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USE OF BODY COMPOSITION CHARACTERISTICS IN DEVELOPING A SCREENING MODEL FOR GENERAL PHYSICAL FITNESS OF POLICE OFFICERS

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УНИВЕРЗИТЕТ У БЕОГРАДУ

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УПОТРЕБА КАРАКТЕРИСТИКА ТЕЛЕСНОГ САСТАВА У РАЗВОЈУ МОДЕЛА ЗА ПРАЋЕЊЕ ОПШТЕ ФИЗИЧКЕ ПРИПРЕМЉЕНОСТИ ПОЛИЦАЈАЦА

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Use of body composition characteristics in developing a screening model for general physical fitness of police officers

Abstract

Introduction: Duties of police officers may occasionally involve physically demanding tasks such as on foot pursuit, sharp direction change, jumping, carrying or dragging the person or lifting heavy objects. However, majority of working hours police officers spend sitting, standing or walking, which often can cause a decrease in physical fitness if followed by a low level of physical activity in leisure time. From the perspective of body morphology, the decrease in physical fitness typically reflects in increased amount of body fats and lowered ability to perform physical tasks. In contrast, regular physical activity and planed exercise programs are associated with morphological changes such as lower amounts of body fats and higher contractile quality of skeletal muscle mass. Higher quality of muscle mass followed by lower amounts of ballast tissue normally increase the potential for the physical performance as the main function of skeletal muscles is their ability to contract and produce movements.

Purpose: Although the associations between the body composition and physical abilities or physical performance of police officers have been investigated, in scientific literature it still has not been investigated if a causal relationship between these two spaces of physical fitness exists. Therefore, the purpose of this dissertation was to investigate the relations between the indices of body composition and physical fitness and to determine the prediction power of body composition indices.

Methods: Three samples were used for the purposes of this dissertation, 199 male police officers, 45 females (19 female officers and 26 female police cadets), and 196 male police cadets. Body composition of all three samples were assessed using the method of multifrequency bioelectrical analysis of variance. A multi-channel bioelectric impedance analyzer InBody 720 (Biospace Co. Ltd,

Seoul, Korea) was used to asses participants' body mass, fat mass and skeletal muscle mass, which were further used to calculate the body composition indexes. Six indexed variables of body composition were calculated, body mass index (BMI), percent body fat (PBF), percent of skeletal muscle mass (PSMM), body fat mass index (BFMI), skeletal muscle mass index (SMMI), and index of hypokinesia (IH). This way, the body composition was presented as body volume and body size-independent amounts of fat and muscle tissue. The assessment of physical abilities included muscular force, muscular strength, muscular power, anaerobic a-lactic power, muscular endurance, anaerobic power, aerobic endurance, and change of direction speed. Furthermore, the results from tested physical abilities were integrated into 13 physical fitness performance indexes. Indexes of body composition were correlated to physical abilities and physical performance indexes to investigate the associations and internal validity. Afterwards, the multiple regression analysis was conducted to determine the possibility of predicting physical fitness parameters from body composition and to test the construct validity of the approach used in this dissertation.

Results: The results showed multiple significant associations between body composition indexes and physical abilities and physical performance indexes (i.e. physical fitness components). Moreover, significant models of prediction were extracted from body composition indexes for all investigated performance indexes: EPFS (R^2 = .379, p < .001), IAT Combined (R^2 = .371, p < .001), IAT FPO (R^2 = 420, p < .001), IAT FPC (R^2 = .315, p = 0.049), MFi (R^2 = .444, p < .001), LBMPi (R^2 = .387, p < .001), UBMPi (R^2 = .225, p < .001), CODi (R^2 = .193, p < .001), SRSi (R^2 = .182, p < .001), REi (R^2 = .283, p < .001), MQPi (R^2 = .422, p < .001), RAi (R^2 = .286, p < .001), TPPi (R^2 = .175, p < .001). The results of extracted prediction models defined statistically significant relation between chosen variables, wherby relations rangeed from small to medium, depending on the complexity of physical performance index and depending on how much the

performance index depends on muscular force, strength, power and skeletal muscle mass.

Conclusion: It is possible to predict physical fitness of police officers by using different indexes that reflect body composition. The power of predictions varied witin the investigated indicators of physical fitness, which is is based on miltidimenstionality and complexity of investigated space. Indicators of muscular status (SMMI or PSMM) correlated to all physical abilities and to all physical performance indexes. Moreover, SMMI or PSMM were included in 8 out of 13 prediction models, while three more models included IH (proportion of PSMM and PBF relative to BMI). Muscular force, strength, power and muscular endurance as well as performance indexes that included these physical abilities were highly associated with either SMMI or PSMM. Indicators of body fatness (BFMI and PBF) did not correlate only to DLFmax, BP1RM, SU30s and TPPi. The strongest model of prediction included only SMMI, indicating that the highest validity of body composition prediction models occurs in predicting muscular force and strength. Only prediction model for MFi did not include any indicator of body fatness, while all other prediction models included either BFMI, PBF or IH. Whenever the weight of the body (whole or partial) had to be moved throughout the space, the ballast mass had a negative effect on the result. In other words, fat mass hinders the performance produced by skeletal muscles. This was evident in all performance indexes, regardless of length and intensity, as IH as an indicator of ratio between skeletal mass and fat mass correlated to all physical abilities and performance indexes. Therefore, skeletal muscles as an active component and body fats as a ballast component of body composition seem to be an important factor in physical performance of police officers.

Keywords: Law enforcement officers, body fat, skeletal muscle mass, physical abilities, physical performance

Употреба карактеристика телесног састава у развоју модела за праћење опште физичке припремљености полицајаца

Резиме

Увод: Дужности полицајаца могу да садрже физички захтевне задатке као што су трчање за преступником, нагле промене правца кретања, прескакања, ношење или вучење особе, као и подизање тешких предмета. Међутим, већину радног времена полицајци проводе седећи, стојећи или ходајући, што често може довести до опадања нивоа физичке припремљености полицајаца, а посебно ако је праћено физичком неактивношћу у слободно време. Опадање нивоа физичке припремљености, са морфолошког аспекта, најчешће се огледа у повећању количине акумулираног масног ткива и умањеном способношћу извршавања физичких задатака. Са друге стране, редовна физичка активност и планирано вежбање повезани су са морфолошким променама као што су нижи ниво телесних масти у организму и бољим контрактилним квалитетом мишићне масе. С обзиром да је основна функција скелетних мишића стварање покрета, боље развијена мишићна маса, праћена нижим нивоом телесних масти повећава потенцијал за спровођење физичких задатака.

Циљ: Релације телесног састава и физичких способности, односно спровођења физичких задатака, истраживане су на популацији полицијских службеника, јер у научној литератури још увек нема истраживања у којима је истраживана узрочно-последична повезаност између ових простора. Из тог разлога, циљ овог истраживања био је да се истраже релације показатеља телесне композиције и физичких способности, са једне стране, као и узрочно-последичне везе између ова два простора, са друге стране.

Методе: За потребе ове дисертације коришћена су три узорка испитаника, 199 полицајаца мушког пола, 45 жена (19 официрки и 26 кадеткиња), као и 196 кадета. Телесна композиција сва три узорка мерен је употребом анализе отпора које ткиво пружа различитим фреквенцијама био-електричног сигнала. Више-канални био-електрични апарат InBody 720 (Biospace Co. Ltd, Seoul, Korea) је коришћена за мерење телесне масе, масе телесних масти и скелетних мишића, који су накнадно коришћени за рачунање индекса телесне композиције. Израчунато је шест индексних варијабли као индикатора телесне композиције, индекс телесне масе, проценат масти, проценат мишића, индекс телесних масти, индекс скелетних мишића и индекс дефицита кретања (хипокинезије). На овај начин, телесне масти и скелетни мишићи приказани су независно од укупне телесне масе и независно од телесне висине испитаника. Мерење физичких способности обухватило је варијабле мишићне силе, мишићне снаге, експлозивности, анаеробно алактатне моћи, мишићне издржљивости, лактатне анаеробне моћи, аеробне издржљивости и способности нагле промене правца при брзом трчању. Резултати тестираних физичких способности интегрисани су у 13 индекса испољавања физичке припремљености. Индекси телесне композиције корелирани су са физичким способностима и са индексима физичке припремљености како би била испитана унутрашња валидност. Након тога, реализована је регресиона анализа како би се утврдила могућност предвиђања параметара нивоа физичке припремљености, као и валидност добијених модела предикције, ради утврђивања дефинисаног нивоа конструктне валидности.

Резултати: Резултати су доказали постојање вишеструке, значајне корелације између различитих индекса телесне структуре и индекса физичке припремљености. Издвојили су се значајни модели предвиђања физичке припремљености из употребљених телесних индекса и то: EPFS ($R^2 = .379$, $p < .001$), IAT Combined ($R^2 = .371$, $p < .001$), IAT FPO ($R^2 = 420$, $p < $

.001), IAT FPC ($R^2 = .315$, $p = 0.049$), MFi ($R^2 = .444$, $p < .001$), LBMPi ($R^2 = .387$, $p < .001$), UBMPi ($R^2 = .225$, $p < .001$), CODi ($R^2 = .193$, $p < .001$), SRSi ($R^2 = .182$, $p < .001$), REi ($R^2 = .283$, $p < .001$), MQPi ($R^2 = .422$, $p < .001$), RAi ($R^2 = .286$, $p < .001$), TPPi ($R^2 = .175$, $p < .001$). Резултати добијених модела су доказали статистички значајну релацију са издвојеним варијаблама, али се она налазила у распону од мале до средње, у зависности од комплексности индекса физичке припремљености и у зависности од тога колико индекс припремљености зависио од мишићне силе, снаге, експлозивности, као и показатеља мишићавости.

Закључци: Могуће је на статистички значајном нивоу предвидети физичку припремљеност полицајаца употребом различитих индекса којима се описује телесна структура. Значајност предикције је варирала између различитих показатеља физичке припремљености, што је у складу са мултидимензионалношћу и комплексности испитиваних простора. Индикатори мишићног статуса тела корелирали су са свим испитиваним физичким способностима, као и са свим индексима физичке припремљености. Индекс мишићне масе и проценат мишићне масе ушли су у 8 од 13 модела предикције, док су још три модела укључила индекс хипокинезије (пропорција процента мишића и маси у оквиту индекса телесне масе. Мишићна сила, снага, експлозивност и издржљивост, као и индекси припремљености који су укључивали ове физичке способности високо су корелирале или са индексом мишићне масе или са процентом мишићне масе. Индикатори масе телесних масти (индекс телесних масти и проценат масти у телу) нису корелирали само са максималном силом при изометријском мртвом дизању, максималним понављањем на потиску са груди, трбушњацима за 30 секунди и свеукупним индексом припремљености. Најзначајнији модел предикције физичке припремљености укључио је само индекс мишићне масе при процени индекса мишићне силе и снаге, што сугерише да се највећа валидност предикције физичке припремљености из телесне структуре јавља управо

при предвиђању мишићне силе и снаге. Са друге стране, ниједан од индикатора телесних масти није био укључен само при процени индекса мишићне силе, док су остали модели предикције, који су подразумевали кретање кроз простор, укључили или индекс телесних масти и проценат масти или индекс хипокинезије. Када год тело треба померати кроз простор, цело или парцијално, баластна маса негативано утиче на ефикасност тог кретања. Другим речима, телесне масти умањују ефикасност кретања произведеног мишићним контракцијама. У складу са тим, могло би се рећи да су скелетни мишићи као активна компонента и телесне масти као баластна компонента телесне композиције важни фактори физичке припремљености, где мишићи имају позитиван, а увећана количина масти негативан утицај на спровођење свакодневних задатака полицијских официра.

Кључне речи: Полицијски официри, телесне масти, скелетни мишићи, физичке способности, предвиђање

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1. INTRODUCTION

During the last century, humans have been going through big fundamental changes of the way of living in order to adapt to modern technological development, environmental changes and socio-cultural trends. It seems that the main actuator of the prosperity was motivated by the liberation of earning for life through physically very demanding occupations (Sharkey & Davis, 2008, p. 4). Therefore, a significant progress in reducing the physical demands of work has been achived during the last 50 years. However, in so-called industrialized and online societies, where habitual physical activity has been tremendously reduced by technology, the prevalence of various uncontrollably non-communicable diseases has increased (Bouchard et al., 2012, p. 4 and 5). Increasing prevalence of obesity due to hypokinezia and poor nutrition represents main triggers of health problems in today's society (Sharkey & Davis, 2008, p. 4), because it increases the risk of cardiovascular diseases, diabetes, lowers one's overall quality of life and increases the risk of premature mortality (Despres & Lamarche, 1993; Stevens et al., 1998; Ardern et al., 2003). According to the World Health Organization (WHO), obesity has nearly tripled since 1975, whereby there were around 1.9 billion of overweight adults in 2016, of which 650 million were obese (WHO, 2017). Conversely, skeletal muscle mass (SMM) has been shown to decrease as people age. This decrease in SMM is typically followed by significant decreases in strength, which further lowers the quality and efficiency of movement and ultimately may increase the risk of injuries (Janssen et al., 2000; Goodpaster et al., 2006; Orr & Pope, 2017).

Although police agencies are the organizations first in the line responsible for security and safety of the society, they were not omitted from aforementioned changes (Sorensen et al., 2000; Boyce et al., 2008; Lagestad et al., 2014) and accordingly, physical fitness became a very important factor for police officers (Kukić & Dopsaj, 2017; Kukic et al., 2018). Some of the tasks

performed by police officers can involve running to catch a suspect, grappling, wrestling and fighting with uncooperative belligerents and carrying injured or unconscious people (Pryor et al., 2012; Sharkey & Davis, 2008, p. 4–8), often while wearing and carrying external loads (Orr & Pope, 2017; Sharkey & Davis, 2008, p. 6). Based on the nature of these tasks and task requirements it is evident that police officers need to be physically prepared to perform these duties sufficiently and effectively, and with a reduced risk of injuries (Anderson et al., 2000; Dopsaj et al., 2007; Guffey et al., 2015). However, officers spend the majority of time at work conducting duties that are not physicaly demanding and often sedentary in nature (e.g. walking, driving, deskwork, sitting in a parked car, etc.) (Garbarino & Magnavita, 2015). In that regard, a reductions of 10 – 32% in officers' physical performance and increase of body fat mass (BFM) may occur due to lack of physical activity and exercise (Lagestad et al., 2014; Orr et al., 2017). Additionally, review studies have shown that components of physical fitness such as body composition and physical abilities are negatively affected as time spent in service increases (Petersen et al., 2016; Kukic et al., 2018).

2. THEORETICAL FOUNDATIONS AND PREVIOUS RESEARCH

2.1. PHYSICAL FITNESS

Physical fitness can be defined as the ability to complete daily tasks without undue fatigue and with enough energy left to enjoy leisure-time pursuits or meet unforeseen emergencies (Riebe et al., 2018, p. 1). When it comes to health, physical fitness consists of five main components: cardiorespiratory fitness, body composition, muscular strength, muscular endurance, and flexibility (Riebe et al., 2018, p. 1). On the other hand, when it comes to performance related fitness variables needed for specific occuaptions and tasks, the main components are agility, coordination, balance, power, reaction time, and speed (Riebe et al., 2018, p. 2). In that regard, two types of physical fitness were defined: health-related and performance-related physical fitness (Bonneau & Brown, 1995; Anderson & Plecas, 2000; Anderson et al., 2001; Hauschild et al., 2017; Riebe et al., 2018, p. 1). Thus, the level of physical fitness is often defined by the success in conducting a specific job or by level of health whereby in both cases physical fitness highly depends on the amount of daily physical activity and exercise accrued (Deuster, 1997; Sharkey & Davis, 2008, p. 183; Bouchard et al., 2012, p. 14). Note that physical activity includes every bodily movement that provokes energy expenditure above the basic threshold such as transferring from one place to another (by walking, cycling, car, etc.), housework, activity at work, etc. Conversely, exercise represents planned and structured body movements aimed to improve or maintain a specific physical ability (Bouchard et al., 2012, p. 12; Riebe et al., 2018, p. 1).

During the last several decades, the daily amount of physical activity of general population was getting lower, which coupled with poor nutritional habits has led to a dramatic increase in the prevalence of obesity, diabetes, cardiometabolic syndrome and other non-communicable diseases (WHO, 2017).

To increase public safety and security physical fitness of police officers needs to be at a higher level (Anderson & Plecas, 2000; Anderson et al., 2001; Dopsaj et al., 2007; Guffey et al., 2015). However, the trend of physical fitness loss can be noticed in police officers as well (Sorensen et al., 2000; Boyce et al., 2008; Charles et al., 2008; Lagestad et al., 2014; Alghamdi et al., 2017; Gibson et al., 2017; Kukić et al., 2017; Kukić & Maamari, 2017; Orr et al., 2017). Therefore, many police agencies have developed recruitment physical fitness standards, as well as age-dependent standards of physical fitness for incumbent officers that need to be met annually. For these purposes, agencies chose the components of physical fitness that are at the same time best associated with health and with the performance of job-related tasks (Sharkey & Davis, 2008, p. 185). The difference between these two is that health-related physical fitness only predicts the basic readiness of police officers to undergo an unexpected physically demanding task and general health status. For example, if an officer during a walking patrol suddenly has to catch a running suspect, he should do it in a safe manner, without getting injured, which is shown to be strongly associated with cardiorespiratory fitness and muscular endurance (Hauschild et al., 2017).

Additionally, Chasse et al. (2014) showed that employees with higher body mass index (BMI) had an increased risk of body injuries, whereby obese persons of both genders were more likely to suffer injuries to the knee and lower leg while performing household chores or using the stairs. Moreover, studies showed that prevalence of overweight and obese officers is as great as be 66.9% – 71.18% (Dopsaj & Vuković, 2015; Kukić & Dopsaj, 2016; Alghamdi et al., 2017) among which were 59% found to be obese due to excess fat mass (Kukić & Dopsaj, 2016). More importantnly, Alghamdi et al. (2017) showed that among those officers with high cholesterol, 48% were obese (BMI ≥ 30 kg/m^2), 37% were overweight (BMI ≥ 25-29.9 kg/m^2), and 13.5% were with normal weight (BMI ≥ 18.5-24.9 kg/m^2). Furthermore, among those with high blood sugar, 58% were obese, 25% were overweight, and 16.7% were with normal weight, and among those with high triglicerids, systolic blood preasure and

diastolic blood preasure, obese were 55%, overweight 66.6% and with normal weight 61.5% (Alghamdi et al., 2017). Thus, Alghami et al. (2017) directly showed that the risk of cardiovascular diseases increases in police officers as the BMI gets higher. In that regard, body composition is one of the main indicators of health-related physical fitness.

