statistical significance was established for VFA ($F = 35.241$, $p = 0.000$) and PSMM ($F = 31.398$, $p = 0.000$).

Table I. Basic descriptive statistics for the analysed body composition variables among professional firefighters.

	MEAN	SD	cV (%)	Min	Max	SEM (Aps.)	SEM (%)
Age (yrs.)	36.6	7.6	20.76	21.0	52.0	0.63	1.72
Work Exp (yrs.)	12.4	7.7	61.99	1.0	31.0	0.75	6.05
BH (cm)	180.6	6.5	3.60	161.9	195.6	0.54	0.30
BM (kg)	90.8	12.7	13.94	63.0	126.8	1.05	1.16
BMI (kg/m ²)	27.83	3.60	12.95	19.91	39.22	0.30	1.08
BFM (kg)	19.6	8.1	41.27	2.0	46.1	0.67	3.43
SMM (kg)	40.6	4.7	11.57	30.9	55.4	0.39	0.96
PBF (%)	21.07	6.62	31.42	2.96	38.97	0.55	2.61
VFA (cm ²)	99.4	36.8	37.1	19.6	195.7	3.06	3.08
PFI (IU)	0.91	0.67	73.39	0.31	6.55	0.06	6.09
PSMM (%)	45.06	4.04	8.97	31.37	56.92	0.34	0.75
IBC (IU)	1.482	0.682	46.04	0.77	7.07	0.06	3.82

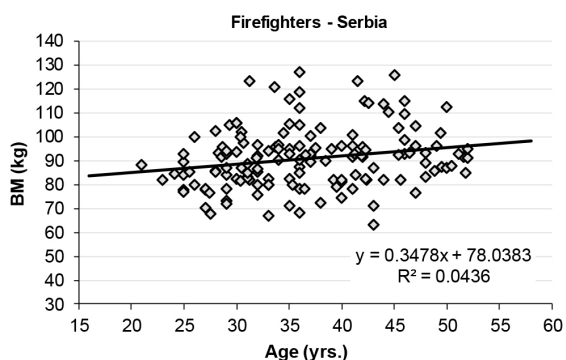


Fig. 1. Relationship between BM and age among professional firefighters.

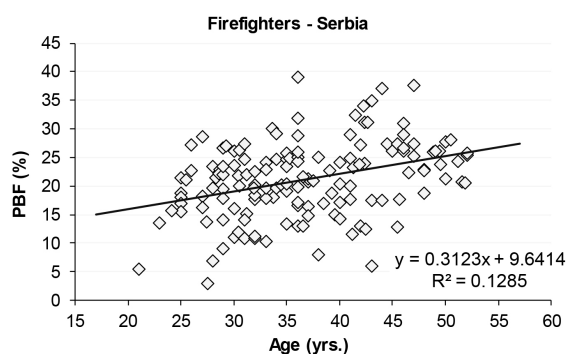


Fig. 4. Relationship between PBF (%) and age among professional firefighters.

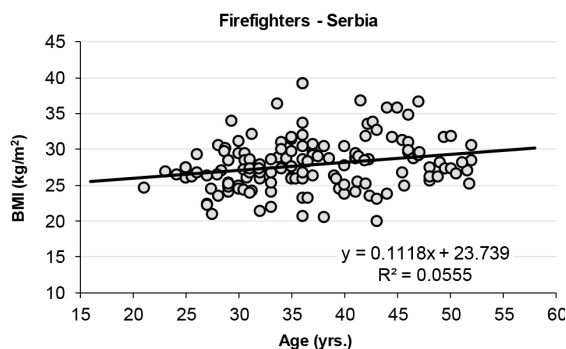


Fig. 2. Relationship between BMI and age among professional firefighters.

