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Kukić, Filip; Koropanovski, Nenad; Janković, Radivoje; Cvorovic, Aleksandar ; Dawes, Jay; Lockie, Robert; Orr, Rob Marc; Dopsaj, Milivoj

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Association of Sex-Related Differences in Body Composition to Change of Direction Speed in Police Officers While Carrying Load

Asociación de Diferencias Relacionadas con el Sexo en la Composición Corporal para Cambiar la Velocidad de Dirección de Oficiales de Policía Durante el Transporte de Carga

Kukic Filip^{1,3}; Koropanovski Nenad²; Jankovic Radivoje²; Cvorovic Aleksandar³;
Dawes J. Jay⁴; Lockie G. Robert⁵; Robin M. Orr^{6,7} & Dopsaj Milivoj⁸

KUKIC, F.; KOROPANOVSKI, N.; JANKOVIC, R.; CVOROVIC, A.; DAWES, J. J.; LOCKIE, R. G.; ORR, R. M. & DOPSAJ, M. Association of sex-related differences in body composition to change of direction speed in police officers while carrying load. *Int. J. Morphol.*, 38(3) 731-736, 2020.

SUMMARY: Regardless of sex or body size, police tasks may require officers to change direction speed (CODS) under occupational loads. The purpose of this study was to investigate body composition and CODS in female and male police cadets in both unloaded and occupationally loaded conditions. Body composition and CODS of 51 female (FPC) and 70 male police cadets (MPC) were assessed. Six body composition indices were used: Body mass index (BMI), percent body fat (PBF), percent of skeletal muscle mass (PSMM), protein fat index (PFI), index of hypokinesia (IH), and skeletal muscle mass index (SMMI). The CODS was assessed by Illinois Agility Test (IAT) and IAT while carrying a 10-kg load (LIAT). An independent sample t-test was used to identify the differences between the sexes. The regression determined associations between body composition and LIAT. The alpha level was set at $p < 0.05$ a priori. MPC had significantly higher ($p < 0.001$) BMI, PSMM, PFI and SMMI and lower PBF and IH than FPC. MPC were also faster in IAT and LIAT, carrying lower relative loads that imparted less of an impact on CODS performance. Body composition was strongly associated with the time to complete LIAT ($R^2 = 0.671$, $p < 0.001$). Difference in relative load and body composition influenced CODS performance in both unloaded and loaded conditions. Thus, optimizing body composition through increasing skeletal muscle mass and reducing fat mass could positively influence unloaded and loaded CODS performance and improve elements of police task performance.

KEY WORDS: Agility; Law enforcement; Police cadets; Occupational load; Human body morphology.

INTRODUCTION

While at the academy, police cadets are prepared for the awaiting duties of incumbent officers. The job tasks performed in the execution of these duties can be varied and diverse, from security checks to attending a vehicle accident (Anderson *et al.*, 2001; Garbarino & Magnavita, 2015). One such task may involve the pursuit of a suspect on foot or moving rapidly towards a problem. In these situations, the police officer can run at maximal to near-maximal speeds, with potential sharp turns, over various distances ranging from 5 to 350 meters (Anderson *et al.*). Physical assessments that closely mimic this potential scenario while on duty are frequently implemented into strategies for improving the job-

related physical fitness, and potential monitoring, of police officers (Strating *et al.*, 2010; Orr *et al.*, 2019).

Considering this, body size and composition have been shown to be associated with job-related physical performance of police officers (Dawes *et al.*, 2016; Kukic *et al.*, 2018a,b). Furthermore, studies have shown that some physical performance can be influenced by body size and composition (Kukic *et al.*, 2018a,b; Zaric *et al.*, 2020). This in part contributed to the recommendation by Jaric *et al.* (2005) who proposed the standardization of performance tests based on body size. Although there is an ample evidence that physical assessment

¹ Faculty of Sport and Physical Education, University of Belgrade, Serbia.

² University of Criminal Investigation and Police Studies, Belgrade, Serbia.

³ Police Sports Education Center, Abu Dhabi Police, UAE.

⁴ School of Kinesiology, Applied Health and Recreation, Oklahoma State University, Stillwater, OK, USA.

⁵ Department of Kinesiology, California State Fullerton, Fullerton, CA, USA.

⁶ Faculty of Health Sciences and Medicine, Bond Institute of Health and Sport, Bond University, Gold Coast, Australia.

⁷ Tactical Research Unite, Bond University, Australia.