Conversely, a performance-related physical fitness shows how well police officers perform a job-specific physical task. For example, how fast, safe and effective a special wapons and tactics (SWAT) officer can approach the scene, secure the scene and arrest the suspect, or how a firefighter can move throughout the scene while wearing gas mask, fire hose or carrying the victim. For these purposes, next to health-related physical fitness of police officers, such as firefighters, first responders, SWAT officers, have to posses a specific set of skills for which they have special training, menaing that performance-related physical fitness may vary among them. It is clear that components of physical fitness needed for each of these tasks and health-related physical fitness are very different. However, certain components among them are common and necessary for good health as well as for each of the tasks (Bonneau & Brown, 1995; Anderson et al., 2001; Anderson & Plecas, 2000; Alvar et al., 2017, p. 139; Hauschild et al., 2017).

In that regard, Hauschild et al. (2017) reviewed 27 different military and police studies that used various physical fitness tests. Authors found out that health-related basic motor abilities such as cardiorespiratory endurance, upper-body strength and lower-body strength correlated with most of the military and police specific tasks (repeated lift and lower, single heavy lift and lower, lift and carry, push and pull, march or walk with load, climb, crawl). Therefore, they recommended following field tests: time runs (1.5 – 3 miles) for cardiorespiratory endurance, vertical or squat jump tests for lower body strength, push-ups for upper-body endurance, and sprint (100 – 400 m) for lower body endurance test (Hauschild et al., 2017). Longitudinal studies additionally showed the importance of these components of physical fitness of

police officers (Sorensen et al., 2000; Boyce et al., 2008; Lagestad et al., 2014). Sorensen et al. (2000) conducted a 15-year follow-up study with Finnish police officers where they used various questionnaires and physical fitness tests to investigate the trends of health and physical fitness level. Physical fitness test battery consisted of body composition assessment (skinfold method), maximal aerobic power test (submax incremental bicycle test) and muscular endurance tests (push-ups and sit-ups in 30 seconds, and a maximal number of pull-ups). The results obtained after 15 years of service showed a significant decline in all measured components. The maximal oxygen consumption (VO_{2max}) declined from 42.8 to 38.4 ml/kg•min^{-1}, sit-ups from 20.9 to 17.5 repetitions, push-ups from 25.5 to 18.6 repetitions, and pull-ups from 5 to 4 repetitions. Body mass increased for 7.2 kg (0.5 kg/year) and BMI increased for 2.1 kg/m^2. Prevalence of overweight officers (BMI > 27 kg/m^2) increased from 29% to 51%, and 27% of officers had cardiovascular disease, while 21% was on medication for high blood pressure, high cholesterol level, coronary heart disease or diabetes. Moreover, measured skinfolds for biceps, subscapular and suprailiac significantly increased, indicating an increase in BFM. Furthermore, BM and waist circumference negatively correlated to VO_{2max} (ml/kg•min^{-1}) on both testing occasions, at the beginning and at the end of the follow-up period, indicating the importance of body composition for aerobic performance.

Another longitudinal study on police officers that followed only one component of physical fitness (body composition) for about 12 years showed an average increase in body mass (BM) of 7.5 kg (0.6 kg/year) in women and 12.3 kg (1 kg/year) in men (Boyce et al., 2008). Furthermore, BFM increased by 5 kg (5.1%) in women and 6.6 kg (4.8%) in men, while lean mass increased 2.5 kg and 5.7 kg in women and men, respectively. Obesity prevalence in male and female police officers defined by BFM percentage (≥ 30% for women and ≥ 25% for men) has raised by 13.5% and 15%, respectively. In contrast, Lagestad et al. (2014) followed only physical abilities (muscular strength, muscular endurance, muscle power and aerobic endurance) as part of physical fitness for 16 years.

They found that one repetition maximum (1-RM) bench press performance significantly reduced by 9 kg in male and 12 kg in female police officers after 16 years of service. Upper-body muscular endurance measured by a maximum number of pull-ups was reduced for 3.6 repetitions, while muscle power measured by the standing long-jump test was reduced by 25 cm in male and 23 cm in female officers. Cardiovascular endurance measured by a 3000-m run test also reduced by 78.3 seconds after 16 years in service.

A cross-sectional study on police officers conducted by Dawes et al. (2017) correlated several measured physical abilities such as lower-body power (vertical jump), upper-body muscular endurance (1-minut sit-up and push-up), isometric strength of legs and lower back (leg/back chain dynamometer), hand grip strength, and aerobic power (20m shuttle-run test) to occupational job-related test (physical agility course). These authors found that all measured physical abilities significantly contributed to the performance of the job-related test, while BMI was negatively associated with performance. However, when authors applied a regression analysis 3 variables entered a statistically significant prediction model ($F_{(3,491)} = 193.95$, $p < 0.001$, $R^2 = 0.54$, adjusted $R^2 = 0.54$), vertical jump, sit-ups, and aerobic power. Furthermore, principal component analysis with a direct oblimin rotation extracted the factor called dynamic fitness, which included exact the same variables, vertical jump, sit-ups and 20m shuttle run. Within the factor, dynamic fitness strongly correlated to job-related physical test and moderately negatively correlated to BMI. These results strongly indicate the contribution of individual physical fitness component to performance-related physical fitness.

Pihlainen et al. (2018) investigated associations of physical abilities (isometric force of lower and upper-body, long jump, sit-up, push-up, pull-up, 3000-m run) and body composition characteristics (BM, BFM, percent of body fat [PBF], dead mass ratio) with anaerobic endurance performance, tested in the combat load using the occupationally relevant military simulation test (MST). Using a correlative analysis, authors found that the strongest variable,

correlated to MST was the ability to perform the counter movement jump with combat load ($r = -0.66$, $p < 0.001$). Among body composition characteristics, PBF and SMM had the strongest relationship with MST time ($r = -0.53$, and -0.47, $p < 0.001$, respectively). However, when BM was divided by BFM accompanied with the weight of the combat load (dead mass ratio), the association to MST time significantly increased and this variable turned out to be the best single predictor ($r = -0.67$, $p < 0.001$) for the MST performance. Furthermore, the best prediction model produced by stepwise multivariate regression analysis included counter movement jump with combat load (power of lower-body), 3000-m run (aerobic power), push-up (upper-body muscular endurance) and SMM.

When investigated a prediction of shooting scores of police officers from physical fitness data, Anderson and Plecas (2000) found that hand grip strength and police officer physical ability test (POPAT) significantly correlated to shooting scores. Although not directly investigated, the results of this research showed that POPAT was significantly associated to handgrip strength, static endurance in half push-up position, and forearm girth (an indicator of forearm SMM). However, a stepwise regression analysis did not establish a significant model for predicting shooting scores from measured anthropometric data and physical abilities. This may be due to several reasons such as that shooting requires mastery of technique, fine motor skill, good alternation between fine and gross motor skill, and interaction between visual and motor stimuli. Having that said, physical abilities and body composition characteristics may be insufficient in predicting the complexity of shooting scores.

Based on these findings, one may conclude that both, health-related and performance-related physical fitness are equally important for police officers. All components of physical fitness are important for particular reasons and depending on the purpose, components can be tested and interpreted in a different manner. Considering studies from aforementioned paragraphs, it seems that components are usually grouped in two main pillars of physical

fitness: physical abilities (strength, power, endurance, flexibility) and body composition (BM, BFM, SMM, PBF). Information on physical abilities and body composition characteristics if appropriately used may indicate a general level of physical preparedness as well as the physical potential for job-related tasks. Additionally, measuring physical abilities and body composition allows appropriate and more precise training planning for individual physical fitness deficiencies, which usually is not the case in performance-related tests (Dawes, 2011, p. 24).

2.1.1. Body composition

The human body is comprised of different tissues that can be further reduced to cells, which are made of atoms. However, the associations and interactions between and within those structural elements make the human body a live organism (Wang et al., 2000; Wang et al., 2004). Having said that, the change in one component influence the change in another (e.g. PBF and percent of skeletal muscle mass [PSMM]), while the origin and constancy of that relationship are fundamentals in body composition research. This allows a better insight into the biology of human body composition and indirectly better control of human health (Despres & Lamarche, 1993; Ellis, 2000; Kukić & Dopsaj, 2017). Nutritional status, level of physical activity and disease state affect the body cell mass, which in return may serve as a biomarker of these changes (Wang et al., 1992). Therefore, the integrity of the human body depends on certain biological laws and every disruption of these laws requires an adaptation which often reflects by changes in body composition (Ilić, 2006, p. 5). For example, for optimal functioning, a person's body needs a certain amount of physical activity and energy from food. However, if a person's daily amount of physical activity is low and food intake is higher than needed, the body will adapt by storing the excess energy into body fat, leading to an increase in body weight (Kukić & Dopsaj, 2017). Conversely, if a person is

regularly attending a planned resistance or aerobic training fallowed by proper nutrition, the adaptation will most probably lead to an increase in SMM or decrease in BFM or both (Demling & DeSanti, 2000; Ilić et al., 2012; Stanković et al., 2013; Stojković et al., 2017). In other words, it has been widely known that body composition is the result of various factors such as diet, stress, the amount of physical activity and other factors that are parts of daily habits (Demling & DeSanti, 2000; Ng et al., 2011; Ng et al., 2012; Kukić & Dopsaj, 2017).

Therefore, body composition assessment and monitoring are necessary screening tools because human body composition is at the same time very important but also a biologically very inconsistent category. Thus, the body composition could be considered as a reliable indicator of the current nutritional and health status. However, since body composition is one of the key pillars of health-related physical fitness (Riebe et al., 2018, p. 2), by choosing its certain components it may be used as an indicator of officers' physical fitness as well (Orr et al., 2013; Dopsaj et al., 2015; Mitrović et al., 2015; Dawes et al., 2017; Dawes et al., 2017; Orr et al., 2017; Čvorović et al., 2018). In that regards, there are components of body composition that more indicative of these changes (Kim et al., 2011; Dopsaj et al., 2015, 2017; Kukić & Dopsaj, 2017).

2.1.1.1. Skeletal muscles

Skeletal muscles are among the largest tissues of the human body (Janssen et al., 2000; Alvar et al., 2017, p. 26). It not only accounts for around 40% of total body mass in men and 32% in women but also is the most essential component involved in moving the body, breathing, chewing and swallowing, maintaining bone health, and regulating glucose levels (Ilić, 2006, p. 19; Alvar et al., 2017, p. 26). Comparing to fat and bone tissue, it is the only live tissue, which makes muscles the prime movers based on the activity of protein structures within the muscle (Ilić, 2006, p. 23; Alvar et al., 2017, p. 28 and 29). According to Alvar et al. (2017, p. 28) there are four main characteristics of each

skeletal muscle: excitability (ability to respond to impulses from central nervous system [CNS]), contractility (ability to shorten and generate force, hence produce strength), extensibility (ability to extend beyond its normal length), and elasticity (ability to return to normal length after it is stretched). These four characteristics cooperate during dynamic movements and each of them can be improved by training (Stanković et al., 2013; Alvar et al., 2017, p. 28). Therefore, muscular fitness can be improved by a well-designed exercise program and nutrition plan but it can also decrease by age and due to lack of physical activity (Demling & DeSanti, 2000; Hughes et al., 2002; Ilić, 2006, pp. 28–32; Alvar et al., 2017, p. 28 and 60).

A longitudinal observational study has shown that skeletal muscle mass in men decreases with age (Hughes et al., 2002) which was followed by 5% decrease in strength (Goodpaster et al., 2006). In a longitudinal study on police officers conducted by Deamling and DeSanti (2000), an increase of 4 kg in lean body mass (LBM) occurred due to applied exercise training and casein-based diet regime. Regardless of the changes in SMM that can be caused by various factors, police duties do not change, neither belligerents get less physically prepared, and importance of being fit for duty does not decrease. In that regards, studies on police and military occupation showed positive associations between SMM and physical abilities and physical fitness (Lyons et al., 2005; Dawes et al., 2016; Pihlainen et al., 2018).

When conducted research on law enforcement officers, Dawes et al. (2016) found that LBM significantly ($p < 0.001$) and positively correlated with push-ups (r = 0.444), 1-RM bench press (r = 0.781) and vertical jump (r = 0.391) performance. In a load carriage study, Lyons et al. (2005) showed that LBM divided by dead or non-functional mass (fat mass + external load) produced a moderate correlation (r = -0.52, $p < 0.01$) with the metabolic demand of heavy load-carriage and concluded that selection criteria for the load carriage occupations should include a lean muscle mass. Moreover, 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., 2005). The study on military specific performance showed moderate correlations between the SMM and a military specific test (r = -0.47, p < 0.001), followed by the regression analysis that included SMM in best fit model of prediction, suggesting that higher skeletal muscle mass might improve a military specific test performance (Pihlainen et al., 2018).

Proper functioning of the musculoskeletal system depends on a good neuromuscular activity that is often called muscular fitness (Plowman & Marilu, 2013, p. 132). The ability of muscles to exert a force (muscle strength), resist fatigue (muscle endurance) and move freely through a full range of motion (flexibility) are the main components of muscular fitness (Janssen et al., 2004; Plowman & Marilu, 2013, p. 132). It has often been associated with quality of life, mineral content, bone strength, and physical performance (Janssen et al., 2004; Plowman & Marilu, 2013, p. 132; Riebe et al., 2018, p. 101). This can be easily noticed when compare a body composition of men and women (Dopsaj et al., 2015; Dopsaj & Đorđević-Nikić, 2016). When investigated population of male and female students, Dopsaj et al. (2015) showed that males were having more protein mass (PM) relative to body weight than females (17.22% vs. 14.94%, p < 0.001) and lower relative amounts of fats (13.53% vs. 24.28%, p < 0.001). Similar results Dopsaj & Đorđević-Nikić (2016) observed on Serbian professional athletes, whereby female athletes possessed significantly lower relative amount of PM (15.93% vs. 17.73%, p < 0.001) and relative amount of SMM (44.98% vs. 51.06%, p < 0.001), while having higher amount of PBF (19.54% vs. 11.01%, p < 0.001). Moreover, in previous study Dopsaj et al. (2009) found a significant sexual dimorphism in dominant handgrip force (Wilks' Lambda = - 0.519, F = 30.567, p < 0.001). Although these were three separate studies it is very indicative that the differences in body composition might be related to differences in handgrip force.

Considering the aforementioned studies conducted on police officers, it seems that it became costumery for majority of researchers to use easily

accessible measures of body composition such as SMM, LBM and PSMM. However, these are the measures of the volume without taking into account the person's height and hence size (Kyle et al., 2001; Kyle et al., 2003). In other words, officers of bigger size would logically have more SMM and LBM, and accordingly, their SMM, LBM or PM would be non-comparable. For that reason, researchers started using more specific and sensitive indicators (indexes as a new variables), whereby absolute measures of muscularity (fat-free mass [FFM], LBM, SMM, or PM) are divided by squared body height (de Oliveira et al., 2016; Dopsaj et al., 2017; Kukić & Dopsaj, 2017; Kyle et al., 2001; Kyle et al., 2003). In that regards, "the theory of geometrical similarities assumes that all human bodies have the same shape and that, therefore, they differ only in size. This means that all lengths are proportional to a characteristic length measured on a subject (e.g., body height [BH]), and all areas (e.g., SMM, FFM, PM) are proportional to BH^2" (Jaric et al., 2005). In other words, absolute measures of muscularity can easily be misinterpreted because bigger bodies (taller officers) may naturally possess a bigger amount of SMM, FFM, or PM. Therefore, measures of muscularity can be expressed as body-size-independent variables and then compared between the persons of different body size. For example, in factorial analysis of Kukic & Dopsaj (2017), protein mass index (PMI), skeletal muscle mass index (SMMI) and fat-free mass index (FFMI) formed an independent factor of body composition of police officers, while the same variables were also extracted on professional combat athletes (judokas, wrestlers and karate) by Dopsaj et al. (2017), strongly indicating the validity and specificity of the chosen indexes.

2.1.1.2. Body fats

Lipids and triglycerides or fats are often used interchangeably, even though they are very different. Traditionally, triglycerides refers to the group of chemical compounds that can be soluble only in organic solvents (diethyl eter, benzene and chloroform) but insoluble in water (Wang et al., 1992). There is about 50 lipids in human body, divided in 5 sub-categories: simple lipids (triglycerides), conjugated lipids (phospho-lipids), steroids, fatty acids, and derivates (Wang et al., 1992). Triglycerides are constructed of three fatty acids and glycerol and fats has been a term used as a synonym for this chemical compound (Wang et al., 1992). Thus, next to compound lipids, steroids, fatty acids, and terpenes, fats are actually a subcategory of lipids. Furthermore, lipids can be classified as essential lipids, consisting 10% of total lipids, and non-essential or storage lipids, consisting remaining 90% of total lipids. More importantly, non-essential lipids are termed fats or adipose tissue (Wang et al., 1992) which is shown to be strongly associated to health (Stevens et al., 1998; Ardern et al., 2003; Charles et al., 2008; Hartley et al., 2011) and physical performance (Mitrović et al., 2015; Dawes et al., 2016; Čvorović & Kukić, 2018; Čvorović et al., 2018; Kukić et al., 2018). An increase in BFM over the criterion levels brings up the risk of cardio-vascular diseases, high blood pressure, diabetes and according to some studies mortality (Stevens et al., 1998; Ardern et al., 2003). Furthermore, an excess amount of fat, especially in the abdomen is one of the main indicators of metabolic syndrome, which further includes hypertriglyceridemia, reduced high density lipoprotein cholesterol (HDL-C), glucose intolerance and hypertension (Violanti et al., 2009; Hartley et al., 2011; Gu et al., 2012; Garbarino & Magnavita, 2015).

In that regard, Violanti et al. (2009) found that 30.6% of the total sample of police officers had increased waist circumference (WC), whereas prevalence among officers from midnight shift was 55%. Moreover, 50% of officers from midnight shift had low HDL-C, while 30% of them were diagnosed with

metabolic syndrome. Similarly, Gu et al. (2012) also showed that officers working night shift were more prone to become fattier, especially those officers who work longer hours. In a 5-year follow up study, Garbarino and Mangavita (2015) found that groups of police officers, who were characterized with lower stress levels, had significantly lower mean levels of triglycerides and total cholesterol, and higher levels of HDL-cholesterol than their colleagues in the highest quartile of job strain. However, the authors showed that the incidence of metabolic syndrome significantly increased in all groups, but the incidence was the lowest in the group characterized as less stressful (Garbarino & Magnavita, 2015). Work shift and stress are not alone in affecting the BFM. Longitudinal studies showed that years of service spent working in police also might have a negative effect on body mass (BM), BMI, due to increase in BFM (Boyce et al., 2008; Sorensen et al., 2000). A 15-year follow up study conducted on Finnish police officers showed that BM increased by 0.5-0.8 kg/year and that WC and sum of skinfolds were significantly higher after 15 years of service. The waist circumference exceeded 94 cm for about two-thirds of the subjects (64%) and 102 cm for 38% of the subjects, increasing prevalence of overweight subjects (BMI > 27 kg/m^2) from 29% to 51%. These negative changes in body composition were also associated with the health of the followed police officers because about one-quarter of the subjects had cardiovascular disease (27%). About every fifth (21%) person was on medication for high blood pressure, high cholesterol level, coronary heart disease or diabetes (Sorensen et al., 2000). Additionally, a 12-year follow up study of Boyce et al. (2008) showed that officers from Charlotte Mecklenburg increased BM by 1 kg/year and that their BFM and PBF increased approximately by 6.6 kg and 4.8%, respectively.