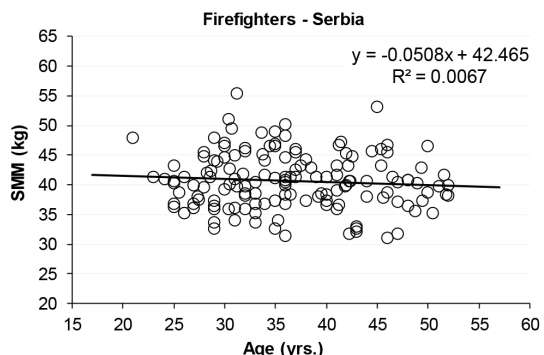


Fig. 5. Relationship between SMM and age among professional firefighters.

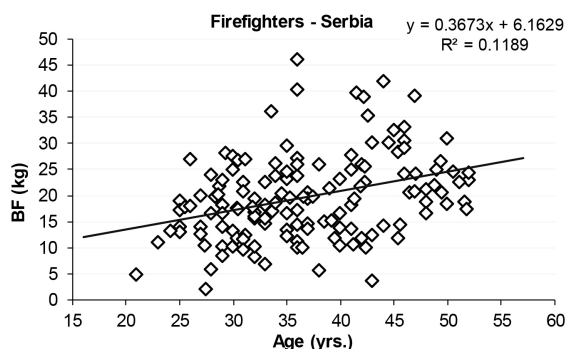


Fig. 3. Relationship between BF and age among professional firefighters.

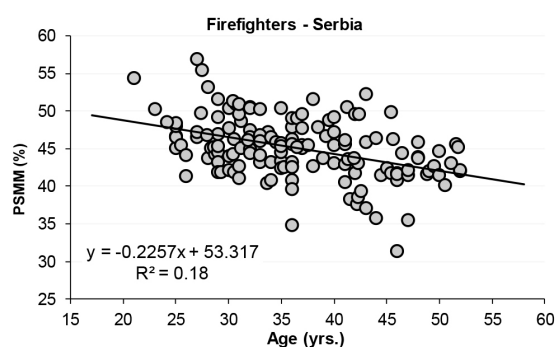


Fig. 6. Relationship between PSMM (%) and age among professional firefighters.

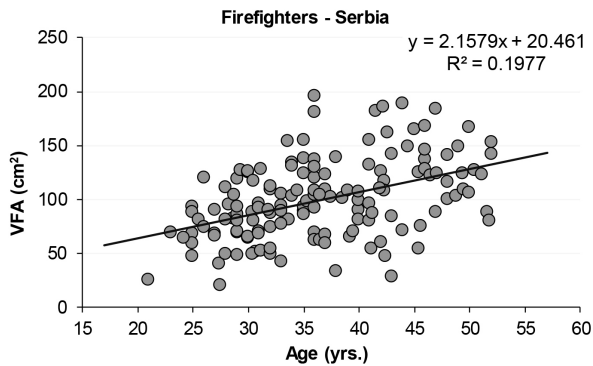


Fig. 7. Relationship between VFA and age among professional firefighters.

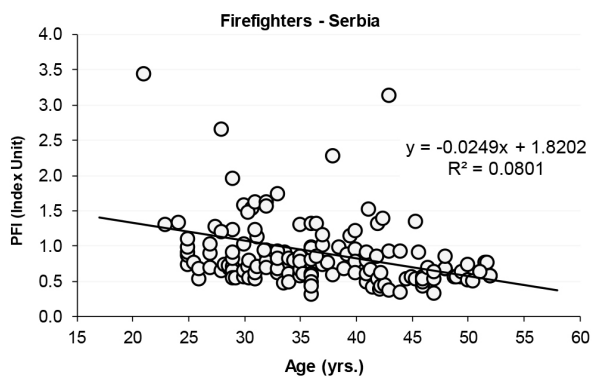


Fig. 8. Relationship between PFI and age among professional firefighters.