⁸ Institute of Sport, Tourism and Service, South Ural State University, Chelyabinsk, Russia.

could give more precise indications of physical abilities and performance when adjusted to body size or volume (Jaric *et al.*), the field tasks, hence task-related performance tests, of police officers have to be performed regardless of these factors.

The Illinois Agility Test (IAT) is a change of direction speed (CODS) test frequently used by law enforcement agencies to simulate the foot chase of a suspect or the ability to quickly seek cover (Beck *et al.*, 2015). The IAT requires the participant to rapidly accelerate, decelerate, and change direction (Orr *et al.*). Moreover, while on duty, police officers are normally loaded with a gear weighing approximately 10 kg (Baran *et al.*, 2018). Considering this, body mass (BM) is highly dependent on body size and, in general, men are taller and heavier than women (Dopsaj *et al.*, 2015). Nevertheless, the weight of the equipment remains the same regardless of the sex of the officer, and as such female officers, may be required to carry relatively heavier loads than male officers (Baran *et al.*). In addition, when arresting a potentially heavier belligerent offender, female officers (and smaller, lighter male officers), will need to overcome a larger relative resistance, meaning that these duties are sex-independent. It is therefore not surprising that next to physical activity and skill, body size, body composition, and external load are well-investigated factors associated to physical abilities (i.e. strength and aerobic power) as well as to the outcome of a number of functional performance tests (Dawes *et al.*, 2017; Kukic *et al.*, 2018a,b; Lockie *et al.*, 2018; Zaric *et al.*, 2020).

There is limited research investigating the IAT and subsequent CODS performance of police cadets while carrying the load in association with body composition. This is particularly important as both females and males apply for the police academy and through this training prepare for the unpredictable nature of police duties. These duties can often require tasks involving CODS under occupational loads, regardless of sex or body size. Agility is a complex motor skill, and occupational loads can make this skill even more complex and unpredictable, especially for smaller individuals. The question then arises whether an IAT where the participants wear load (LIAT) would be associated with body composition and if these associations would differ by sex. Thus, the purpose of this study was to investigate the differences in LIAT performance based on the body composition of police cadets and if the differences in LIAT are associated with cadet sex.

MATERIAL AND METHOD

Subjects. The sample included 121 police cadets, among which 51 were female police cadets (FPC) (age = 20.20 ± 1.17 years, body height (BH) = 170.05 ± 4.23 cm, BM =

64.96 ± 7.76 kg) and 70 were male police cadets (MPC) (age = 20.31 ± 0.96 years, BH = 182.58 ± 5.18 cm, BM = 82.24 ± 11.13 kg). The assessment of physical abilities was conducted as part of the academy curricula; however, all subjects signed an informed consent, agreeing to the use of their data for this 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.

Procedures

Body composition. Body composition measurement procedures were conducted using a multi-channel bioelectric impedance analyzer (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 detail (Dopsaj *et al.*, 2017; Rakic *et al.*, 2019). All body composition measurements were conducted between 08:00-10:00 am, whereby all participants fasted the night before the measurements being taken, and were advised not to eat a large meal for dinner, and not to exercise the day prior to the measurement. Participants were wearing underwear, were barefoot, and had all metal, plastic, and magnetic accessories removed before standing on the device and on the metal spots designated for their feet. Three body composition measures, body mass index (BMI), body fat (BF), and skeletal muscle mass (SMM) were collected directly from the device. Afterwards, five more variables were calculated as index variables, representing a certain tissue or tissue ratio independently of participant's body size and body mass. These were: Index of hypokinesia (IH) – body size and volume-independent ballast tissue, skeletal muscle mass index (SMMI) – body size-independent (i.e., BH₂) amount of contractile tissue, percent of skeletal muscle mass (PSMM) – relative amount of contractile tissue, percent of body fat mass (PBF) – relative amount of ballast tissue, and protein/fat index (PFI) – contractile/ballast tissue ratio independent of body size. BMI in general represents the ratio of body volume relative to body size, but without giving a specific information on the source of the volume (Rothman, 2008; Provencher *et al.*, 2018). In contrast, PBF and PSMM approximately explain the ratio of fat and muscle tissue within the given BMI, and they are basically opposing tissues of human body (active and ballast), meaning that an increase in PSMM will lead to decrease in PBF and vice versa (Kukic *et al.*, 2018a,b, 2019). Finally, IH was generated to represent the source of BMI more precisely, SMMI so that skeletal muscle mass can be compared between two bodies of different size (for example female and male) and PFI for the comparison of the contractile/ballast tissue ratio between different bodies.