Considering the possible negative effects of increased BFM on health, it is very clear why BFM is one of the most important factors for health-related physical fitness. However, body fats negatively affect not only police officers' health but also physical performance (Čvorović & Kukić, 2018; Dawes et al., 2016; Violanti et al., 2017). In that regard, Čvorović and Kukić (2018) reported a

negative correlation between indicators of fatness (BFM, PBF and fat of trunk) and muscular and aerobic endurance. Body fat mass, PBF and FT correlated with push-up performance (r = -0.373, 0.332, -0.365, *p* < 0.001, respectively) and 2.4-km run test (r = 0.309, 0.314, and 0.303, *p* < 0.01, respectively). Furthermore, Dawes et al. (2016) found that PBF was negatively associated with push-ups (0.413, *p* < 0.001), vertical jump (r = -0.566, *p* < 0.001), and bench press ratio (r = -0.448, *p* < 0.001), while BFM was negatively associated with vertical jump (-0.369, *p* < 0.001), 2.4-km run (r = 0.399, *p* < 001) and estimated VO_{2max} (r = -0.419, *p* < 0.001). Recently, Violanti et al. (2017) used a linear regression analysis on 1826 police officers to investigate the nature of relationship between PBF and physical abilities and defined the following: every 1% increase in PBF was associated with 10 seconds of increased time to complete the 2.4-km run (β = 10.29, *p* < 0.001), and was associated with reduction of one push-up (β = -1.00, *p* < 0.001) and nearly one sit-up per minute (β = -0.55, *p* < 0.001), and about 0.25 cm in the sit-and-reach test (β = -0.08, *p* < 0.001). Concludingly, indices of body fatness are very associated with health and performance of police officers and accordingly very important variable in the screening process.

Similar to measures of muscularity, BFM, PBF and trunk fat are representatives of absolute amount of fat, meaning fatness of a bigger person could be overestimated if body height is not part of the estimation. Conversely, fatness of a smaller person could be underestimated. The PBF standards were developed so people of different sizes, gender and age can estimate their amount of fat relatively precisely (Riebe et al., 2018). However, in order to develop even more specific and precise indicators of fatness, researchers started developing indexes as a new variables (de Oliveira et al., 2016; Kukić & Dopsaj, 2017; Kukic et al., 2018; Kyle et al., 2003). When inserted 12 variables into factorial analysis, 3 independent factors were extracted and 8 calculated indexes were spread among the factors (Kukic & Dopsaj, 2017). Regarding the factor called physical inactivity and nutrition, body fat mass index (BFMI) and newly developed indexes, index of hypokinesia (IH) and protein-fat index (PFI)

entered the factor. Note that PFI is based on the relationship between dry contractile mass and fat mass or movement potential and movement inertia. The validity and specificity of this index can further be seen in the study of Dopsaj et al. (2017), because it was one of the variables that entered the factor obtained by factorial analysis.

2.1.1.3. Methods of body composition assessment

Body composition has been frequently investigated over the years because of its biological meaning, and various methods have been developed and used (Wang et al., 1992; Ellis, 2000). Traditionally, approaches based on the classic two compartment model that divides body weight into BFM and FFM, such as underwater weighing (densitometry) and isotope dilution, have been used as reference methods for measuring body density and total body water. However, the latest technological development has brought major conceptual and technological advances in the measurement of body composition (Wang et al., 1992; Hu, 2008, p. 53; Riebe et al., 2018, p. 69).

The most basic, least complex and least costly is an anthropometric model of measurement, which includes body height (BH), BM, WC, and other anthropometric measurements (Hu, 2008, p. 62). After the measurements are taken, nutritional status can be estimated using a BMI, calculated as BM divided by squared BH (m²) (Hu, 2008, p. 65; Riebe et al., 2018, p. 70), which is one of the most commonly used variables in epidemiology studies (Hu, 2008, p. 65) as well as in police studies (Kukić et al., 2018; Maupin et al., 2018).

Another commonly used method of body composition assessment is skinfold method which is based on estimating fat distribution from determining the thickness of several folds of skin across the body (Hu, 2008, p. 73; Riebe et al., 2018, p. 74). The principle behind the skinfold measurements is that the amount of subcutaneous fats is proportional to one-third of the total amount of body fat. For that reason, skinfolds must be measured at precise standard

locations using standard techniques. Even so, skinfold measurements are more prone to interobserver variations and less reproducible than other anthropometric methods, such as weight, height, and body circumferences (Hu, 2008, p. 73; Riebe et al., 2018, p. 74). Since skinfold method can easily be applied as a field test it was used in studies on police officers (Sorensen et al., 2000; Boyce et al., 2008; Lyons et al., 2005; Dawes et al., 2014; Dawes et al., 2016). Basically, the skinfold method is probably the most used method in police studies that included estimated measures of fatness or muscularity.

Most of the other body composition methods such as densitometry, air-displacement plethysmography (ADP), dual-energy x-ray absorptiometry (DXA) and multifrequency bioelectrical impedance analysis (BIA), are laboratory-based assessment methods. They are relatively more accurate but also costly and time consuming, and therefore hardly accessible for most of the police agencies. Moreover, densitometry, ADP and DXA are impossible to be used as field tests at all, however, a gradual increase in use of BIA method can be noticed in literature (Dimitrijević et al., 2013; Dopsaj & Vuković, 2015; Kukić & Dopsaj, 2016, 2017; Čvorović et al., 2018; Pihlainen et al., 2018). The main advantage of the BIA analysis is that it provides data such as SMM, BFM, PBF, FFM, PM, mineral mass, total body water (TBW), intra cellular water (ICW), just to name a few, which allows a multicompartment body composition analysis (Wang et al., 1992; Ellis, 2000). During the last 15 years a simpler systems based on a single frequency have gradually been replaced by those based on multisegmental and multifrequency analysis, with more complex methods for estimating body fat, FFM, skeletal muscle, body water, and water distribution (Hu, 2008, p. 60 and 61), which were shown to be more accurate (Lee et al., 2017). The multisegmental approach assumes that the body is made up of a group of cylinders (left and right arms, the left and right legs, and the total body are measured (Lee & Gallagher, 2008). Multifrequency BIA allows for the differentiation of TBW into ICW and extracellular water (ECW) compartments, which is useful to describe fluid shifts and fluid balance and to

explore variations in levels of hydration (Lee & Gallagher, 2008). Several reasons could be underlined for the use of multisegmental and multifrequency BIA: equipment is relatively affordable, easy to be transported, user friendly, relatively quick, making it a good choice for the field studies of various sizes. The biggest disadvantage of this method is that all measurements have to be done by the specific procedure, whereby the timing, hydration and food intake have to be controlled before the measurements (Hu, 2008, p. 50 and 61).

2.1.2. Physical abilities

At the beginning of the 20th century, police agencies started using arbitrary cut-off points for height and weight for being a police officer because it was thought that bigger men were more suitable for the duties of a police officer at a time. However, until 1950th many agencies realized that these cut-off points could be discriminatory by nature so due to possible issues with law regulations agencies started removing them (Anderson et al., 2001). Therefore, it became clear that next to anthropometric measures, candidates had to pass the tests of physical abilities in order to meet more objective and less discriminatory standards of employment (Anderson et al., 2001). Nowadays, PO have to be highly equipped with a wide range of theoretical and practical knowledge and be able to apply available resources in a very effective but safe manner. Sometimes that involves use of a coercive means (use of force, police batt, gun, cuffs), primarily for preventive purposes and to maintain the public safety (Lauš et al., 2015; Pryor et al., 2012; Rhea, 2015; Blagojević et al., 2016, p. 131).

In that regard, numerous studies showed that success and effectiveness in police duties depend on a good level of general and specific physical abilities (Violanti et al., 2006; Subošić et al., 2011; Dawes et al., 2014; Dawes et al., 2016). Firefighters, special task units, SWAT, just to name a few, are duties that require higher levels of general and specific physical abilities (Anderson &

Plecas, 2000; Anderson et al., 2001; Dopsaj et al., 2007; Guffey et al., 2015). However, each of these police occupations has different needs for physical abilities and therefore physical training (Abel et al., 2011; Abel et al., 2015; Rhea, 2015). For example, duties of the SWAT officers may include riot controls, hostage extraction, arresting resisting suspect, or chasing a flee suspect (Clark et al., 2000; Dawes et al., 2014), while firefighters may need to crawl and drag an injured person while wearing gas mask, carry oxygen and fire hose or axe while climbing ladders or stairs (Abel et al., 2015; Abel et al., 2011). Furthermore, regular duties of police officers may involve driving, sitting, chasing, standing or lifting and carrying (Anderson et al., 2001; Rhea, 2015). From the training specificity and biomechanics perspective, these occupations are very different. However, when it comes to physiology of these various tasks their bioenergetics is similar, meaning that all three systems of energy production should be able to produce the energy needed for the given situation (Zaciorski, 1975, p. 5; Milišić, 2003, p. 6; Abel et al., 2015; Abel et al., 2011; Alvar et al., 2017, p. 50).

Finally, it could be concluded that police officers fit into an existing theoretical model of physical abilities (Zaciorski, 1975, p. 5; Milišić, 2003, p. 6) defined by three main pillars: 1) muscle properties, 2) bioenergetics of human body, and 3) flexibility, mobility and agility. Each of the 3 pillars could be further divided to smaller subcomponents among which not all of them would be equally important for being an officer. For instance, after reviewing 27 scientific studies, Hauschild et al. (2017) found that basic motor abilities such as cardiorespiratory endurance, upper-body strength and lower-body strength correlated with most of the military and police specific tasks consisted of repeated lift and lower, single heavy lift and lower, lift and carry, push and pull, march or walk with load, climb, crawl. The most recent review study on fitness profiles of elite tactical units also showed that most common measures were in the areas of anthropometric measures, strength, power, and aerobic capacity (Maupin et al., 2018). In that regard, physical abilities of police officers

are often defined as muscular fitness (further divided into subcomponents) and aerobic endurance.

2.1.2.1. Muscle properties

Proper functioning of the musculoskeletal system depends on a good neuromuscular activity, which is often called muscular fitness (Plowman & Marilu, 2013, p. 132). The ability of muscles to exert a maximal force or muscle strength, resist fatigue (muscle endurance) and move freely through a full range of motion (flexibility) are the main components of muscular fitness (Janssen et al., 2004; Plowman & Marilu, 2013, p. 132). It has often been associated with quality of life, mineral content, bone strength, and physical performance (Janssen et al., 2004; Plowman & Marilu, 2013, p. 132; Riebe et al., 2018, p. 101). Chronic disease and mortality rates are shown to be lowered when muscular fitness is moderate to high, regardless of cardiorespiratory fitness, body composition, and other potentially confounding factors (Plowman & Marilu, 2013, p. 132).

2.1.2.1.1. Muscular force and strength

The main characteristic of skeletal muscles is the ability to contract and produce force (Blagojevic et al., 2016, p. 135; Nedeljković, 2016, p. 1), whereby force can be produced in relatively independent ways (Milišić, 2003, p. 43; Nedeljković, 2016, p. 10): in relation to muscle length (F-L relationship); in relation to time (F-T relationship); and in relation to velocity of muscle shortening (F-V relationship). When a maximal muscle contraction is not strong enough to overcome an external load, it is defined as a maximal muscle force on a specific muscle length because there is no movement and as such only a muscle force is expressed (Milišić, 2003, p. 43; Blagojevic et al., 2016, p. 135; Nedeljković, 2016, p. 35). Conversely, as long as there is a movement, there is a

movement velocity, and ultimately there is a strength as a product of force (i.e external load such as the mass of body segment or mass of external weight) produced relative to time and movement velocity (Milišić, 2003, p. 44 and 45; Blagojevic et al., 2016, p. 135; Nedeljković, 2016, p. 35). In that regard, muscular strength is often defined as the maximum amount of force that a muscle or muscle group can generate at a specific velocity or against the load (Zaciorski, 1975, p. 11; Nedeljković, 2016, p. 35; Alvar et al., 2017, p. 59; Riebe et al., 2018, p. 97).

The production of controlled movement depends on input from the CNS, physiological and anatomical properties of the muscle (Alvar et al., 2017, p. 59). Motor neurons are the ones who deliver the signals from the CNS to skeletal muscle and trigger the contraction. Individual motor neuron innervates a specific set of muscle fibers whose contraction produces a movement and therefore is called a motor unit (Nedeljković, 2016, p. 6; Alvar et al., 2017, p. 59; Riebe et al., 2018, p. 97). Therefore, how strong the contraction will be, depends on the activation level (signal from CNS) and muscle characteristics such as the type of muscle fiber and muscle size (Zaciorski, 1975, p. 26; Zatsiorski & Kraemer, 2006, p. 48 and 60; Nedeljković, 2016, p. 6 and 7).

Considering the variety of tasks performed by police officers (carrying shields, arresting belligerents, crawl and drag, carry oxygen and fire hose or axe while climbing ladders or stairs, lifting and carrying) studies showed a positive association between the measures of muscle force and strength and performance-related physical fitness (Dawes et al., 2017; Orr et al., 2017; Pihlainen et al., 2018). In that regards, police agencies often use some test to estimate muscle strength, either statically or dynamically (Anderson & Plecas, 2000; Thomas et al., 2014; Beck et al., 2015; Dawes et al., 2017;).

Dawes et al. (2017) found that handgrip strength and leg/back chain dynamometer strength (tests of maximal muscle force) significantly correlated to a specific physical ability test (physical agility course). Furthermore, Anderson & Plecas (2000) reported that the grip strength of the dominant hand

significantly correlated to handgun marksmanship. The study of Beck et al. (2015) showed that upper and lower-body absolute strength (bench press and leg press test) although very close to significance, were not significantly associated to occupational, physical ability test. Conversely, Dillern et al. (2014) investigated the association between the physical ability index (bench press, hangs-up, standing long jump and 3000-m run) and arrest index (2 taekwondo and 2 self-defence tests) and found a significant positive correlation. More importantly, authors explained that bench press and hang-up test explained the most of the variance in physical ability index.

2.1.2.1.2. Muscular power

The main characteristic of skeletal muscle is certainly an ability to contract, but the power, however, is not of less importance because it relates to how big force a muscle can produce in a short period of time (Milišić, 2003, p. 44; Alvar et al., 2017, p. 62). For example, a contact between the foot and the surface in sprinting lasts up to 0.10 s, in long jump up to 0.12 s, and in high jump 0.18 s, while in shot put and javelin throw muscle has around 0.21 s to do the work (Zatsiorski & Kraemer, 2006, p. 26). To produce enough strength for a successful and efficient performance of different tasks, a muscle usually has to contract in a short period of time as much as possible (F-T relationship), therefore to be powerful. Muscle power can often make a difference in performance between people of different fitness (Milišić, 2003, p. 45; Pazin et al., 2013) as well as within a relatively homogenous group of athletes such as judo athletes (Franchini et al., 2005).

Since duties on police officers may involve elements of wrestling and judo, jumping and landing (often while carrying load), power is a very important factor of their physical fitness. Police and military studies showed that next to aerobic and muscular endurance, power is one of the key factors in predicting the performance-related physical fitness (Dawes et al., 2017;

Pihlainen et al., 2018). Dawes et al. (2017) reported that "physical ability test time decreased by one and a quarter seconds for every inch achieved for the vertical jump (VJ), decreased by approximately two-thirds of a second for every second more in the 20 meter multi-stage fitness test (MSFT), and decreased by approximately a half-second for every subsequent sit-up completed". Similarly, when conducted a stepwise regression analysis, Pihlainen et al. (2018) found that together with a 3000-m run, SMM and push-up performance, counter movement jump with an operational load entered the model of prediction of simulated military task performance. More importantly, counter movement jump with the load was a better indicator of performance, comparing to counter movement jump without the operational load. This suggests that power should be assessed in conditions as similar to the occupational task as possible, meaning that power is a more performance-related component of physical fitness (Zatsiorski & Kraemer, 2006, p. 27 and 28; Alvar et al., 2017, p. 61).

2.1.2.1.3. Muscular endurance

Muscular endurance is ability of muscle to contract repeatedly against a submaximal load in a given period of time or to sustain a given submaximal force for an extended period of time, sufficient to cause muscular fatigue (Alvar et al., 2017, p. 58; Riebe et al., 2018, p. 101). If the total number of repetitions at a given amount of resistance is measured, the result is termed absolute muscular endurance. If the number of repetitions performed at a percentage of the 1-RM is used the result is termed relative muscular endurance (Zatsiorski & Kraemer, 2006, p. 52 and 53; Alvar et al., 2017, p. 58; Riebe et al., 2018, p. 101). A long-term endurance training may lead to several morphological and enzymatic adaptations such as increased size and number of mitochondria, which are responsible for the better aerobic production of adenosine triphosphate (ATP) (Alvar et al., 2017, p. 59). In contrast, prolonged lack of physical activity and exercise (detraining) can lead to decrease in muscular endurance (Lagestad et

al., 2014; Sorensen et al., 2000) because number and size of mitochondria normally adapt to a muscle's demand for oxygen. Thus, using a proper muscular endurance test may indicate changes evoked by the applied training and estimate the potential for performing duties that require muscular endurance of police officers. In that regard, it has been shown that upper-body muscular endurance measured by different variations of push-up and sit-up was positively associated to the physical performance of task-related tests (Anderson & Plecas, 2000; Dawes et al., 2017; Hauschild et al., 2017; Pihlainen et al., 2018).

2.1.2.2. Bioenergetics of human movement

Like any machine, the human body needs the energy to operate properly, and this energy is contained in food and drink we consume daily (Ilić, 2006, p. 32; Alvar et al., 2017, p. 50). The process of transferring the food into energy usable for the body is called bioenergetics. The ability of doing physical activity mostly depends on the amount of energy that a muscle can utilize and how fast that energy can be used by contractile elements of the muscle (Abernethy et al., 2004, p. 123). The energy for physical work can be produced either aerobically by burning glucose or free-fatty acids thanks to sufficient amount of oxygen or anaerobically by engaging high intensity, fast fuels, without the presence of oxygen (Milišić, 2003, p. 33 and 34; Ilić, 2006, p. 32 and 33). The three main bioenergetic pathways of energizing body include ATP and creatine phosphate (ATP-CP), glycolytic and oxidative. However, the only energy that muscles can directly use comes from ATP, while other energy pathways (CP, glycolysis and oxidation) can be used to resynthesize the ATP (Abernethy et al., 2004, p. 124; Ilić, 2006, p. 33). Each of the pathways is operating at the same time during physical activity, but to a different degree, depending on the intensity and duration of the activity (Milišić, 2003, p. 7 and 34–39; Abernethy et al., 2004, p. 124).

The capacity and power of these bioenergetic systems and hence endurance, strength, power, speed, and muscle size are subject to adaptation due to applied physical training (Milišić, 2003, pp. 34–39; Alvar et al., 2017, p. 50). Well-developed bioenergetic systems would mean better functioning under the effort and faster recovery during the rest, which is the foundation for any type of physical activity. Furthermore, understanding that behind the result in each physical ability lies a certain bioenergetic system means that by assessing the result in specific physical activity, the bioenergetic system behind it can be estimated. In that regard, some physical abilities can be used as good indicators of both, health and performance-related physical fitness of police officers, because they indirectly show potential for performing demanding tasks and for buffering various stressors (physical or mental). For the aforementioned reasons, the bioenergetic system behind any movement is a fundamental ability of the human body.