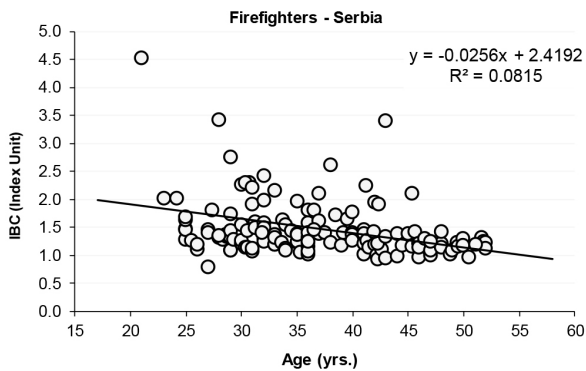


Fig. 9. Relationship between IBC and age among professional firefighters.

DISCUSSION

Regarding body constitution, the results showed that the average values of BH, BM, and BMI for the sample of professional firefighters were: 180.6 ± 6.10 cm, 90.8 ± 12.7 kg, and 27.83 ± 3.60 kg/m² respectively (Table I). When compared to standards for the general population of Serbia [BH = 181.61 ± 6.76 cm, BM = 87.68 ± 14.73 kg, BMI = 27.74 ± 4.26 kg/m² (Dopsaj *et al.*, 2018a)], it can be argued that professional firefighters have lower BH (-1.01 cm), higher BM (3.12 kg), and a slightly higher BMI value (0.09 kg/m²). For the derived body composition variables, firefighters had average PBF values of 21.07 ± 6.62 % and PSMM of 45.06 ± 4.04 % (Table I), while average values for the general population are PBF = 21.90 ± 7.40 % and PSMM = 44.95 ± 4.28 % (Dopsaj *et al.*, 2020a; Dopsaj *et al.*, 2021). Although these values are very similar, it can be concluded that professional firefighters have a lower PBF (-0.83 %) and a higher PSMM (0.11 %).

Based on the standards for the police in Serbia (Vukovic *et al.*, 2022), with average values of PBF = 21.18 ± 5.95 % and PSMM = 44.99 ± 3.59 %, it can be argued that professional firefighters have a lower PBF (-0.11 %) and a slightly higher PSMM (0.07 %). Since the values for these two variables are quite similar, it can be argued that professional firefighters and police in Serbia are comparable in terms of body fat and muscle mass composition.

The results showed that the ratio of protein (as pure contractile mass, essential for quality motor skills) to fat (as ballast mass in terms of quality motor skills) in the body, i.e. the PFI variable, was 0.91 ± 0.67 kg. This is 0.04 kg higher than the average values for the Serbian working population (PFI = 0.87 ± 0.46 kg) (Dopsaj *et al.*, 2018b). This means that, on average, professional firefighters have 40 g of protein more per kg of body fat than the general population in Serbia.

Previously published data show that the average IBC value for the Serbian police is 0.91 ± 0.22 %/kg/m², while for the examined firefighters, it was considerably higher - IBC = 1.48 ± 0.68 , an increase of 0.57. Analytically speaking, since a

Table II. Model summary results for regression analyses.

Variable	Model Summary Results			ANOVA of Regression		Equation Model for Prediction
	r	Adj. R ²	St. Err. Est.	F value	p sig.	
BM (kg)	0.209	0.037	12.41	6.518	0.012	BM = 78.043 + (0.348 • Age)
BMI (kg/m ²)	0.236	0.049	3.51	8.406	0.004	BMI = 23.738 + (0.112 • Age)
BF (kg)	0.345	0.113	7.62	19.293	0.000	BF = 6.166 + (0.367 • Age)
PBF (%)	0.359	0.122	6.20	21.090	0.000	PBF = 9.640 + (0.312 • Age)
SMM (kg)	0.082	0.000	4.70	0.973	0.326	SMM = 42.468 - (0.051 • Age)
PSMM (%)	0.424	0.174	3.67	31.398	0.000	PSMM = 53.319 - (0.226 • Age)
VFA (cm ²)	0.445	0.192	33.14	35.241	0.000	VFA = 20.458 + (2.158 • Age)
PFI (IU)	0.283	0.074	0.64	12.433	0.001	PFI = 1.819 - (0.025 • Age)
IBC (IU)	0.285	0.075	0.66	12.681	0.001	IBC = 2.420 - (0.026 • Age)

lower index value indicates a higher fat content in terms of body composition, it can be concluded that the examined firefighters have a physique characterised by a lower fat content than the police.