CODS. The IAT provides information about the ability to accelerate, decelerate, turn in different directions, as well as run at different angles, and is often used upon established criteria data for males and females (Orr *et al.*). Hachana *et al.* (2013) reported a high intra-trial reliability of this test (ICC = 0.96). Unlike the standard IAT, the participants in this study wore a 10 kg vest. Both, IAT and LIAT test outcomes were recorded using the electronic timing gates (Fitro Light Gates, Fitronic, Bratislava, Slovakia). Precision of the measurement was 0.01 s. The LIAT course (same as IAT course) was used as previously reported in literature (Orr *et al.*). Two cones were used to mark the turning points, while four center cones were placed down the center and spaced 3.3 m apart. The participants began the test lying prone on the floor behind the starting line. On the start command, the participants ascended and ran, forward to the first turning cone. The participants were required to turn around the first turning cone and moved back to the first center cone, where they weaved up and back through the four center cones. The participants then ran to the second turning cone. After turning around, the participants were required to run across the finish line. Participants were instructed to complete the test as quickly as possible. The difference between the IAT and LIAT (IATD) and the relative load (RL) of the vest were calculated in order to establish the between-group difference in impact of RL on LIAT.

Statistical Analysis. Descriptive statistics were used to calculate the measure of central tendency (mean) and measures of data dispersion (standard deviation, minimum and maximum) for the FPC and MPC combined as well as individually. The between-group differences in investigated variables were analyzed using an independent sample t-test. The multiple regression analysis was used to identify if a causal relationship existed between the LIA and body composition and what the most important variables for performance of LIA were. All statistical procedures were conducted in Statistical

Package for Social Sciences (IBM, SPSS Statistics 20), with the significance level was set at $p < 0.05$.

RESULTS

The descriptive statistics for mean, standard deviation (SD), minimum (Min) and maximum (Max), showed that the data dispersion decreased almost twice, once the sample was divided into subsamples (Table I). There were significant differences between FPC and MPC in all investigated variables except age (Table II). FPC performed IAT and LIAT an average 3.03 and 3.89 seconds slower than the MPC respectively, with the magnitude of the between-group difference being larger in LIAT. Furthermore, FPC were more affected by the load than the MPC because the difference between the IAT and LIAT was moderately higher in FPC than in MPC. Moreover, RL was significantly higher in FPC comparing to MC. Regarding body composition, the highest relative difference occurred in PFI, IH, PBF, and SMMI. A large magnitude of difference also occurred in anthropometric measures (hence body size), such as BH and BM, while moderate difference occurred in BMI (Table II).

A backward regression analysis revealed a strong predictive value of PBF, IH and PFI within the simplest regression model with the lowest standard error of the estimate in predicting LIAT, establishing a causal association of LIAT to relative volume of ballast tissue, body size and volume-independent ballast tissue and contractile/ballast tissue ratio independent of body size (Fig. 1).

Once adjusted for sex and analyzed separately, the strength of regression analysis decreased in FPC ($R^2 = 0.181$, $F = 81.26$, $p = 0.008$), without the presence of significance in

Table I. The descriptive statistics for the investigated variables.