2.1.2.2.1. Anaerobic pathways of energy production

During a high intensity physical activity, the body uses the fuels that are easily and quickly accessible, without waiting for the aerobic system to produce the energy. Fuels produced through the anaerobic system of energy production deliver big amounts of energy in a short period of time (Milišić, 2003, p. 34). Since this energy is produced without the presence of oxygen, an oxygen debt increases as the high intensity activity continues, while the maximal amount of oxygen debt is a measure of the person's anaerobic ability (Milišić, 2003, p. 34). However, once anaerobic work is performed, the oxygen debt needs to be repaid for which a good aerobic metabolism plays the most important role. The fastest anaerobic way of energy production is anaerobic-alactic energy production, which comes from ATP-CP systems and lasts 20 – 30 seconds (Milišić, 2003, p. 34; Ilić, 2006, p. 33; Abernethy et al., 2004, p. 124). All activities of maximal intensity such as lifting heavy loads, jumping, throwing objects,

putting the suspect on the ground, arresting a suspect, or sprint running of up to 30 seconds, just to name a few, require a well-developed ATP-CP system of energy production.

The second way of anaerobic energy production is anaerobic glycolysis (degradation of muscle glycogen) or anaerobic-lactic, which starts overtaking after about 20 – 30 seconds and reaches the maximum at about 60 to 90 seconds but can last to 120 – 150 seconds (Milišić, 2003, p. 34; Abernethy et al., 2004, p. 124). These are submaximal activities of high intensity, such as 300-m to 1500-m run, arresting a struggling suspect, or stair climbing while carrying occupational load (firefighters and SWAT teams).

There is only a few studies on police officers investigating anaerobic performance and those are usually specific, job-related physical tests consisted of short sprint runs followed by a direction change, crawling, jumping, carrying, cuffing, etc. (Janković et al., 2014; Janković et al., 2015; Vučković & Dopsaj, 2007; Beck et al., 2015; Dawes et al., 2016; Dawes et al., 2018). Jankovic et al., 2014 showed that there were no statistically significant differences in metabolic response (p = 0.493 for maximum heart rate [HRmax] and p = 0.832 for lactate level after 5 minutes) between male and female police officers. Furthermore, in a reliability study, Jankovic et al. (2015) found no statistical test-retest differences in HRmax (p = 0.602) and lactate level after 3 minutes (p = 0.302) and 5 minutes (p = 0.523). Very recently, Dawes et al. (2018) found a significant correlation (r = 590) between the score in defensive tactics test and post-activity (2-3 min) lactate level of police officers. The scores were determined based on multiple aspects of performance, such as technique appropriateness of the technique selected, and relative intensity.

2.1.2.2.2 Aerobic endurance

Aerobic endurance, aerobic power or cardiorespiratory fitness could be used as synonyms, and they are generally defined as the ability to perform

dynamic, moderate to vigorous intensity physical activity for prolonged periods of time (Riebe et al., 2018, p. 79). More precisely, large and moderate intensity physical activities that last longer than 3 minutes dominantly depend on an aerobic way of energy production (Milišić, 2003, p. 34; Abernethy et al., 2004, p. 124). Performance of any such task for prolonged period of time with undue fatigue depends on the joined action of physiologic and functional properties of respiratory, cardiovascular, and musculoskeletal systems (Riebe et al., 2018, p. 79).

The ability of cardiovascular system to collect the oxygen from lungs and then deliver it to muscles (central adaptation), and ability of muscles to produce ATP using oxygen (peripheral adaptation) is the main reason aerobic endurance is one of the key pillars of good health and physical performance (Milišić, 2003, p. 7; Alvar et al., 2017, p. 57). Moreover, a low cardiorespiratory fitness has been associated with increased risk of premature death from all causes (Riebe et al, 2018, p. 80) as well as with increased number of injuries in police and military (Knapik et al., 1993; Knapik et al., 2013; Orr et al., 2013). In contrast, aerobic endurance has been identified as a good predictor of performance in job-related physical tests for police officers (Anderson & Plecas, 2000; Dawes et al., 2013; Dawes et al., 2016; Dawes et al., 2014; Mitrovic et al., 2015), correctional officers (Jamnik et al., 2010), firefighters (Perroni et al., 2010), and military (Pihlainen et al., 2018). Aerobic power may be particularly important during the sustained pursuit, finding the exit, child rescue, operational load carriage or when the use of force for greater than a few minutes becomes necessary (Dawes et al., 2014). In that regard, police officers with better aerobic endurance have shown to better compensate a stressogenic situation because their blood pressure gets to normal range significantly faster (Blagojevic et al., 2016, p. 128).

As such, the assessment of aerobic endurance is very important part of almost every physical fitness test battery in police occupations. The most commonly used unit of expressing aerobic power has been a maximal VO_{2max},

presented as absolute values (VO$_{2max}$ = L) or relative values (VO$_{2max}$ = ml O$_2$/min/kg BM) (Riebe et al., 2018, p. 81). However, to asses aerobic endurance police agencies around the world usually use various field tests such as 1.5-km run, 2.4-km run, 3000-m run, 3.2-km run, or incremental multi stage shuttle-run test (Mitrovic et al., 2015; Dawes et al., 2016; Kukić & Maamari, 2017; Čvorović & Kukić, 2018; Čvorović et al., 2018). Thus, agencies often express the results in minutes or seconds needed to cover the distance or in a number of levels and shuttles completed, while afterwards VO$_{2max}$ can be estimated by using a certain prediction formula (Riebe et al., 2018, p. 86).

2.1.2.3. Flexibility, mobility and agility

Flexibility is the ability of expressing muscular and tendon properties throughout the biggest possible joint amplitude, while mobility refers to a coordinated and effective activation of agonist, antagonist and stabilizing muscles throughout the whole range of multi-joint movements (Zaciorski, 1975, p. 151; Alvar et al., 2017, p. 262). Agility is the interaction between perceptual abilities and physical abilities or ability of being mobile in its comprehensive meaning on the unknown stimulus (auditory, kinesthetic, visual) (Alvar et al., p. 371). In that regard, measure of flexibility is the maximal amplitude of the joint and can be measured actively by engagement of muscles and passively with application of external force to help reach the maximal amplitude (Zaciorski, 1975, p. 151; Milišić, 2003, p. 50). On the other side, mobility should be measured by coordinative complexity, movement accuracy and time needed for the task to be completed (Zaciorski, 1975, p. 146).

Numerous factors can affect the flexibility, mobility and agility such as age, gender, type of physical activity, and body composition. Studies have shown that sarcopenia (loss of SMM) may increase by age, leading to a decrease in flexibility of muscles and arthritis, which can cause painful joints (Janssen et al., 2000; Alvar et al., 2017, p. 263). Furthermore, there are 7 main abilities

required for good agility: dynamic flexibility, multilimb coordination, power, dynamic balance, acceleration, stopping ability and strength, which further multiplies the factors that can affect agility (Alvar et al., p. 372).

2.1.3. Association between body composition and physical abilities

Body composition components and physical performance of police officers are shown to be very well associated, whereby SMM positively affects the performance, while increased amount of BFM leads to lower or even underperformance on physical fitness tests (Dawes et al., 2014; Mitrovic et al., 2015; Dawes et al., 2016; Pihlainen et al., 2018). In that regard, Dawes et al. (2014) found that an estimated LBM significantly and positively ($p \leq 0.001$) correlated with 1RM bench press, 1-minute push-ups, and vertical jump performances. In another study, 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 armour, helmet and 3 kg assault rifle replica (Pihlainen et al., 2018). When considering a specific task common to police officers, research on load-carriage has found the increasing importance of LBM as the load that needs to be carried gets heavier. The LBM relative to fat and dead mass (load carried) combined highly correlated to heart rate while carrying a 40 kg load ($r = -0.52$) (Lyons et al., 2005). On the other side, increase in BM, BMI, BFM and PBF are shown to be negatively associated with physical performance of police officers (Dawes et al., 2017; Dawes et al., 2016; Dawes et al., 2014; MacDonald et al., 2016; Mitrovic et al., 2015). Research by Dawes et al. (2014) found that BFM and estimated PBF significantly ($p \leq 0.001$) and negatively correlated with 1RM bench press, 1-minute push-ups, 1-minute sit-ups, vertical jump height, 1.5 mile run, and maximal voluntary oxygen consumption.

Additionally, Mitrović et al. (2015) conducted a study on Serbian special force officers and discovered that officers with normal BMI $\leq$ 24.99 kg/m^2 performed significantly better on the 3000-m run test compared to obese officers with BMI $\geq$ 30 kg/m^2 (p = 0.021). Likewise, in a military population, (Ricciardi et al., 2007) observed a reduced aerobic capacity and load carriage task performance ability (p = 0.01) in male and female participants with increased levels of body fat. Even though participants were wearing a relatively light load of 10 kg, the amount of body fat of males (17%) and females (26%) was found to negatively correlate (r = -0.88, p < 0.001) with physical task performance (Ricciardi et al., 2007).

3. PROBLEM, PURPOSE, AIMS AND TASKS OF THE STUDY

3.1. DEFINING THE PROBLEM

Numerous studies on police officers investigated the association between physical abilities and body composition. Since testing in police occupations normally require a large number of officers to be tested at the same time on the field, the choice of methods is limited. In that regard, the most commonly used body composition assessment methods reported in researches were anthropometric measurements, skinfold measurements and a few times DXA or BIA method. Furthermore, police agencies tend to have simple and easily addressable but accurate enough procedures and therefore investigating and switching to newer procedures have not been the priority. For that reason, body composition characteristics such as BMI, BFM and PBF are the ones that are often used, while LBM, SMM or percent of SMM were used even less frequently due to the complexity of collecting those data. A strong background for associations of these measures with physical performance has been established through numerous studies.

However, there is a scarcity of studies that tried to experiment with these data in order to get more accurate indicators of physical fitness. Most of the measurement procedures of physical fitness were developed by prominent institutions such as the American College of Sports Medicine, Cooper Institute and National Strength Association and Conditioning and then applied by police agencies. In recent history, not many studies investigated the possibility of predicting physical performance based on body composition characteristics, and those studies that did, they did not use neither index values of body composition nor index of total physical performance.

The rationale behind using indexed body composition lies in the inability of commonly used characteristics sometimes to accurately define the difference between seemingly same bodies. For example, while a police officer may have a

normal PSMM it does not necessarily mean that the same person is not underweight (i.e., PSMM = 35.0% and BMI < 18.5 kg/m^2), which ultimately may also hinder physical performance. Conversely, a higher percentage of BFM may lead to lower PSMM, even though the quality of SMM will remain the same. For instance, if officer's BMI is 27.0 kg/m^2 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 is good. Therefore, in both cases, PSMM and BMI may be misleading in regard to the potential for performance. Similarly, PBF and BMI can also be often misleading. For instance, police officer's BMI may seem normal, even though their PBF is high (i.e., BMI = 24.0 kg/m^2 and PBF = 25.0%), which in turn would usually lead to lower physical performance, and accordingly, their nutritional status should not be defined as normal. Furthermore, if two officers have the same BMI of 27.0 kg/m^2 but one has 52.0% of SMM and 12.0% of BFM, while the other has 40.0% of SMM and 24.0% of BFM, their potential for performance can be expected to be totally different. Thus, building the body composition indexes that more closely define these differences in relation to police officers' physical performance could be a valuable tool for both, police officers and practitioners.

3.2. PURPOSE OF THE STUDY

The purpose of this dissertation is 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 police officers' 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.

3.3. AIMS OF THE STUDY

Since the investigated problem belongs to multidimensional space, the aims of the study are defined according to the following:

- Determining the association of body composition indexes and physical performance of commonly used police tests,
- Determining the validity of chosen body composition indexes and prediction models,
- Establishing a statistically significant model of physical fitness prediction by determining a causal relation between body composition indexes and physical performance index.

3.4. TASKS OF THE STUDY

Based on the defined problem, purpose and aims of the study, this research will be conducted through the following tasks:

- Defining the body composition indexes,
- Defining the physical performance index,
- Defining body composition and physical fitness assessment procedures,
- Defining the groups of participants and their characteristics,
- Collecting the data on chosen set variables,
- Analyzing data using specialized software for statistical analysis,
- Describing the analyzed variables, quantitatively and qualitatively.

4. HYPOTHESES

Based on the literature overview and literature analysis as well as on defined problem, purpose, aim and tasks of the dissertation, the following hypotheses are defined:

GENERAL HYPOTHESIS

H_g – It is possible to define a physical fitness prediction model based on body composition characteristics.

SUPPORTING HYPOTHESES

H_1 – There will be a significant association between the characteristics of body muscularity, expressed as indexed calculation and physical performance.

H_2 – There will be a significant association between the characteristics of body fatness, expressed as indexed calculation and physical performance.

H_3 – There will be a significant internal and construct validity of chosen body composition indexes.

H_4 – There will be a significant causal relationship between body composition characteristics and individual physical ability.

5. METHODS

This study was of an applied non-experimental cross-sectional research design conducted through a combination of laboratory and field tests. Three separate samples from two different police agencies were used to investigate the hypotheses, among which the second sample consisted of two subsamples. Measures of health-related physical fitness and performance-related physical fitness were assessed and correlated with body composition. Moreover, the differences between the groups were assessed and the predicting power of body composition indexes was tested.

5.1. SAMPLE CHARACTERISTICS

The first sample consisted of 196 male police officers whose main characteristics were: mean age = 31.61 ± 4.79 years, mean BH = 172.97 ± 6.09 cm, mean BM = 77.53 ± 11.66 kg and mean BMI = 25.86 ± 3.26 kg/m². Their data was used to investigate the associations between the body composition indexes and measures of health-related physical fitness such as PU, SU and RU, and to test the possibility of predicting the estimated physical fitness score (EPFS) calculated from these three measures. Police officers were called through the police mailing system and the assessment of RU, SU and PU was conducted as part of departmental process, while body composition was measured additionally.

The second sample consisted of 27 female police officers (FPO) and 19 female police cadets (FPC) whose body composition was measured and who performed PU, SU, RU and IAT. The main characteristics of the subsample of FPO were: mean age = 32.19 ± 5.09 years, mean BH = 162.78 ± 5.01 and mean BM = 71.30 ± 13.50 kg. The main characteristics of the subsample of FPC were: mean age = 20.16 ± 1.07 years, mean BH = 171.22 ± 6.05 cm, and mean BM = 66.46 ± 13.98 kg. The differences in body composition and physical abilities

were tested between the groups, and the regression power was analysed for the combined sample as well as partially for each subsample.

The third sample consisted of 116 male police cadets (MPC) who were students at the University pf Criminal Investigation and Police studies (UCIPS), Serbia. The main characteristics were: age = 21.96 ± 1.29 years, BH = 182.88 ± 6.86 cm, and BM = 83.09 ± 9.54 kg. Six body composition indexes, among which four were body size-independent and two were body volume-independent indexes of body composition were correlated to thirteen measures of physical abilities. Thirteen measures of physical abilities were used to calculate nine physical performance indexes: MFi – Muscle Force index, LBMPi – Lower-body Muscular Power index, UBMPi – Upper-body muscular power index, CODi – Change of Direction speed index, SRSi – Straight Running Speed index, REi – Running Endurance index, MQPi – Muscle Quality and Performance index, RAi – Running Ability index, and TPPi – Total Physical Performance index. All physical performance indexes were calculated by reducing the number of dimension using the factorial analysis.

The participants in each sample as well as trainers that conducted the measurements were informed about the aim of the data collection and their data was included in analysis 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.

5.2. TESTING PROCEDURES

A body composition analysis was conducted, and the indexes of body composition were calculated following the same procedure for all three investigated samples (see Table 1).

Regarding the first sample, body composition indexes were correlated with RU, SU, PU, and the EPFS, followed by a regression analysis. The assessment of physical abilities was conducted as a mandatory part of annual physical fitness assessment, while body composition assessment was conducted additionally for the purposes of this dissertation. Three physical tests were conducted (a 3.2 km run, a 2-minute push-ups and 2-minute sit-ups assessment) with the individual scores from each of them being converted into EPFS.

Regarding the second sample, the differences between the subsamples in body composition and physical abilities were tested, followed with the regression analysis to define the power of body composition indexes in predicting the change of direction speed (COD).

Regarding the third sample, six body composition indexes were correlated with 13 measures of physical abilities and 9 physical performance indexes that were calculated from these 9 measures, using the same statistical procedure as in calculating EPFS.

5.2.1. Body composition

The assessment of body composition was conducted indoors under the control of trained practitioners. Measurement procedures were conducted using a 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 in accordance with previously reported procedures (Dopsaj & Vuković, 2015; Kukić & Dopsaj, 2016, 2017), whereby all participants were instructed not to eat and drink overnight prior to the

measurements being taken and they were standing steadily for about five minutes to allow a proper redistribution of body fluids. The participants, who were only wearing 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, with the head in Frankfurt plane position. After measuring the body weight, participants grasped the device's handles with electrodes positioned on the lower and the upper edge of the handles. Four fingers were positioned on the lower edge and thumb was placed on the upper edge. Hands were parallel to the body with 15-20º of shoulder abduction. Participants stood steadily in this position until the device's sound and an instructor signaled that measurement procedure was complete. Once the measurement was completed, the result sheet for each participant was printed out with the numerus variables available. Once the measurement was completed, the result sheet for each participant was printed out with the numerus variables available. 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).

5.2.2. Physical abilities

The first sample was tested according to an official annual physical fitness assessment of Abu Dhabi Police consisting of aerobic endurance, tested by using 3.2-km run test and upper-body muscular endurance tested by a maximal number of push-ups performed within 2 minutes (2-min PU) and a maximal number of sit-ups performed within 2 minutes (2-min SU). The second sample's physical abilities were tested according to the annual assessment procedures of Abu Dhabi Police, and according to procedures of UCIPS. Only the Illinois agility test (IAT) was tested additionally in both subsamples because IAT is considered to mimic the performance of a maximal short running pursuit

of police officers. The aerobic endurance was tested using a 12-minutes Cooper test. The third sample was tested according to the procedures of UCIPS whereby 13 measures that presented muscular force and strength, muscular power, muscular strength endurance, change of direction speed (COD), aerobic endurance and anaerobic capacity were chosen for the analysis.