The results of the defined regression models showed that five of the variables exhibited a statistically significant positive change, i.e. an increasing trend in terms of the numerical values of the variables as a function of age. It was found that BM increased by an average of 0.348 kg per year (Table I, Fig. 1). Although the model explains only 3.7 % of the common variance, it is still highly statistically significant with a prediction error of 12.41 kg (Table II, $p = 0.012$). The variable that determines a person's nutritional status, i.e. the level of BMI in the examined sample, also increased by an average of 0.112 kg/m² per year (Table I, Fig. 2). The model explains 4.9 % of the common variance and is highly statistically significant, while the prediction error was determined to be 3.51 kg/m² (Table II, $p = 0.004$).

The BF in firefighters increased by an average of 0.367 kg per year (Table I, Fig. 4). The defined model explains 11.3 % of the common variance and is highly statistically significant with a prediction error of 7.62 kg (Table II, $p = 0.000$). On the other hand, PBF increased by an average of 0.312 % per year (Table I, Fig. 5). Again, the defined model is highly statistically significant (Table II, $p = 0.000$) and explains 12.2 % of the common variance with a model prediction error of 6.20 %. The final variable exhibiting an increasing trend was that defining the level of fat in internal organs, i.e. VFA. This showed the highest level of dependence on age, with a common variance of 19.2 % (Table II, $p = 0.000$). It increased by 2.158 cm² per year, with the predictive error of the model calculated at 33.14 cm² (Tables I and II, Fig. 8).

On the other hand, the results showed that three variables had a negative correlation with age, i.e. they exhibited a decreasing trend with increasing age. These variables are PSMM, PFI, and IBC. The PSMM in the examined sample of firefighters decreased at an average of -0.226 % per year (Table I, Fig. 7). The defined model explains 17.4 % of the common variance and is highly statistically significant level with a prediction error of 3.67 % (Table II, $p = 0.000$). The index that defines the ratio of pure contractile (protein) and ballast (fat) components in the body (PFI) decreased by an average of -0.025 index units (Table I, Fig. 9), with the defined model explaining 7.4 % of the common variance at a highly statistically significant level and with a model prediction error of 0.64 IU (Table II, $p = 0.001$). The (IBC, which defines the relationship between the BMI and the PBF, also decreased by an average of -0.026 index units (Table I, Fig. 10). The defined model

explains 7.5 % of the common variance at a highly statistically significant level and with a standard error of prediction of 0.66 IU (Table II, $p = 0.001$).

The only variable for which no statistically significant change in terms of its dynamics in relation to age was determined is SMM (Table II, Fig. 5). It did not change statistically significantly ($p = 0.736$, and $p = 0.326$, Table II) across the age range of the examined sample (31 years, i.e. from 21 to 52 years of age). Nominally speaking, SMM decreased by an average of -0.051 kg per year (51 g of skeletal muscle reduction per year of life) (Fig. 5).

Overall, the obtained results indicate certain regularities in body composition changes among professional firefighters in relation to their specific lifestyle and working environment. Notably, the highest level of change relates to the increase in VFA, while the decrease in the relative representation of the PSMM also stood out.