| Variables | Combined | | | FPC | | | MPC | | |
|---------------------------|---------------|--------|--------|---------------|--------|--------|---------------|--------|--------|
| | Mean ±SD | Min | Max | Mean ±SD | Min | Max | Mean ±SD | Min | Max |
| Age | 20.26 ± 1.05 | 19.00 | 26.00 | 20.20 ± 1.17 | 19.00 | 26.00 | 20.31 ± 0.96 | 19.00 | 24.00 |
| BH (cm) | 177.30 ± 7.84 | 162.70 | 195.40 | 170.05 ± 4.23 | 162.70 | 180.10 | 182.58 ± 5.18 | 173.00 | 195.40 |
| BM (kg) | 74.96 ± 13.03 | 53.10 | 125.00 | 64.96 ± 7.76 | 53.10 | 96.80 | 82.24 ± 11.13 | 66.50 | 125.00 |
| BMI (kg/m ²) | 23.70 ± 2.74 | 18.70 | 34.10 | 22.45 ± 2.39 | 18.70 | 34.10 | 24.62 ± 2.63 | 20.30 | 33.70 |
| PBF (%) | 19.46 ± 7.14 | 6.60 | 38.50 | 26.04 ± 4.99 | 17.20 | 38.50 | 14.66 ± 3.91 | 6.60 | 26.00 |
| PSMM (%) | 45.34 ± 4.85 | 32.44 | 54.34 | 40.77 ± 2.81 | 34.61 | 45.93 | 48.66 ± 2.93 | 32.44 | 54.34 |
| PFI | 0.98 ± 0.50 | 0.28 | 2.87 | 0.58 ± 0.16 | 0.28 | 0.94 | 1.27 ± 0.46 | 0.56 | 2.87 |
| IH | 0.83 ± 0.31 | 0.28 | 1.52 | 1.16 ± 0.17 | 0.81 | 1.52 | 0.59 ± 0.13 | 0.28 | 0.83 |
| SMMI (kg/m ²) | 10.75 ± 1.71 | 7.80 | 14.75 | 9.11 ± 0.70 | 7.80 | 11.81 | 11.94 ± 1.13 | 8.69 | 14.75 |
| IAT (s) | 20.68 ± 2.00 | 16.84 | 25.14 | 22.43 ± 1.37 | 19.67 | 25.14 | 19.41 ± 1.30 | 16.84 | 22.31 |
| LIAT (s) | 22.26 ± 2.33 | 18.25 | 27.70 | 24.52 ± 1.37 | 21.88 | 27.70 | 20.62 ± 1.25 | 18.25 | 23.68 |
| IATD (s) | -1.58 ± 0.91 | -4.82 | 0.92 | -2.08 ± 0.97 | -4.82 | -0.16 | -1.22 ± 0.66 | -2.58 | 0.92 |
| RL (%) | 13.72 ± 2.25 | 8.00 | 18.83 | 15.59 ± 1.68 | 10.33 | 18.83 | 12.36 ± 1.52 | 8.00 | 15.04 |

Table II. The independent sample t-test results.

| Variables | t | Mean Difference | 95% CID | | Δ (%) | ES |
|---------------------------|--------|-----------------|---------|--------|---------|-------|
| | | | Lower | Upper | | |
| Age | -.61 | -.12 | -.50 | .26 | -.59 | -0.10 |
| BH (cm) | -14.17 | -12.53** | -14.29 | -10.78 | -7.37 | -2.96 |
| BM (kg) | -10.06 | -17.28** | -20.68 | -13.87 | -26.59 | -2.23 |
| BMI (kg/m ²) | -4.65 | -2.17** | -3.09 | -1.24 | -9.65 | -0.91 |
| PBF (%) | 13.54 | 11.38** | 9.71 | 13.05 | 43.72 | 2.28 |
| PSMM (%) | -14.90 | -7.89** | -8.94 | -6.84 | -19.36 | -2.81 |
| PFI | -11.59 | -.69** | -.81 | -.57 | -118.53 | -4.43 |
| IH | 20.47 | .57** | .51 | .62 | 48.88 | 3.42 |
| SMMI (kg/m ²) | -16.96 | -2.83** | -3.16 | -2.50 | -31.09 | -4.06 |
| IAT (s) | 12.41 | 3.03** | 2.54 | 3.51 | 13.50 | 2.22 |
| LIAT (s) | 16.24 | 3.89** | 3.42 | 4.37 | 15.88 | 2.85 |
| IATD (s) | -5.50 | -.87** | -1.18 | -.55 | 41.58 | -0.89 |
| RL (%) | 11.02 | 3.23** | 2.65 | 3.81 | 20.70 | 1.92 |

Table III. Regression coefficients for combined sample and FPC.

| Model | Variables | B | Lower limit | Upper Limit | t | p |
|----------|------------|-------|-------------|-------------|-------|------|
| Combined | (Constant) | -0.11 | 12.84 | 17.93 | 11.99 | 0.00 |
| | PBF | 1.02 | -0.23 | 0.01 | -1.74 | 0.08 |
| | PFI | 9.62 | -0.08 | 2.13 | 1.84 | 0.07 |
| | IH | -0.11 | 7.18 | 12.05 | 7.82 | 0.00 |
| FPC | (Constant) | 36.98 | 29.13 | 44.82 | 9.47 | 0.00 |
| | BM | -0.07 | -0.12 | -0.02 | -2.80 | 0.01 |
| | PSMM | -0.19 | -0.33 | -0.05 | -2.71 | 0.01 |