5.2.2.1. Muscular force and strength

Maximal force of lower back measured by isometric dead lift (DLFmax): The DLFmax was conducted using a standardized measurement procedures previously reported in research (Dopsaj, Milosevic, & Blagojević, 2000). In short, maximal isometric force of back extensors was measured while the participants were standing with their knees straight while being slightly flexed in their hip joint and the feet in parallel position, a shoulder width apart (Photo 1). They held the tensiometric probe with a built-in A/D converter connected to a software system. After the signal was given, the participant pulled the isometric probe as strong as possible by engaging lower back, with no movements made in the front and lateral planes. The participants were cheered and encouraged verbally and they had a live visual feedback of their force development.
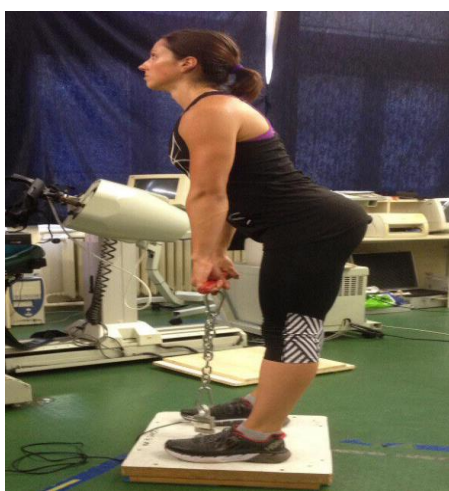
Photo 1. Isometric maximal force of dead lift.

One repeat maximum bench press (BP1RM): The BP1RM was conducted according to the procedure explained by Dawes et al. (2016). In short, participants laid down on their back on a standard flat bench with the side holders which were holding the weight. The participants were obligated to maintain a 5-point contact (head, shoulders and glutes in contact with the bench and both feet on the floor), aligning their ayes directly under the barbell. The starting position was with the barbell lifted off the holders and positioned over the chest. The correct repetition was recorded when the participant lowered the bar to the chest in a controlled manner, made a light contact between the bar and chest, then extended the arms to return the bar to the starting position (Photo 2).

Photo 2. One repeat maximum bench press.

5.2.2.2. Muscular power

Standing long jump test (SLJ): The SLJ, is a common and easy to administer a test of lower-body explosive power and will be conducted according to the procedure reported in a study on the military (Pihlainen et al., 2018). The participants were standing behind the line marked on the ground with feet slightly apart, approximately pelvis to shoulder width. Before the test, the participants were instructed on a proper technique and they were given five to seven submaximal and maximal warm-up trials. They were instructed to use

a two-foot take-off and landing, with the swinging of the arms and bending of the knees to provide a forward drive (Photo 3). The participants were required to jump as far as possible and to lend on both feet without falling backwards. Three performed the test three times, and the measurement was taken from the take-off line to the nearest point of contact on the landing (back of the heels or hands if fall backwards). The best of three attempts was recorded in centimetres for the further analysis, with the precision of 0.5 cm.

Photo 3. Standing long jump.

Abalakow vertical jump test (ABL): The ABL is consisted of countermovement jump with arm swing that was used to measure the explosive power of legs in the vertical plane (Markovic & Jaric, 2004). The participants were instructed to jump as high as possible after performing a preceding countermovement with arm swing and to land approximately at the point of take-off. The test was conducted on a contact platform (Contact plate, Globus, Codogne, Italy; accuracy ± 0.001 second) that records flight time (t). The rise of the centre of gravity above the ground (height in centimetres) was calculated from the time of flight (t, expressed in s) applying the ballistic law: $h = 1/8 \, t^2 g$ ($g = 9.81$ m/s^2), which was shown to be highly reliable, with ICC > 0.9 (Markovic, Dizdar, Jukic, & Cardinale, 2004).

50-m sprint run (RU50): Participants had a 10-minute warm-up, several gradual incremental 20 to 30-meter runs, and 3-5 minutes of dynamic stretching. The testing procedure started by approaching the starting line and performing a 50-m sprint run one by one as fast as physically able. One tester

was at the start line giving the signals 'ready', 'steady', and 'go'. On the 'go' command, the tester at the start line moved the hand sharply down as a signal for the two testers positioned at the finish line, to start the stopwatch. The average of two measured times was used for the analysis. The same testers conducted the assessments for each testing session and for each participant individually.

20-m sprint run (RU20m): The RU20m was conducted at a hard surface. The participants were instructed to run 20 meters as fast as possible, starting from the standing start position on the testers mark "Ready", "Set", "Go". The test outcomes were recorded using the electronic timing gates (Fitro Light Gates, Fitronic, Bratislava, Slovakia). Precision of the measurement was 0.01 s.

10-m sprint run (RU10m): The RU10m was conducted at a hard surface. The participants were instructed to 10 m as fast as possible, starting from the standing start position on the testers mark "Ready", "Set", "Go". The test outcomes were recorded using the electronic timing gates (Fitro Light Gates, Fitronic, Bratislava, Slovakia). Precision of the measurement was 0.01 s.

10-sec push-ups test (PU10s): A maximal number of PU in 10 seconds is a standardized test conducted at UCIPS to assess a repetitive power of arm extensors. Starting position as well as a correct PU repetition were the same as in a regular PU test. The participants were required to complete as many correct PU as possible within 10 seconds and the results were expressed in number of correct repetitions.

30-sec sit-ups (SU30s): A maximal number of SU in 30 seconds is another test for upper-body muscular strength used by the UCIPS for assessing the repetitive power of abdominal flexors (Dimitrijević et al., 2014). Starting position is the same as in procedure of Abu Dhabi Police, with only difference being the position of the hands. According to procedure from the UCIPS, the palms are positioned on the back of the head with fingers overlapped and elbows opened. One sit-up was counted when the participant raised and rotated the upper-body into sitting position, connecting the opposite knee and

elbow and came back to starting position. The participants were performing a maximal number of sit-ups with alternate rotations in 30 seconds and the results were expressed as the number of SU performed within 30 seconds.

10 pull-ups (10PullU): A 10PullU as fast as possible was used by the UCIPS to assess the repetitive power of arm flexors and shoulder extensors. The starting position was with the pull up bar held by pronated grip and hands totally extended and one correct repetition was counted then the participant pulls up the chin above the bar. The participants were instructed to complete 10 pull-ups as fast as possible, and the results were expressed as seconds need to complete 10PullU.

5.2.2.3. Muscular endurance

2-min and 1-min push-up test (PU): Abu Dhabi Police utilize a PU and 2-min sit up tests for the assessment of upper-body muscular endurance of male police officers and 1-min PU and sit-up test for female police officers. A 20-minute rest was given to participants between the run test and the PU test. Afterwards, participants were briefed about the requirements for the PU and sit-up test. Following a 5-minute upper-body warmup, participants were organized into six columns, while a number of rows depended on the number of the participants that passed the running test. There was one tester for each column so that six participants were tested at once. A 7th tester acted as the time keeper. The same testers were used for each testing day. A maximum of 4-points of contact with the ground (feet and palms) were allowed and the participants were required to hold their body straight and firm (straight line from toes to the head). The difference with 1-min PU for ladies was that they were performing the PU from their knees. The hand width was chosen individually, 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 considered correct when the participant's elbow joint crosses

the position of 90 degrees of flexion (upper arms parallel to the ground) before returning to the straight-arm position. Resting during the test was allowed but without touching the floor with knees or chest and only by raising one hand in order to unload and relax the hand. If any part of the body except feet or palms touched the ground, the participant was stopped, and a number of the accurate push-ups until that point was saved as the result of the test.

2-min and 1-min sit-up test (SU): Following the PU test, the participants proceed to the assessment of the maximal number of SU in two minutes, in accordance with a previously described procedure (Dawes et al., 2014). As soon as the last row of PU completes the testing, the SU test commenced with the initial PU row of participants starting first. This process ensured a minimum of 15 minutes of rest following the PU, as there were always five or more rows of participants. Participants were required to lay on their back, with both feet on the ground, knee angles at not more than 90° of flexion, both shoulder blades on the ground, and arms crossed over the chest. One sit-up repetition was counted when the participant sat up until he touched the knees with elbows and returned back to the starting position. While moving towards the upper position to touch the knees, palms were not allowed to leave the participant's shoulders and chest. Swinging and using momentum was also not allowed nor any means of shortening the distance between the elbows and knees. Testers were standing on the participants' feet fixing their feet to the ground and counting only correct repetitions. Whenever a wrong repetition was performed, the tester would verbally warn the participant by clearly stating what the mistake was.

5.2.2.4. Anaerobic power and aerobic endurance

300-m shuttle run (ShR300): The anaerobic power was estimated using a 300-m shuttle run test, conducted outdoors on a concrete surface. The procedure was similar to the one reported in Moore and Murphy (2003),

whereby cadets run repeatedly forth and back between two parallel lines 25 yards apart until they completed 300 meters. The requirement was to run as fast as possible and they were verbally encouraged do their best. The time was measured using a hand stopwatch. The result was expressed as time needed to complete the test. It was recorded in seconds, to the nearest 0.5 s. The test was shown to be reliable (ICC = 0.99, SEM = 0.65 s) and sensitive (p = 0.005) to detect the differences between different level of athletes (Moore and Murphy, 2003).

3.2-km run test: Abu Dhabi Police uses 3.2-km run test for testing the aerobic endurance of police officers. The procedure for the 3.2km run has been reported in the previous literature (Kukić & Maamari, 2017). After a 10-minute warmup routine, and 3 – 5 minutes of active stretching, the 3.2-km run started (starting at 07:00am). The instruction for the participants was run the test in the quickest time possible, and they were briefed about the time needed to pass the test. During the registration for the test, participants were tagged with a numbered sleeveless green t-shirt. Those numbers were connected to the employee's ID number, so the testing team can easily mark participant's times as they complete the run distance. At the finish point, two coaches were waiting for the participants: one measuring the time, and the other one writing down the participants' t-shirt numbers. A Casio stopwatch (Casio HS-70W), with the capability to record over 200 split times, was a standard measuring tool for the run times. After all officers passed the finish line, the timings on the stopwatch were recalled from first to the last and connected with the numbers on the green t-shirts. The data collection occurred from December to February as the weather conditions are acceptable and similar for all participants: December (average temperature 24°C, humidity 63%, and pressure 1018mbar), January (average temperature 22°C, humidity 60%, and pressure 1017mbar), and February (average temperature 21°C, humidity 56%, and pressure 1018mbar). This way the heat and the humidity did not significantly affect the results of the running test.

12-min Cooper test (CT): General aerobic endurance at UCIPS was estimated by using a standardized 12-minute Cooper running test, whereby the participants were required to cover the longest possible distance in 12 minutes, which was shown to have a high predicting value with r = 0.93 and p < 0.001 (Bandyopadhyay, 2015). The test was conducted outdoors, the participants were tagged the same way as the participants from Abu Dhabi Police, and the time was measured using a Casio stopwatch. The test was conducted on a 230 m long circuit running track, where participants were running for 12 minutes since the signal for the start until the signal to stop, after which the distance covered between the signals was recorded and used for the further analysis.

5.2.2.5. Change of direction speed

Illinois agility test (IAT): Agility refers to the ability to alter direction to achieve a specific goal (evade, deceive, and react to unknown signal), and has been often included in physical fitness assessment of police officers. 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 (Miller et al., 2006). Hachana et al. (2013) reported a high intra-trial reliability of this test (ICC = 0.96). The test started by lying face down by the first cone, head on the starting line and hands next to the shoulders. Staring at cone 1 participants run as fast as possible to cone 2, which was placed straight in front of cone 1 at a distance of 10 meters away. The participants then turned sharply around the cone, returned to the middle of the starting line, again sharply turned around cone, and then weaved in and out of the row of cones and back again towards the bottom of the course. After this, they again had to run as fast as possible to the far line at the top of the course turn around the cone and sprint back to the finish line (Figure 1). The

time to complete the test was recorded once the participant reaches the final cone.
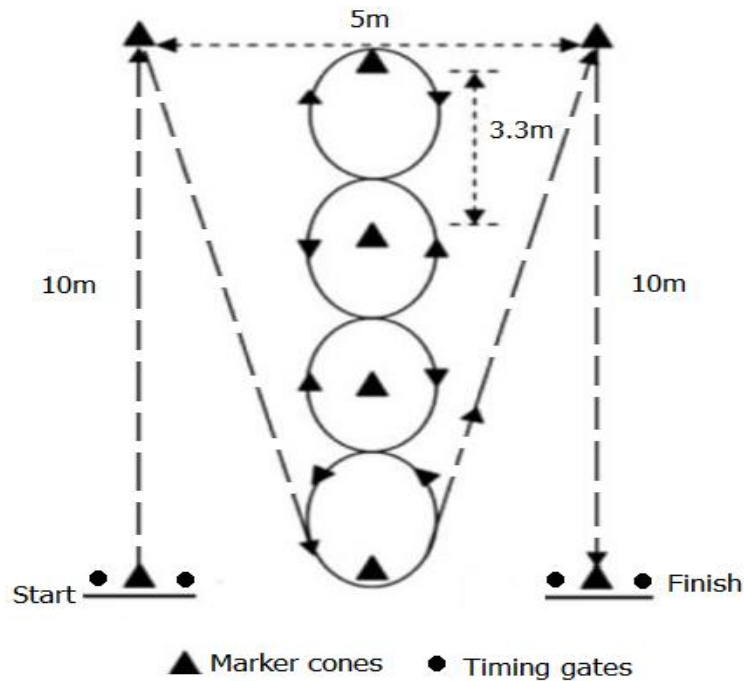
Figure 1. Illinois agility test course.

T-test (TT): The TT was used for as a lateral COD test, which was reported to be reliable with an ICC = 0.98 across three trails (Kainoa et al., 2000). Four cones were arranged in a "T" shape formation (Figure 1), and the subjects started the test with their legs behind the starting line next to the cone A. On an whistle signal they run 9.14 m to the central cone B. After touching the cone, the subjects shuffled laterally (without crossing the feet over) to the right 4.57 m touched the cone C and then shuffled to the left 9.14 m and touched the cone D. The subjects continued shuffling 4.57m in an opposite direction, touched the cone B, and ran backwards 9.14 m to the starting line. The subjects performed several graded submaximal trials to familiarize with the test. Once familiarized, the subject performed the test as fast as possible. They completed two maximal trials and the better result was recorded for the further analysis.
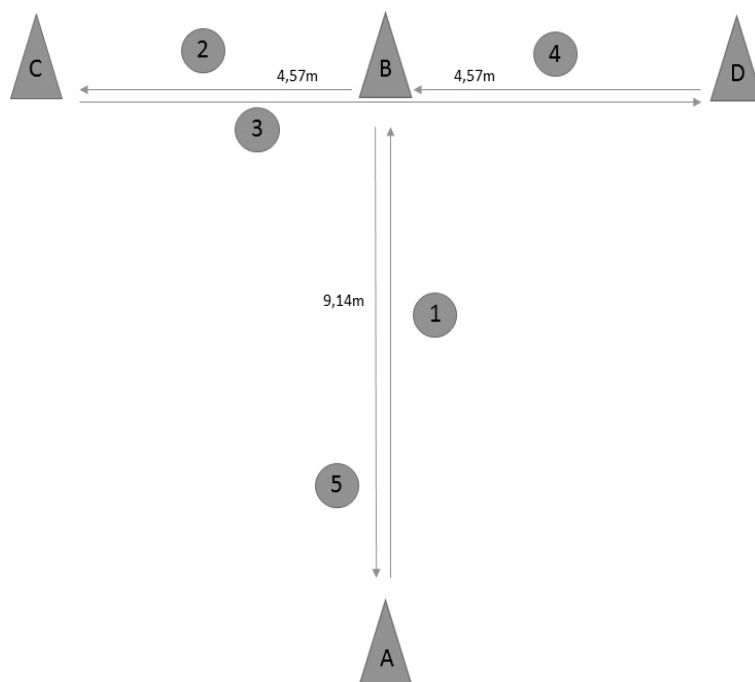
Figure 2. The T-test layout.

5.3. VARIABLES

5.3.1. Body composition variables

Ten body composition variables were used (Table 1), among which 4 were be direct (BH, BM, FM, and SMM) and 6 were indexes calculated from these measures. Index-values approach was applied so the body structure can be explained on a tissue level, independently of body height and volume.

Table 1. Body composition variables.

#	Variable	Calculation	Unit	
1	Body height - BH		cm	
2	Body mass - BM		kg	Direct
3	Body fat mass - BFM		kg	measures
4	Skeletal muscle mass - SMM		kg	
5	BMI – Body Mass index	BM/BH^2	kg/m^2	
6	BFMI – Body Fat Mass Index	BFM/BH^2	kg/m^2	
7	PBF – Percent of Body Fat	$(BFM/BM) * 100$	%	Index
8	PSMM – Percent of Skeletal muscle Mass	$(SMM/BM) * 100$	%	measures
9	IH – Index of Hypokinezia	PBF/BMI	$\%/(kg/m^2)$	
10	SMMI – Skeletal Muscle Mass Index	SMM/BH^2	kg/m^2	

5.3.2. Physical performance variables

Muscular force and strength:

- Maximal force of lower back assess by dead lift – DLFmax, expressed in DecaNewton (DN), assessed according to procedure reported in Dopsaj et al. (2000),
- 1 repeat maximum bench press – BP1RM, expressed in kg, assessed following the procedures reported in Dawes et al. (2016).

Muscular power:

- Standing long jump – SLJ, expressed in centimetres, according to procedure previously explained in Pihlainen et al. (2018),

- Abalakow vertical jump test – ABL, expressed in cm, assessed according to procedure reported in Markovic et al. (2014),

- 20-m sprint run – RU20m, expressed in seconds, according to the procedures from University of Criminalistic and Police Studies,

- 10-m sprint run – RU10m, expressed in seconds, according to the procedures from University of Criminalistic and Police Studies,

- A maximal number of push-ups in 10 seconds – PU10, expressed in number of repetitions,

- 10 pull-ups in the shortest time possible – 10PullU, expressed in seconds,

- 30-sec sit-ups – SU30s, expressed in number of repetitions.

Muscular endurance:
- 2-min push-up – PU, expressed as a number of performed sit-ups, according to procedure previously explained in Dawes (2011, p. 48),

- 2-min sit-up – SU, expressed as a number of performed push-ups, according to procedure previously explained in Dawes (2011, p. 48).

Anaerobic power and aerobic endurance:
- Shuttle run 300y – ShRun300, expressed in seconds,

- 3.2-km run, expressed in seconds, according to procedure previously explained in Kukic & Maamari (2017),

- 12-min Cooper test – CT, according to procedure previously explained in Dimitrijević et al. (2014), expressed in meters.

Change of direction speed (COD):
- Illinois Agility test – IAT, expressed in seconds, according to procedure explained in Dawes (2011, p. 41),

- T-test for lateral change of direction speed ability, expressed in seconds (Kainoa et al., 2000).

Physical performance indexes:

- Estimated Physical Fitness Score – EPFS, calculated using a Multidimensional scaling, expressed as the score (number),

- Muscular force index – MFi, calculated from DLFmax and BP1RM using a Multidimensional scaling,

- Lowe-body muscular power index – LBMPi, calculated from SLJ and ABL using a Multidimensional scaling,

- Upper-body muscular power index – UBMPi, calculated from PU10s, 10PullU and SU30s, using a Multidimensional scaling,

- Change of direction speed index (CODi), calculated from IAT and TT, using a Multidimensional scaling,

- Straight running speed index – SRSi, calculated from RU10m. RU20m and RU50m, using a Multidimensional scaling,

- Running endurance index – REi, calculated from CT and ShRun300m, using a Multidimensional scaling,

- Muscle quality and performance index – MQPi, calculated from MFi, LBMPi, and UBMPi, using a Multidimensional scaling,

- Running ability index – RAi, calculated from CODi and SRSi, using a Multidimensional scaling,

- Total physical performance index – TPPi, calculated from REi, MQPi and RAi, using a Multidimensional scaling.