It has been established that an increase in VFA during one's lifetime is a risk factor linked to the development of metabolic disorders and chronic diseases (diabetes and coronary heart disease). This increase often stems from unhealthy habits such as smoking, alcohol consumption, and an unhealthy diet that is high in fat (Seidell & Bouchard, 1997). An epidemiological study conducted in Japan found that adopting a lifestyle that does not increase VFA plays an important role in preventing metabolic syndrome and that there is a greater chance of high triglyceride levels and low high-density lipoprotein cholesterol levels in subjects with visceral fat over 50 cm² (Matsushita *et al.*, 2013).

This increase in visceral fat and also the increasing trend in total body fat at a level of 0.3673 kg per year, which all leads to increasing body weight and affects nutrition levels (0.1118 kg/m² per year), indicates the likely dominance of higher caloric intake in relation to caloric expenditure as a work-life pattern in the examined sample. This, along with smoking and stress, can also have a negative impact on the health and career of firefighters (Seidell & Bouchard, 1997; Matsushita *et al.*, 2013). On the other hand, the stability determined in terms of changes in SMM still indicates that there is no loss of muscle mass over the observed lifespan.

The average SMM in men aged 30–39.9 years is 40.78 ± 5.53 (Dopsaj *et al.*, 2020b), which closely matches the SMM values determined in this study for professional firefighters of the same average age (40.60 ± 4.70 kg). However, the results showed that the trend of muscle mass loss is less marked among professional firefighters than among the general male population in Serbia. This can be attributed to the physical demands of their job, i.e. regular

training and frequent physical exertion during their daily firefighting and rescue tasks (Samardzic *et al.*, 2023; Bajic *et al.*, 2024).

CONCLUSION

The results of this study showed that among professional firefighters in the Republic of Serbia, aged 21 to 52 years, in terms of dynamics of change, the most pronounced increases in body composition components occurred in fat-related variables, following this hierarchical order: VFA, PBF, BF, and BMI. Muscle-related variables decreased in the following order of significance: PSMM, PFI and IBC. Only skeletal muscle mass (SMM) was found to remain unchanged during the observed time period. The results indicate that professional firefighters in Serbia belong to the category of people with normal nutritional indicators. However, the most significant changes during their working life were found to be an increase in visceral fat area (VFA) and a reduction in the percentage of skeletal muscle mass (PSMM).

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RESUMEN: El objetivo de este estudio fue establecer un modelo de dinámica de cambio relacionada con la edad para predecir cambios en los indicadores de composición corporal en bomberos profesionales. El estudio incluyó una muestra total de 145 sujetos, incluidos bomberos profesionales de Serbia (Edad: $36,6 \pm 7,6$ años, mín. – máx.: 21,0 – 52,0 años). Se analizaron cuatro variables básicas: Masa Corporal - MC, Masa Grasa Corporal - MGC, - Masa Muscular Esquelética - MME y Área Grasa Visceral - AGV, así como cinco variables derivadas o indexadas: Índice de Masa Corporal - IMC, Porcentaje de grasa corporal - PGC, porcentaje de masa muscular esquelética - PMME, índice proteína-grasa - IPG e índice de composición corporal - ICC. Los resultados mostraron una dinámica de cambio estadísticamente significativa en función de la edad para ocho de las variables examinadas, mientras que sólo una, MME no fue estadísticamente significativa. La mayor significancia estadística en términos de dinámica de cambio en función de la edad se encontró para la variable AGV ($F = 35,241$, $p = 0,000$) y la variable PMME ($F = 31,398$, $p = 0,000$). Los bomberos profesionales de Serbia pertenecen a la categoría de personas con indicadores nutricionales normales. Sin embargo, debido a un aumento dominante de la grasa visceral combinado con una disminución dominante de la PMME, se puede concluir que están expuestos a un riesgo de desarrollar diversas enfermedades crónicas, mientras que las condiciones de trabajo, que promueven ciertos hábitos de vida negativos, también contribuyen al aumento observado de los componentes de la grasa corporal.

PALABRAS CLAVE: Composición corporal; Bomberos; Grasa corporal; Regresión lineal.

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