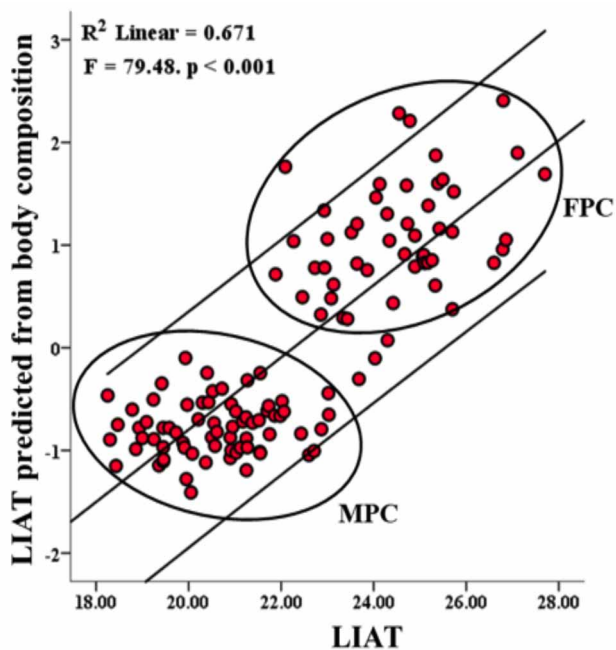


Fig. 1. The regression analysis. FPC = female police cadets, MPC = male police cadets, LIAT = loaded Illinois Agility test.

MPC ($R^2 = 0.174, F = 102.14, p = 0.092$). Moreover, the model of LIAT prediction in FPC differed from the one extracted on the combined sample, with BM and PSMM (total body volume based on active tissue) being the only prediction variables (Table III).

DISCUSSION

The main purpose of this study was to investigate if the CODS while carrying the load is associated with the differences in body composition of police cadets. For that reason, the data confirmed that FPC and MPC were significantly different in body size and body composition. Thus, the RL that the cadets carried was 3.23 % higher in FPC comparing to their male counterparts. FPC were slower in both IAT and LIAT when compared to MPC. More importantly, the IATD was significantly higher in FPC than in MPC, indicating that the RL may have a different impact on these two groups' time to complete LIAT. In that regard, the regression analysis on the combined sample established a large coefficient of determination of LIAT from body composition

indices such as PBF, PFI and IH. However, when conducted separately the coefficient of determination was small in FPC and non-significant in MPC.

In general, human males exceed human females in size, while females are typically have a higher amount of fat and lower amount of lean muscular. Dopsaj *et al.* (2015) found that Serbian male students, in general, were around 9 % taller and 26 % heavier than female students, followed by 12 % higher BMI. Moreover, males had about 11 % lower PBF and about 100 % higher PFI. Considering the aforementioned differences in BH, BM, PBF, PSMM and PFI, our results are quite similar as MPC were in average 7 % taller and 27 % heavier, followed by 10 % higher BMI, with their PBF being 11 % lower. In contrast, the difference between the MPC and FPC in PSMM and PFI was 8 % and 118 %, respectively, on account of the male participants. Therefore, police officers (which cadets are to become) of naturally different body composition may be required to perform equally demanding physical tasks, regardless of sex.

In that regard, our results showed that body composition was associated with IAT and LIAT. Male cadets were significantly faster than females in IAT and LIAT, whereby a 10-kg load had a significant impact on IAT performance, because the IATD was significantly lower among FPC. Moreover, the RL was also significantly larger in FPC. Treloar & Billing (2011) found similar trends between male and female soldiers, as they reported slower average times of females compared to males in first 5 m (explosive strength) as well as in total time of break contact drill (altering between covering fire and sprinting), while carrying the combat load of 21.6 kg. More importantly, a greater decrement in performance occurred in females when carrying a load compared to that of male. Furthermore, Mala *et al.* (2015) reported that soldiers were slower in an anaerobic based task, which included a 27 m zig-zag run, once they were loaded with additional weight of approximately 43 kg. More recently, Orr *et al.* reported that the IAT time to completion was between 23.17 ± 2.75 s (unloaded) to 24.14 ± 2.78 s (loaded) among female police officers. The aforementioned studies, found significant, strong correlations between the times to complete the course in both the unloaded, and loaded conditions with lower body strength (1 RM squat), lower-body power (peak power and standing long jump), and upper-body strength (1 RM bench press, 1-min push-ups and sit-ups). Therefore, it could be argued that offices should have developed lower-body strength and power and upper-body muscular endurance for better performance in LIAT.