5.4. STATISTICAL PROCEDURES

All variables were analysed descriptively by using measures of central tendency, data dispersion and for normality of distribution such as:

- Mean,

- Standard deviation (SD),

- Minimum (min),

- Maximum (max),

- The coefficient of variation (cV%),

- Skewness,

- Kurtosis,

- Kolmogorov-Smirnov test.

Following statistical procedures were used to investigate the association of body composition characteristics and physical abilities and performance, the differences in performance based on body composition characteristics, and the possibility of predicting physical performance from body composition characteristics (Hair et al., 1998):

- Correlation analysis,

- Factorial analysis,

- T-test,

- Univariate analyses of variance (ANOVA), with Bonferroni post-hoc analysis,

- Multivariate analysis of variance (MANOVA), with Bonferroni post-hoc analysis,

- Linear regression analysis,

- Multiple regression analysis.

A factorial analysis was used to create a FACT_bod variable (one variable) from several variables, which was further converted into performance indexes. This was done 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). The correlations were defined as follows: small = ± .20, medium = ± .50 and large = ± .80; and regression R^2 was defined as: small = .04, medium = 0.25, and large = 0.64 (Sullivan and Feinn, 2012). The strongest model that explained the highest level of variance of the dependent variable, with the lowest level of the standard error of the estimate (SEE), and the simplest model (i.e. the model that included the least number of variables) were the criteria for choosing the best-fit models of prediction. All statistical analyses were conducted using the IBM's Statistical Package for the Social Sciences (SPSS, version 20, Chicago, IL, USA) and with significance level set at $p < .05$, meaning that minimum 95% of variance was explained in order for the results to be accepted as significant.

6. RESULTS OF THE STUDY

6.1 DESCRIPTIVE STATISTICS

The first sample included 196 police officers, whose descriptive statistics are presented in Table 3. The lowest and highest values for the age are based on the fact that below 22 years are cadets whose physical fitness assessment is consisted of different tests, while officers above 45 years are not required to do the annual fitness assessment. However, since they can join voluntarily, participants that are older than 45 years were included in order to increase an external validity. In average, participants were slightly overweight considering their BMI, but more importantly in average their PBF belongs to poor fitness level relative to average age (Riebe et al., 2018, p. 79). Considering the average results in physical performance measures, the participants were positioned at 74th percentile in RU, 64th percentile in PU and 72nd percentile in SU comparing to physical fitness standards of Abu Dhabi Police. However, due to the rule pass all or none, the investigated sample included only officers who passed the required minimum standards which was set at 50th percentile.

The second sample consisted of 27 FPO and 19 FPC, whose descriptive characteristics are shown in Table 4 and Table 5. The relative variations (cV%) in body composition components among FPO were similar to those of FPC. In contrast, relative variations in IAT of FPC were almost twice lower than in FPO.

The third sample consisted of 114 MPC who were recruited for the academy and therefore, due to selection, the data dispersion in their physical fitness characteristics was lower than among the officers (Table 6). The reason for using selected sample was to increase the validity and to test the sensitivity of the used body composition indexes because for the sample of lower data dispersion the sensitivity has to be higher in order to detect the differences and provide a significant model of prediction.

Table 3. Descriptive statistics for male police officers.

Variables	Mean	SD	Min	Max	cV(%)	Skew	Kurt	KST
Age (years)	31.54	4.74	22.00	52.00	15.04	.619	1.038	.205
BH (cm)	173.62	6.66	156.00	196.00	3.84	.419	.398	.172
BM (kg)	78.44	11.64	48.30	115.30	14.84	.428	.326	.615
BMI (kg/m²)	25.97	3.12	18.80	35.59	12.03	.209	.175	.783
PBF (%)	22.74	7.06	4.83	39.31	31.05	-.126	-.626	.738
PSMM (%)	43.65	4.36	33.51	55.02	9.98	.149	-.519	.705
BFMI (kg/m²)	6.02	2.32	1.19	12.80	38.54	.341	-.306	.506
SMMI (kg/m²)	11.29	1.38	7.78	15.25	12.23	.305	-.004	.602
IH (Index unit)	0.88	0.25	0.20	1.80	28.22	-.006	.563	.628
RUN (sec)	1068.65	146.36	724.00	1509.00	13.70	.432	1.113	.081
PU (No)	37.03	13.98	0.00	67.00	37.74	-.402	.006	.118
SU (No)	42.81	12.13	11.00	85.00	28.33	.390	1.009	.060
EPFS (Index unit)	49.98	15.38	9.50	90.50	30.76	-.002	.471	.218

SD – Standard Deviation, Min – Minimum, Max – Maximum, cV (%) – Coefficient of Variation (SD / mean * 100), Skew – Skewness, Kurt – Kurtosis, KST – Kolmogorov-Smirnov Test.

Table 4. Descriptive Statistics for female police officers.

Variables	Mean	SD	Min	Max	cV (%)	Skew	Kurt	KST
Age	32.19	5.09	22.00	42.00	15.82	-0.19	-0.69	.396
BH (cm)	162.78	5.01	155.00	173.00	3.08	0.30	-0.69	.912
BM (kg)	71.30	13.50	50.00	110.00	18.93	0.81	1.23	.801
BMI (kg/m²)	26.93	4.53	21.00	37.00	16.83	0.64	-0.51	.390
BFMI (kg/m²)	9.99	3.74	3.38	17.68	37.44	0.39	-0.20	.794
SMMI (kg/m²)	9.20	1.01	7.19	10.90	10.95	-0.17	-0.70	.984
PBF (%)	36.15	8.44	15.62	49.82	23.36	-0.71	0.20	.582
PSMM (%)	34.79	4.57	27.37	46.52	13.14	0.87	0.55	.669
IH (Index unit)	1.34	0.23	0.72	1.77	17.29	-0.72	0.80	.462
IAT (s)	23.22	2.67	19.00	28.00	11.48	0.36	-0.64	.785

SD – Standard Deviation, Min – Minimum, Max – Maximum, cV (%) – Coefficient of Variation (SD / mean * 100), Skew – Skewness, Kurt – Kurtosis, KST – Kolmogorov-Smirnov Test.

Table 5. Descriptive statistics for female police cadets.

Variables	Mean	SD	Min	Max	cV (%)	Skew	Kurt	KST
Age	20.16	1.07	19.00	24.00	5.30	2.71	9.81	.008
BH (cm)	171.22	6.05	165.00	190.40	3.53	1.96	4.94	.810
BM (kg)	66.46	13.98	53.20	108.90	21.04	2.25	4.87	.128
BMI (kg/m²)	22.55	3.64	18.70	34.10	16.16	2.36	5.79	.086
BFMI (kg/m²)	5.61	2.14	3.46	13.15	38.15	2.58	8.61	.621
SMMI (kg/m²)	9.39	1.48	7.86	14.18	15.71	2.26	5.78	.446
PBF (%)	24.49	5.71	18.52	38.53	23.31	1.08	0.55	.491
PSMM (%)	41.81	3.33	34.61	47.20	7.97	-0.67	-0.08	.425
IH (Index unit)	1.09	0.21	0.64	1.51	19.68	0.24	0.66	.632
IAT (s)	22.26	1.45	20.00	25.00	6.50	0.35	-0.29	.699

SD – Standard Deviation, Min – Minimum, Max – Maximum, cV (%) – Coefficient of Variation (SD / mean * 100), Skew – Skewness, Kurt – Kurtosis, KST – Kolmogorov-Smirnov Test.

Table 6. Descriptive statistics for male police cadets.

Variables	Mean	SD	Min	Max	cV (%)	Skew	Kurt	KST
Age	21.96	1.29	20.00	26.00	5.87	1.05	0.46	.000
BH (cm)	182.88	6.86	169.10	197.00	3.75	-0.05	-0.71	.932
BM (kg)	83.09	9.54	64.50	112.70	11.48	0.89	1.06	.089
BMI (kg/m²)	24.84	2.39	19.50	32.00	9.60	0.58	0.44	.419
SMMI (kg/m²)	12.05	0.98	9.86	16.13	8.16	0.86	2.18	.365
BFMI (kg/m²)	3.76	1.43	1.09	8.39	38.17	0.72	0.58	.122
PBF (%)	14.86	4.62	4.10	30.40	31.09	0.39	0.44	.637
PSMM (%)	48.65	2.75	39.20	56.23	5.64	-0.30	0.69	.757
IH (Index unit)	0.59	0.15	0.15	1.10	26.15	0.10	0.56	.981
DLFmax (DN)	162.70	22.87	119.70	224.70	14.05	0.76	0.61	.397
BP1RM (kg)	98.89	17.98	60.00	160.00	18.18	0.46	0.08	.317
SLJ (cm)	233.47	17.27	190.00	285.00	7.40	0.44	0.56	.552
ABL (cm)	43.59	5.96	30.90	63.50	13.68	0.52	0.36	.733
PU10s (No)	13.11	1.27	9.00	16.00	9.70	-0.67	0.93	.000
10PullU (s)	13.08	5.03	0.00	26.00	38.45	0.53	0.20	.075
SU30s (s)	30.47	2.90	23.00	36.00	9.53	-0.32	-0.35	.094
IAT (s)	18.30	1.07	16.30	21.14	5.83	0.49	-0.42	.288
TT (s)	12.26	0.92	10.35	15.37	7.47	0.50	0.35	.541
RU10m (s)	1.95	0.12	1.65	2.30	6.35	0.51	0.89	.694
RU20m (s)	3.32	0.19	2.83	3.91	5.62	0.55	1.31	.703
ShRun300 (s)	66.90	3.79	57.70	79.00	5.67	0.51	0.46	.360
CT (m)	2627.06	202.66	2150.00	3150.00	7.71	0.23	-0.03	.787
MFi (score)	63.17	9.06	43.73	94.20	14.34	0.60	0.50	.815
LBMPi (score)	62.12	10.25	41.25	91.02	16.51	0.51	0.14	.377
UBMPi (score)	62.71	9.11	38.48	83.81	14.53	0.09	-0.13	.959
CODi (score)	49.95	16.80	18.03	100.89	33.64	0.51	0.05	.232
SRSi (score)	49.93	16.72	7.21	100.91	33.49	0.52	1.22	.468
REi (score)	50.03	16.70	9.67	91.91	33.38	0.05	0.03	.895
MQPi (score)	50.26	16.48	14.28	91.80	32.79	0.27	-0.28	.924
RAi (score)	49.96	16.81	10.35	107.07	33.64	0.40	0.55	.606
TPPi (score)	63.21	7.88	47.85	87.37	12.47	0.20	-0.17	1.000

SD – Standard Deviation, Min – Minimum, Max – Maximum, cV (%) – Coefficient of Variation (SD / mean * 100), Skew – Skewness, Kurt – Kurtosis, KST –Test. MFi – Musclar Force index, LBMPi – Lower-body Muscular Power index, UBMPi – Upper-body muscular power index, CODi – change of direction speed index, SRSi – Straight Running Speed index, REi – Running Endurance index, MQPi – Muscle Quality and Performance index, RAi – Running Ability index, TPPi – Total Physical Performance index.

6.2 ASSOCIATIONS OF BODY COMPOSITION WITH PHYSICAL ABILITIES AND PHYSICAL PERFORMANCE

6.2.1 Sample No 1 – Correlations

Correlation analyses revealed multiple associations between the body composition measures and physical fitness tests and EPFS (Table 7). Five out of six variables significantly correlated with RUN, PU, SU and EPFS. Indicators of ballast as well as contractile tissue significantly correlated with executed number of PU and SU. Moreover, the EPFS was also associated to both, fat and muscle indices of body composition.

Table 7. Pearson's correlations coefficients.

Variables	RUN (sec)	PU (No)	SU (No)	EPFS (Index unit)
BMI (kg/m^2)	.263**	-.100	-.084	-.136
PBF (%)	.393**	-.512**	-.429**	-.527**
PSMM (%)	-.358**	.504**	.421**	.514**
BFMI (kg/m^2)	.424**	-.460**	-.395**	-.490**
SMMI (kg/m^2)	-.080	.341**	.308**	.329**
IH (Index unit)	.311**	-.514**	-.435**	-.517**

*Significant at $p < 0.05$, **Significant at $p < 0.01$

6.2.2 Sample No 2 – T-test

The t-test analysis revealed significant differences in body composition and measures of COD (IAT) between the FPO and FPC (Table 8). Since the body compositions of FPO (i.e. more fatty) and FPC (i.e. more muscular) were different, with a similar within-group body composition consistency, the variations in IAT could be more reliably based on the body characteristics of these two groups. This suggests a higher validity of the utility of the chosen body composition indices.

Table 8. Independent sample t-test results for female police officers and female police cadets.

Variables	t	df	p	MD	SED	95% CID	
						Lower	Upper
BH (cm)	-5.17	44.0	.001	-8.44	1.63	-11.74	-5.15
BMI (kg/m²)	3.49	44.0	.001	4.38	1.26	1.85	6.91
BFMI (kg/m²)	5.02	42.5	.000	4.38	.87	2.62	6.14
SMMI (kg/m²)	-0.53	44.0	.602	-.19	.37	-.93	.54
PBF (%)	5.23	44.0	.000	11.66	2.23	7.17	16.16
PSMM (%)	-5.70	44.0	.000	-7.02	1.23	-9.50	-4.54
IH (Index unit)	3.72	44.0	.001	.25	.07	.11	.39
IAT (s)	1.57	41.8	.124	.96	.61	-.27	2.19

MD – Mean Difference, SED – Standard Error of the Difference, CID – Confidence Interval.

6.2.3 Sample No 3 – Correlations

The correlations between the indices of maximal strength, power, muscular endurance, agility and aerobic endurance and indices of body composition were significant in 114 male police cadets (Table 9). Moreover, all physical performance indexes significantly correlated to body composition indexes. The IH correlated to all physical abilities and performance measures, except to TPPi, while BFMI, PBF and PSMM did not significantly correlate to only DLFmax, BP1RM, and TPPi.

Table 9. Correlations between physical abilities and body composition in male police cadets.

Variables	BMI	SMMI	BFMI	PBF	PSMM	IH
DLFmax (DN)	.388**	.535**	.056	-.056	.117	-.205*
BP1RM (kg)	.478**	.647**	.073	-.054	.112	-.228*
MFi (score)	.501**	.666**	.097	-.034	.101	-.212*
SLJ (cm)	-.101	.223*	-.398**	-.451**	.477**	-.500**
ABL (cm)	-.194*	.144	-.466**	-.514**	.530**	-.547**
LBMPi (score)	-.169	.195*	-.479**	-.535**	.557**	-.579**
RU10m (s)	.125	-.109	.313**	.339**	-.361**	.354**
RU20m (s)	.135	-.154	.376**	.409**	-.435**	.431**
SRSi (score)	.133	-.134	.351**	.381**	-.406**	.400**
PU10s (s)	.047	.284**	-.236*	-.294**	.312**	-.356**
10PullU (s)	-.161	.110	-.399**	-.423**	.414**	-.434**
SU30s (s)	.077	.235*	-.125	-.177	.198*	-.233*
UBMPi (score)	-.022	.262**	-.328**	-.384**	.397**	-.438**
IAT (s)	.089	-.080	.220*	.240*	-.256**	.259**
TT (s)	-.013	-.237*	.230*	.283**	-.310**	.344**
CODi (score)	.040	-.171	.242**	.282**	-.305**	.325**
ShRun300 (s)	.167	-.074	.349**	.371**	-.383**	.384**
CT (m)	-.298**	-.053	-.429**	-.419**	.415**	-.384**
REi (score)	.263**	-.013	.441**	.447**	-.452**	.435**
MQPi (score)	.125	.480**	-.317**	-.422**	.465**	-.540**
RAi (score)	.170	-.135	.415**	.447**	-.469**	.469**
TPPi (score)	.344**	.371**	.153	.081	-.056	-.019

*Significant at $p < 0.05$, **Significant at $p < 0.01$. MFi – Musclar Force index, LBMPi – Lower-body Muscular Power index, UBMPi – Upper-body muscular power index, CODi – change of direction speed index, SRSi – Straight Running Speed index, REi – Running Endurance index, MQPi – Muscle Quality and Performance index, RAi – Running Ability index, TPPi – Total Physical Performance index.

6.3 PREDICTIONS OF PHYSICAL FITNESS USING BODY COMPOSITION MEASURES

6.3.1 Sample No1 – Regression analysis

The multiple regression analysis extracted two multidimensional best-fit prediction models of police officers' physical fitness (Table 10). The one with the smallest SEE (model 3) included IH, BMI, BFMI, PBF (R^2 = 0.383, F[4,195] = 29.598, p < 0.001, SEE = 12.20). The another model was the simplest model (model 3) of EPFS prediction and included BMI, BFMI and PBF (R^2 = 0.379, F[3,195] = 39.005, p < 0.001, SEE = 12.21). Based on the number of included measures, prediction models were named 4-measure (4M) model and 3-measure (3M) model. The analysis of variance (ANOVA) showed that both models were significant (Table 10). The same SEEs and higher F value of 3M model indicate that the precision and sensitivity of 3M model are higher comparing to 4M model.

Table 10. Prediction models produced by the backward regression analysis.

Model	Predictors	R²	SEE	F	*p*
1		.386	12.24	19.80	*p* < .001
2		.384	12.23	23.65	*p* < .001
3	IH, BMI, BFMI, PBF	.383	12.20	29.60	*p* < .001
4	BMI, BFMI, PBF	.379	12.21	39.00	*p* < .001

SEE – standard error of the estimate. IH – Index of Hypokinesia, BMI – Body Mass Index, BFMI – Body Fat Mass Index, PBF – Percent of Body Fat.

Considering each variable within the models (Table 11), even though the unstandardized coefficient of IH was not significant in 4M model, it seems to contributes to accuracy of prediction model and decreases the error of measurement. All other indices of body composition were significantly involved in predicting EPFS.

Table 11. The coefficients of change for each variable within the models.

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
4M	**(Constant)**	-43.78	23.35		-1.88	.062	-89.83	2.27
	BMI (kg/m²)	4.85	.92	.99	5.25	.000	3.03	6.67
	PBF (%)	4.37	1.40	2.01	3.13	.002	1.61	7.12
	BFMI (kg/m²)	-19.37	3.97	-2.92	-4.87	.000	-27.21	-11.53
	IH (index unit)	-16.94	15.24	-.27	-1.11	.268	-47.00	13.13
3M	**(Constant)**	-48.21	23.02		-2.09	.038	-93.61	-2.81
	BMI (kg/m²)	5.02	.91	1.02	5.51	.000	3.23	6.82
	PBF (%)	3.24	.96	1.49	3.37	.001	1.34	5.14
	BFMI (kg/m²)	-17.60	3.64	-2.66	-4.83	.000	-24.79	-10.42

Dependent Variable: EPFS - estimated physical fitness score.