On the other hand, numerous studies have reported that strength, power and muscular endurance are positively associated to indicators of muscular status and negatively

associated to body fatness (Dawes *et al.*, 2016; Kukic *et al.*, 2018a,b). This especially reflects in tasks that require whole body locomotion where skeletal muscles are the main functional units of the body, contracting to move the body through physical space. Conversely, fat tissue acts as ballast mass that may hinder the movements performed by muscles. In that regard, the regression analysis revealed a strong linear association between the indices of body composition and IAT, with 67.1 % of the variance in IAT being explained by the differences in PBF, PFI and IH. It should be noted that the PBF represents the relative amount of ballast tissue, while PFI and IH represent the ratio of contractile and ballast tissues within the body. Thus, the regression indicated that the LIAT performance of cadets depends on what the body is made of, rather than the total body size or volume per se. Moreover, when the sample was divided and analyzed separately for FPC and MPC, the associations between the LIAT and body composition were smaller. In fact, the associations in MPC were not significant, while the coefficient of determination in FPC was small. Nevertheless, the results suggest that the FPC who were heavier due to higher PSMM, hence more muscular, performed better in LIAT. These results, together with the results reported by Orr *et al.*, further reinforce the assumption that officers who are stronger and more powerful may have better body composition (i.e. more muscular and less fat). Accordingly, they may have a better potential to perform the tasks consisting of CODS while loaded with duty gear. Finally, the results suggested that body composition, potentially more so than sex, may explain performance results of police cadets.

CONCLUSIONS

It could be concluded that sex-related differences in body composition of police officers may affect the performance of occupational tasks that require CODS, because characteristics of the body as “movement tool” provide officers with a certain potential to perform the tasks such as LIAT. The added occupational load have greater impacts on females, which would have been influenced by the relatively greater load carried. In that regard, good body composition could positively influence unloaded and loaded CODS in cadets.

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KUKIC, F.; KOROPANOVSKI, N.; JANKOVIC, R.; CVOROVIC, A.; DAWES, J. J.; LOCKIE, R. G.; ORR, R. M. & DOPSAJ, M. Asociación de diferencias relacionadas con el sexo en la composición corporal para cambiar la velocidad de dirección en los agentes de policía mientras transportan carga. *Int. J. Morphol.*, 38(3):731-736, 2020.

RESUMEN: El trabajo policial puede requerir que los oficiales cambien la velocidad de dirección (CVD) bajo cargas ocupacionales, indistintamente del sexo o tamaño corporal. El propósito de este estudio fue investigar la composición corporal y los CVD en cadetes de policía de ambos sexos, tanto en condiciones de descarga como de trabajo. Se evaluaron la composición corporal y los CVD de 51 mujeres (CPF) y 70 cadetes de policía masculinos (CPM). Se utilizaron seis índices de composición corporal: índice de masa corporal (IMC), porcentaje de grasa corporal (PGC), porcentaje de masa muscular esquelética (PMME), índice de grasa proteica (IGP), índice de hipocinesia (IH) e índice de masa muscular esquelética (IMME). El CVD fue evaluado por Illinois Agility Test (IAT) y IAT mientras transportaba una carga de 10 kg (LIAT). Se usó una prueba t de muestra independiente para identificar las diferencias entre los sexos. La regresión determinó asociaciones entre la composición corporal y LIAT. El nivel alfa se estableció en $p < 0,05$ a priori. CPM registraron un IMC, PMME, PGC e IMME significativamente más altos ($p < 0,001$) y PGC e IH más bajos que las mujeres (CPF). Los CPM también fueron más rápidos en IAT y LIAT, llevando cargas más bajas, las que tuvieron un impacto menor en el rendimiento de CVD. La composición corporal estaba asociada con el tiempo para completar LIAT ($R^2 = 0,671$, $p < 0,001$). La diferencia en la carga relativa y la composición corporal influyeron en el rendimiento de CVD tanto en condiciones descargadas como cargadas. Por lo tanto, la optimización de la composición corporal a través del aumento de la masa del músculo esquelético, y la reducción de la masa grasa podrían influir de manera positiva en el rendimiento de CVD descargados y cargados, mejorando el rendimiento del trabajo policial.

PALABRAS CLAVE: Agilidad; Aplicación de la ley; Cade-tes policiales; Carga ocupacional; Morfología del cuerpo humano.

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Corresponding author:
Filip Kukic
Faculty of Sport and Physical Education
University of Belgrade
Airport road
Porsche Centre, Apartment 1205
PO Box: 253
Abu Dhabi - UNITED ARAB EMIRATES

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Email: filip.kukic@gmail.com