The regression's coefficients of determination suggest that body composition measures in 4M model explain 38.3% of the variability in EPFS, wherein the majority of the variability (37.9%) is determined by BMI, PBF, and BFMI (Figure 3). Although the R^2 was relatively small, both multidimensional models of prediction indicate that body composition explains the variations in EPFS in 95% of the investigated sample.
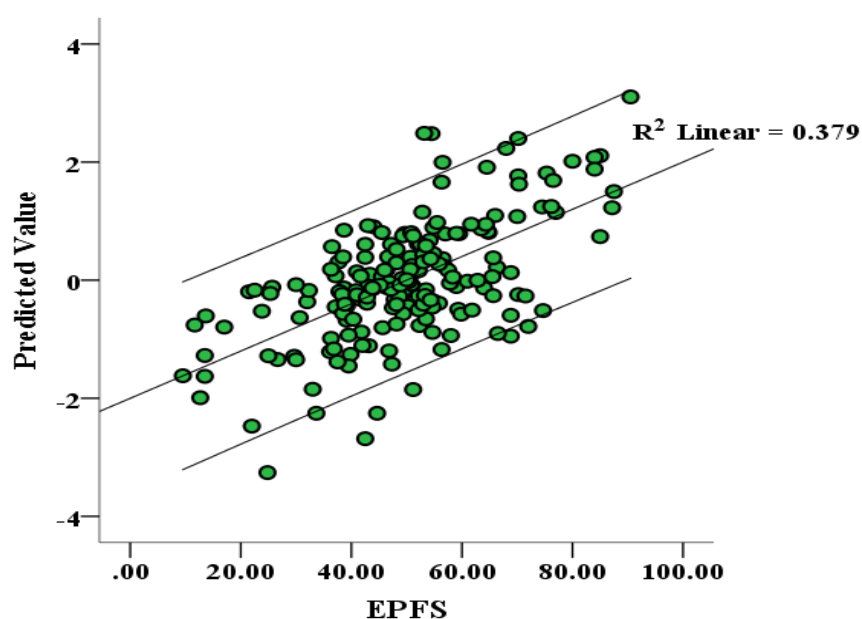
Figure 3. Scatterplot showing the regression line for the 3M model.

6.3.2 Sample No 2 – Regression analyses

A backward regression analysis on FPO and FPC, combined as well as separately, extracted one multidimensional best-fit prediction model for each group (Table 12). The results show that 37.1% of variation in IAT of the whole sample can be explained by the differences in body composition. When analysed partially, the performance of IAT among FPO was influenced in higher degree (41%) and more significantly, comparing to FPC (31.5%). Moreover, the difference in IAT among FPO occurred solely based on differences in PBF, while differences among FPC are associated to differences in PSMM.

Table 12. Prediction models for IAT for FPO and FPC combined and partial prediction model for each group.

Model	Predictors	R²	SEE	F	Sig.
Combined	SMMI, BFMI	.371	1.84	12.70	$p < .001$
FPO	PBF	.420	2.07	18.11	$p < .001$
FPC	BMI, PSMM	.315	1.27	3.67	$p = .049$

SEE – Standard Error of the Estimate. SMMI – Skeletal Muscle Mass Index, PBF – Percent of Body Fat, BFMI – Body Fat Mass Index, PSMM – Percent of Skeletal Muscle Mass, BMI – Body Mass Index.

The variables for each model (Table 13) showed that in general, body size-independent measures of fatness and muscularity are the most significant for performance of IAT. However, when analysed in a more specific group such as FPO and FPC, a relative volume of ballast or active tissue seems to be responsible for the differences in IAT performance. In that regard, IAT performance of selected group of FPC, whose body composition and physical abilities were similar, was the least associated to body composition. Scatterplots for each prediction model is presented graphically in Figures 4 – 6.

Table 13. Coefficient of determination for each prediction model of IAT.

Model	Predictors	Unstandardized Coefficients		Standardized Coefficients	t	p	95.0% Confidence Interval for B	
		B	SE	Beta			Lover Bound	Upper Bound
Combined	(Constant)	25.23	2.129		11.85	.000	20.94	29.53
	BFMI	.35	.073	.595	4.82	.000	.21	.50
	SMMI	-.57	.232	-.304	-2.46	.018	-1.04	-.11
FPO	(Constant)	15.83	1.783		8.88	.000	12.16	19.50
	PBF	.21	.048	.648	4.26	.000	.11	.30
FPC	(Constant)	35.48	4.887		7.26	.000	25.12	45.84
	BMI	-.14	.086	-.363	-1.67	.114	-.33	.04
	PSMM	-.24	.094	-.549	-2.53	.022	-.44	-.04
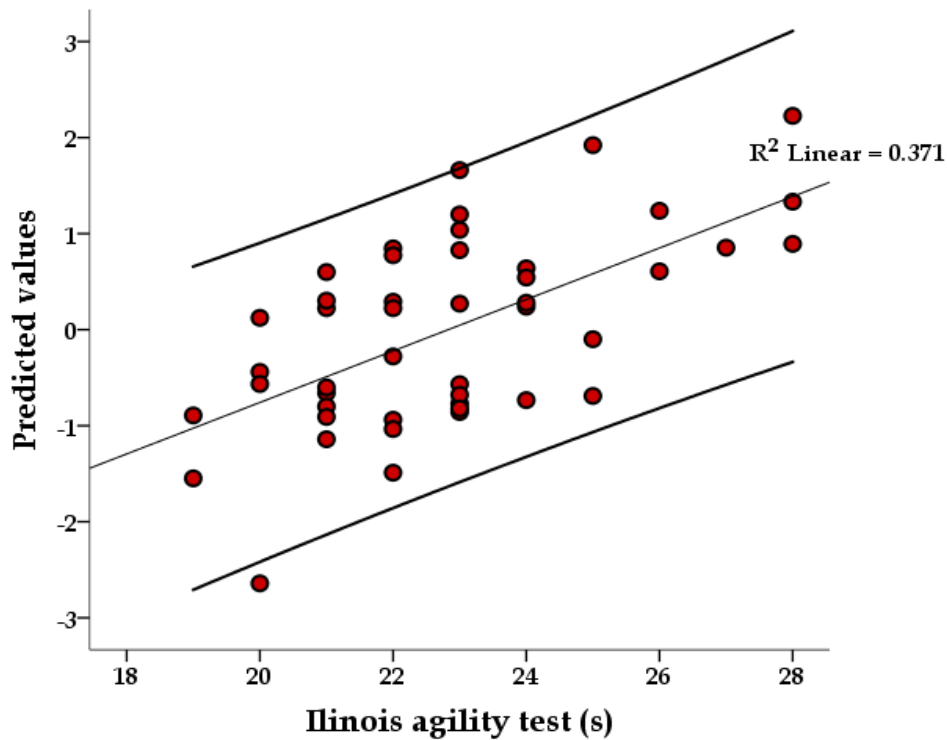
Figure 4. Scatterplot showing the regression line for the combined sample of FPO and FPC.
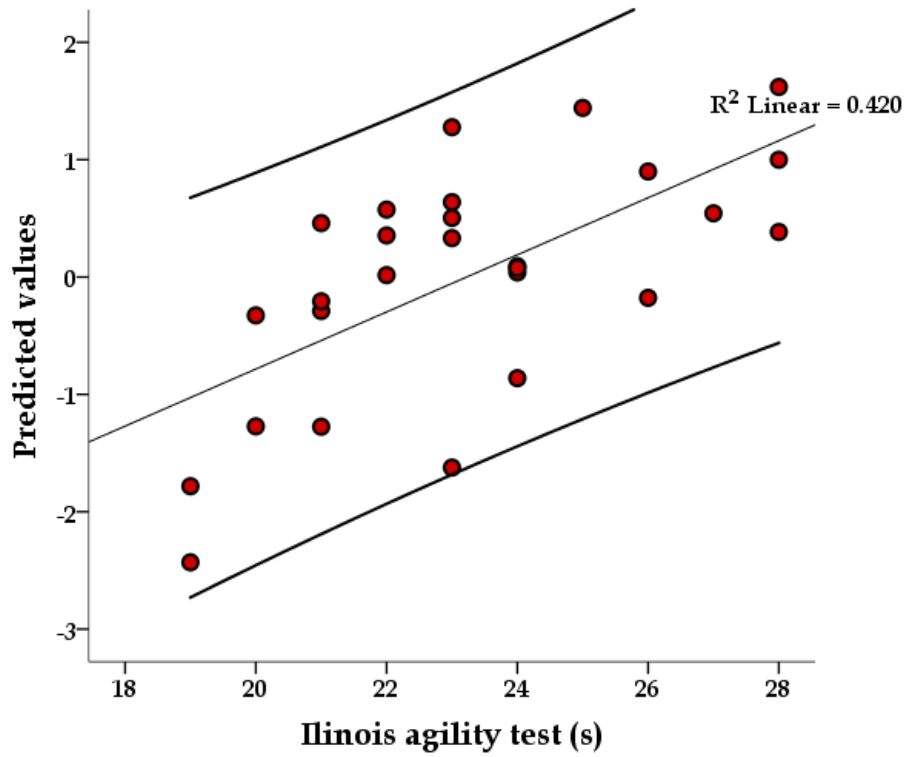
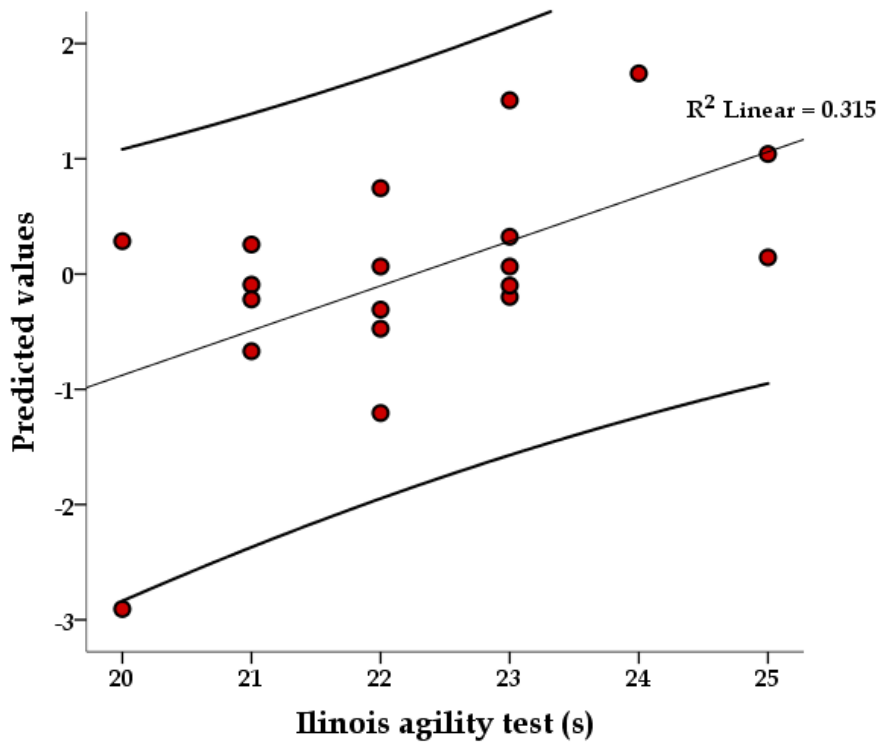**Figure 5**. Scatterplot showing the regression line for the sample of FPO.

Figure 6. Scatterplot showing the regression line for the sample of FPC.

6.3.3 Sample No 3 – Regression analyses

When it comes to various performance indexes of MPC, a multiple regression analysis with backward model extracted one or two models of prediction depending on the performance index that was predicted (Table 14). The simplest was at the same time the model with the lowest SEE in predicting MFI, CODi and REi. Two prediction models were extracted for the LBMPi, UBMPi, SRSi, MQPi, RAi and TPPi but the simplest models were having higher F values, which indicates higher sensitivity of the model. Therefore, a simpler, more sensitive model was analysed. Regardless of which index was analysed, the significance was high (p < 0.001), while R^2 ranged between 0.175 (SRSi) and 0.444 (MFi). The coefficients of change for each prediction model is presented in Table 15.

Table 14. Prediction models for physical abilities and performance measures of MPC.

Model	Predictors	R^2	SEE	ANOVA	
				F	*p*
MFi	SMMI	.444	6.78	89.47	*p* < .001
LBMPi1	BMI, BFMI, SMMI, PBF, PSMM, IH	.398	8.18	11.78	*p* < .001
LBMPi2	BMI, IH, SMMI, PBF, PSMM	.387	8.21	13.61	*p* < .001
UBMPi1	SMMI, BFMI, PSMM	.234	8.09	11.18	*p* < .001
UPMPi2	SMMI, BFMI	.225	8.09	16.14	*p* < .001
CODi	BMI, SMMI, PBF, PSMM, IH	.193	15.45	5.15	*p* < .001
SRSi1	BFMI, PBF, PSMM, IH	.198	15.24	6.74	*p* < .001
SRSi2	BFMI, PBF, IH	.182	15.33	8.16	*p* < .001
REi	BFMI, PBF, IH	.283	14.33	14.47	*p* < .001
MQPi1	BFMI, SMMI, PBF, IH	.433	12.64	20.78	*p* < .001
MQPi2	IH, SMMI	.422	12.65	40.45	*p* < .001
RAi1	BFMI, SMMI, PBF, IH	.299	14.39	9.23	*p* < .001
RAi2	BFMI, PBF, IH	.286	14.39	14.7	*p* < .001
TPPi1	BFMI, SMMI, PBF, PSMM, IH	.193	7.24	5.17	*p* < .001
TPPi2	IH, SMMI, BFMI, PBF	.175	7.29	5.77	*p* < .001

SEE – Standard Error of the Estimate, SMMI – Skeletal Muscle Mass Index, BMI – Body Mass Index, PBF – Percent of Body Fat, PSMM – Percent of Skeletal Muscle Mass, BFMI – Body Fat Mass Index, IH – Index of Hypokinesia. MFi – Muscle Force index, LBMPi – Lower-body Muscle Power index, UBMPi – Upper-body muscular power index, CODi – Change of direction speed index, SRSi – Straight Running Speed index, REi – Running Endurance index, MQPi – Muscle Quality index, RAi – Running Ability index, TPPi – Total Physical Performance index.

Table 15. Coefficients of change for each variable within the model.

Model	Predictors	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Err	Beta			Lower Bound	Upper Bound
MFi	Constant	-10.77	7.84		-1.37	.172	-26.31	4.77
	SMMI	6.14	0.65	0.67	9.46	.000	4.85	7.42
LBMPi	Constant	1233.89	474.83		2.60	.011	292.70	2175.08
	BMI	-50.83	18.22	-11.83	-2.79	.006	-86.96	-14.71
	SMMI	84.88	30.72	8.14	2.76	.007	23.99	145.77
	PBF	17.69	6.10	7.97	2.90	.004	5.61	29.78
	PSMM	-19.10	8.04	-5.12	-2.37	.019	-35.05	-3.16
	IH	-447.63	148.35	-6.76	-3.02	.003	-741.70	-153.57
UBMPi	Constant	33.08	9.36		3.53	.001	14.53	51.62
	SMMI	3.26	0.79	0.35	4.11	.000	1.69	4.84
	BFMI	-2.58	0.54	-0.41	-4.74	.000	-3.66	-1.50
CODi	Constant	-2420.97	892.79		-2.71	.008	-4190.64	-651.31
	BMI	107.29	34.27	15.23	3.13	.002	39.37	175.21
	SMMI	-180.14	57.76	-10.54	-3.12	.002	-294.62	-65.66
	PBF	-36.65	11.47	-10.07	-3.20	.002	-59.38	-13.93
	PSMM	40.98	15.13	6.70	2.71	.008	11.00	70.97
	IH	889.23	278.94	8.20	3.19	.002	336.32	1442.14
SRSi	Constant	22.44	6.18		3.63	.000	10.20	34.68
	BFMI	50.60	29.62	4.34	1.71	.090	-8.10	109.30
	PBF	-26.24	15.38	-7.25	-1.71	.091	-56.71	4.23
	IH	383.45	200.99	3.55	1.91	.059	-14.85	781.76
REi	Constant	21.37	5.78		3.70	.000	9.92	32.81
	BFMI	98.45	27.70	8.46	3.55	.001	43.56	153.34
	PBF	-49.68	14.38	-13.74	-3.46	.001	-78.17	-21.18
	IH	669.43	187.94	6.21	3.56	.001	296.97	1041.89
MQPi	Constant	3.61	16.82		0.21	.830	-29.73	36.95
	SMMI	6.23	1.25	0.37	4.99	.000	3.76	8.70
	IH	-47.88	7.91	-0.45	-6.05	.000	-63.56	-32.20
RAi	Constant	16.55	5.80		2.85	.005	5.05	28.04
	BFMI	88.83	27.81	7.58	3.19	.002	33.71	143.95
	PBF	-46.04	14.44	-12.65	-3.19	.002	-74.65	-17.43
	IH	647.27	188.73	5.97	3.43	.001	273.25	1021.29
TPPi	Constant	3.36	25.75		0.13	.896	-47.68	54.40
	SMMI	4.44	1.79	0.55	2.48	.015	0.90	7.98
	BFMI	29.28	14.50	5.33	2.02	.046	0.54	58.03
	PBF	-16.06	7.87	-9.41	-2.04	.044	-31.67	-0.46
	IH	227.71	111.92	4.48	2.03	.044	5.88	449.54

The regression lines and belonging confidence intervals are presented on Figures 7 – 15, showing that 18.2 – 44.4% of the variance in multidimensional indexes of physical performance corresponds to differences in body composition of MPC.
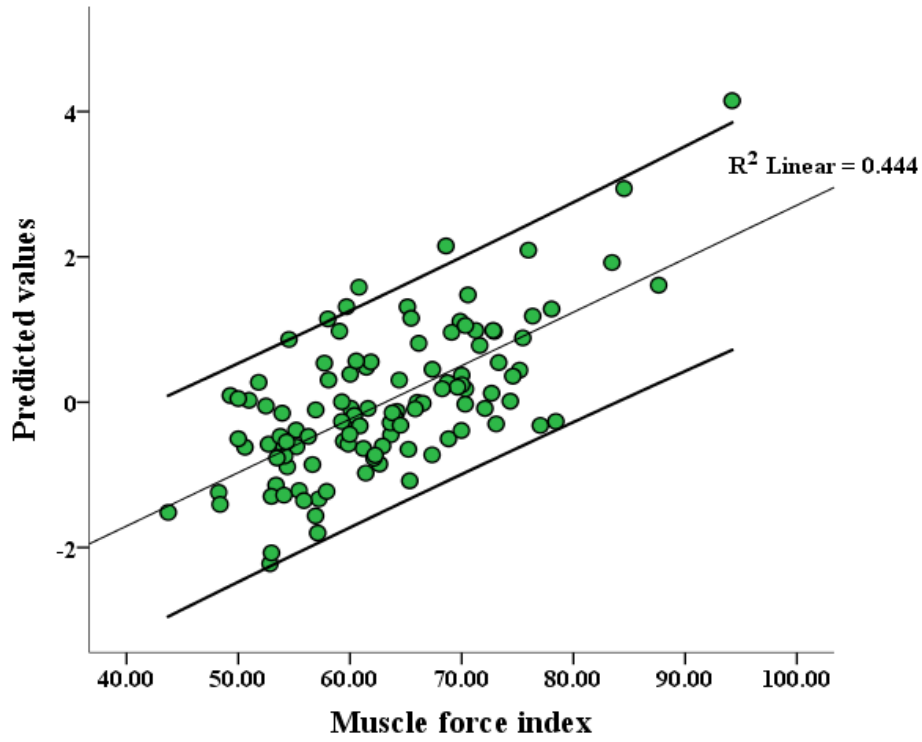
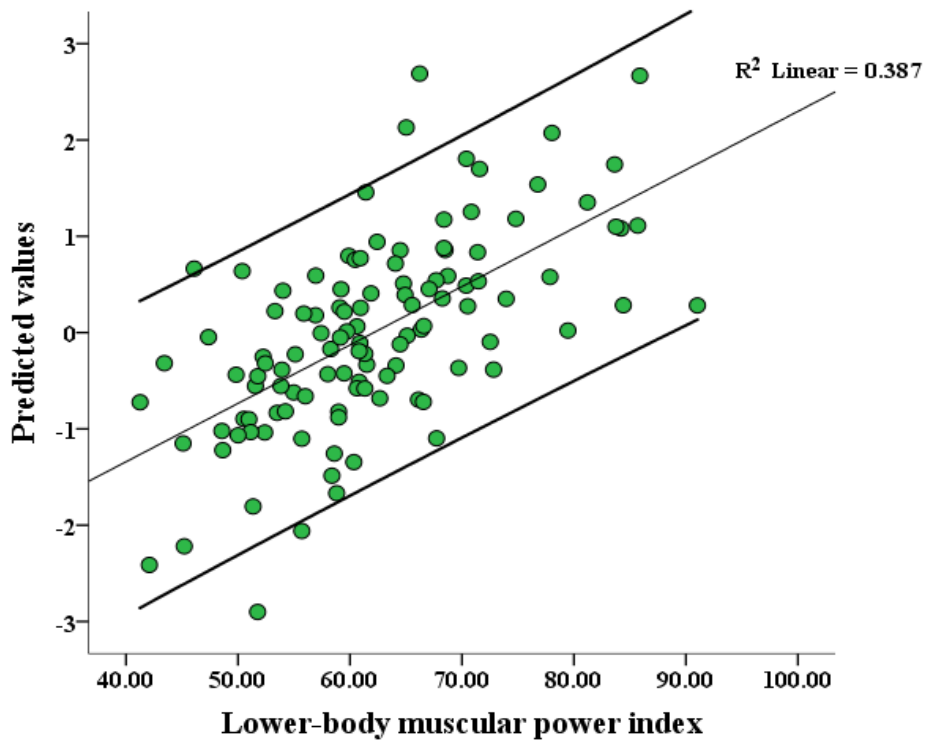**Figure 7.** Scatterplot for prediction of MFi of MPC.

Figure 8. Scatterplot for prediction of LBMPi of MPC.
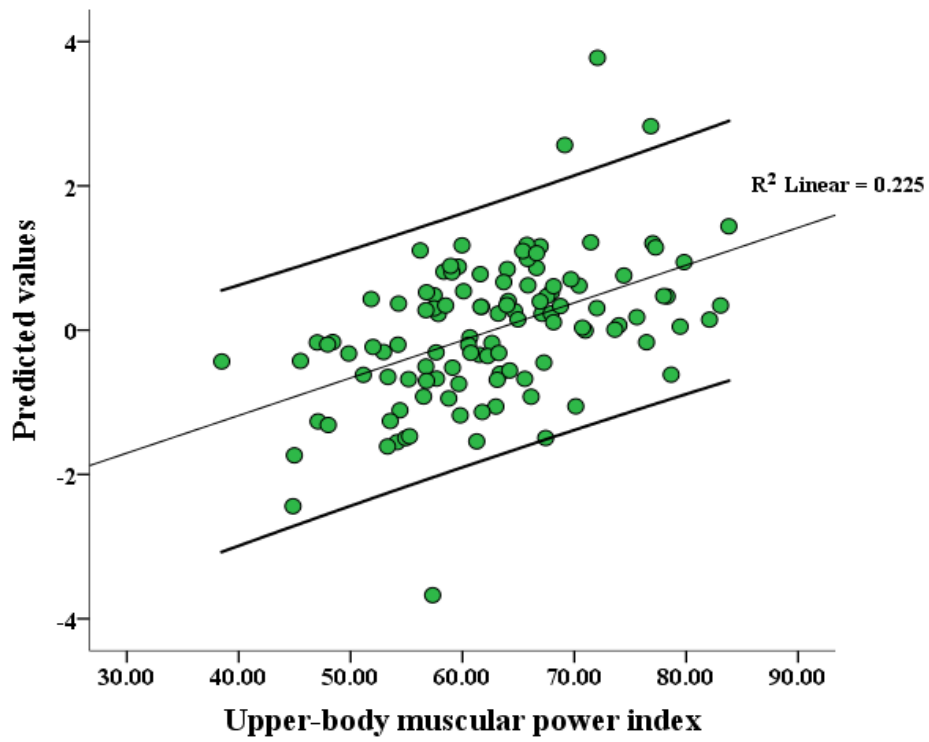
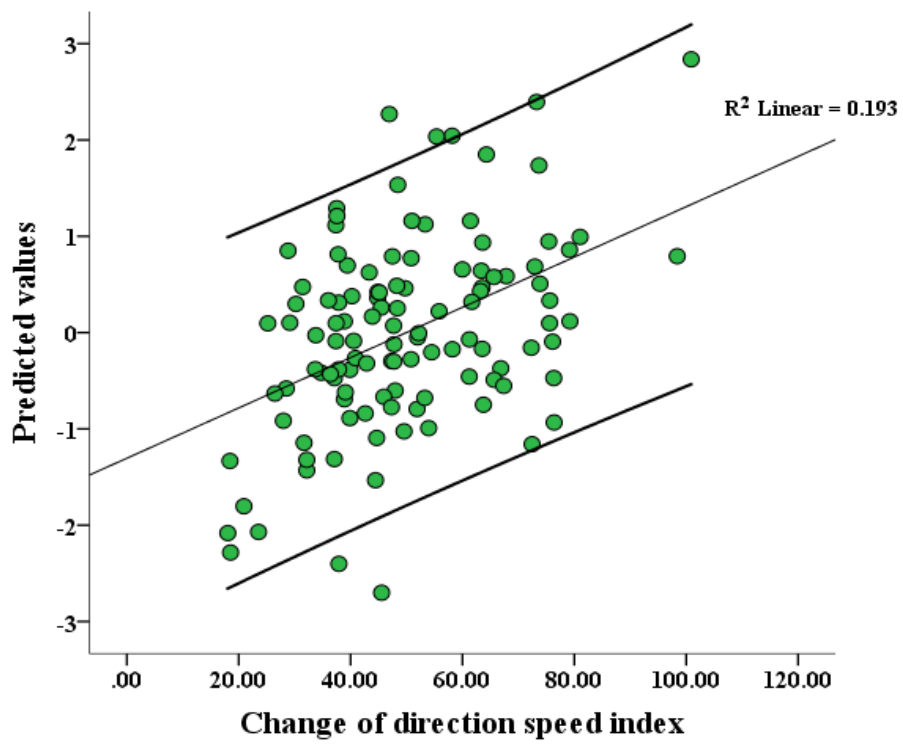**Figure 9.** Scatterplot for prediction of UBMPi of MPC.

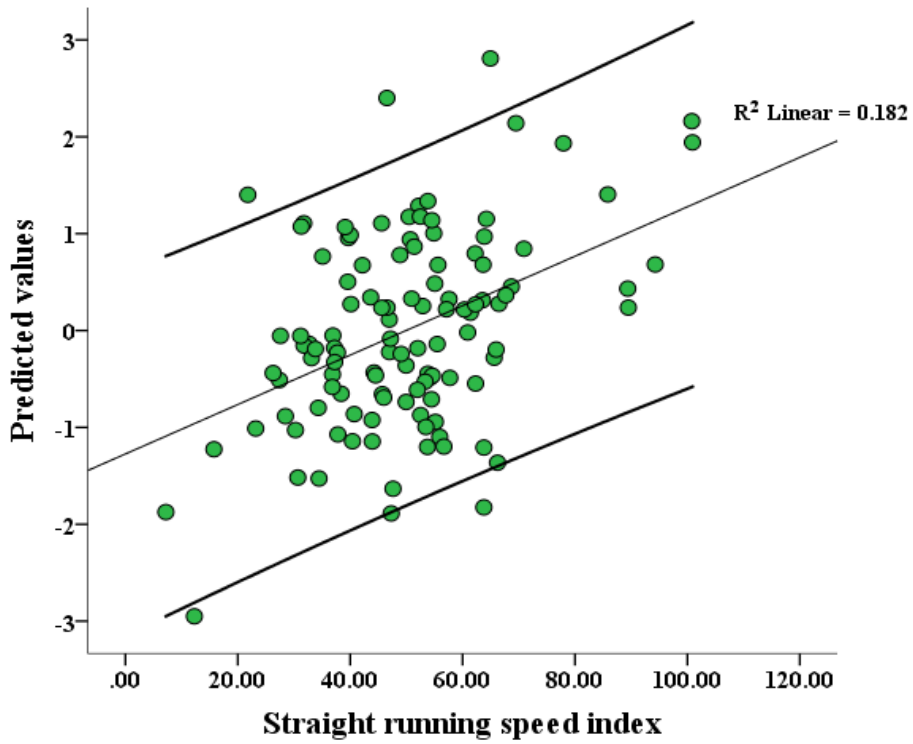**Figure 10.** Scatterplot for prediction of CODi of MPC.

Figure 11. Scatterplot for prediction of SRSi of MPC.
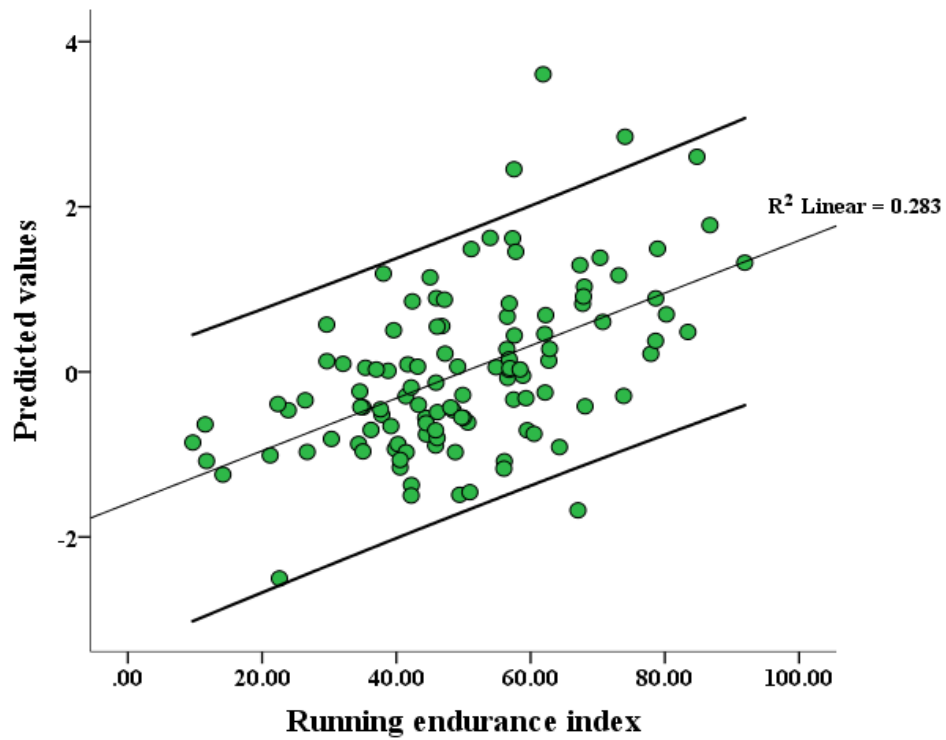

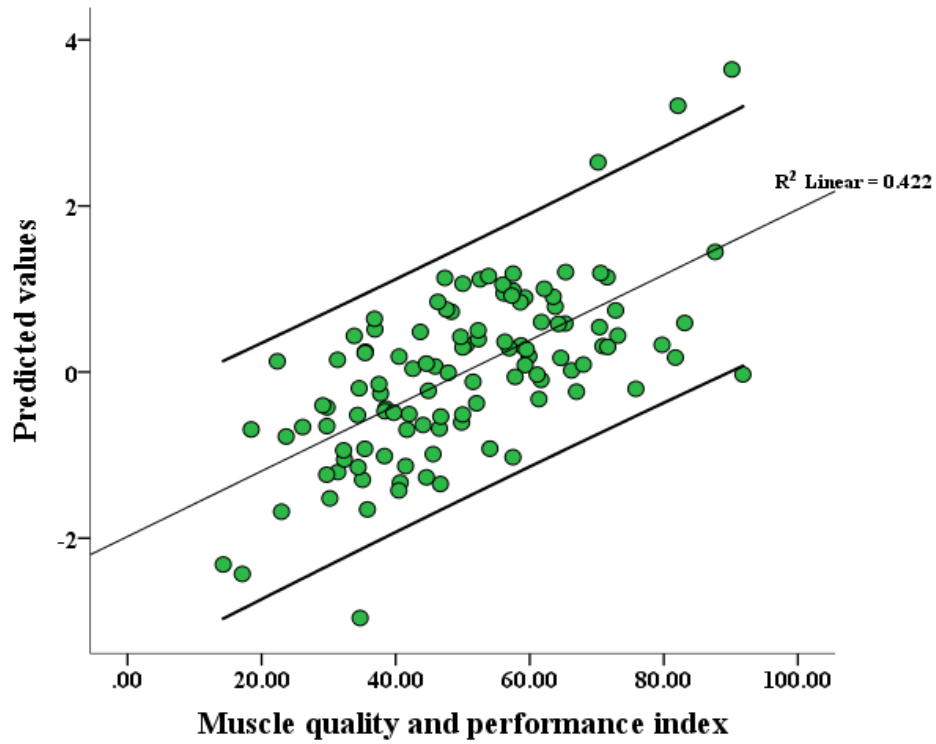**Figure 12.** Scatterplot for prediction of REi of MPC.

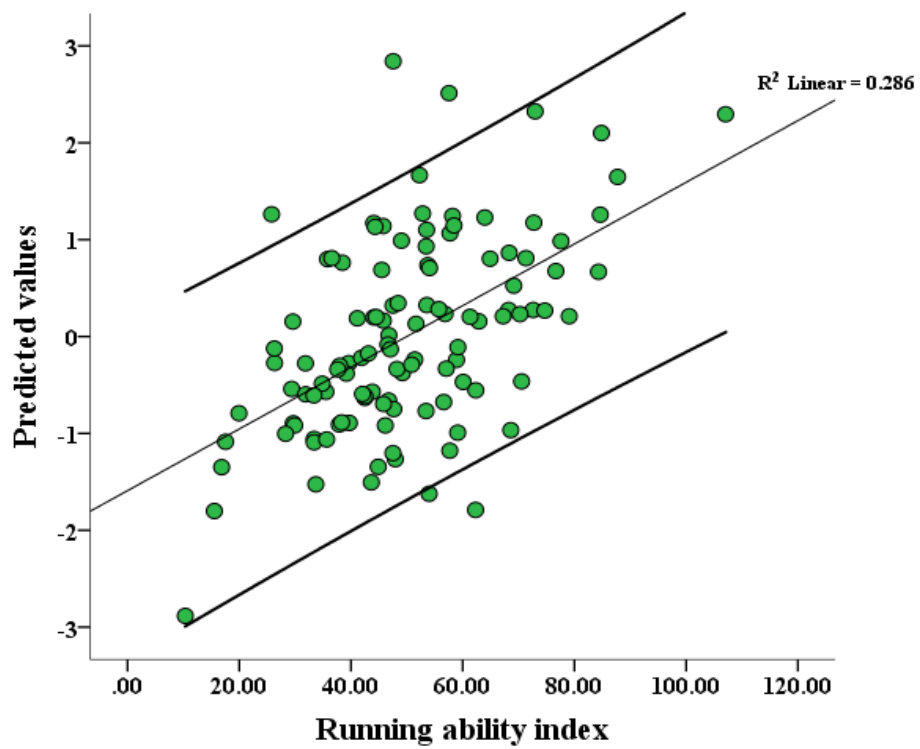**Figure 13.** Scatterplot for prediction of MQPi of MPC.

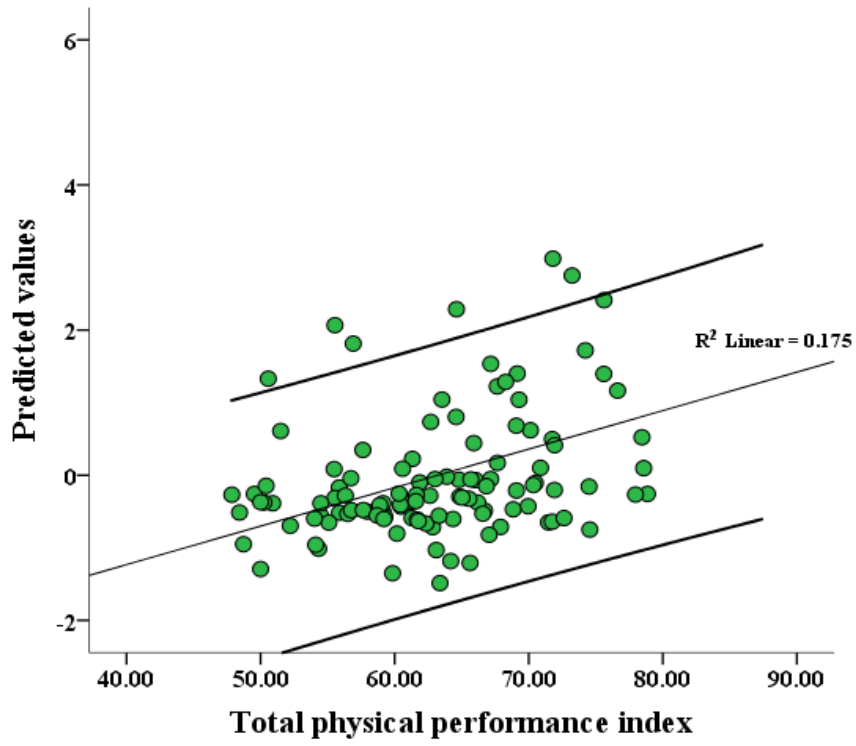**Figure 14.** Scatterplot for prediction of RAi of MPC.

Figure 15. Scatterplot for prediction of TPPi of MPC.

7. DISCUSSION

There were two main purposes of this dissertation: 1) to investigate the associations of novel index variables of body composition with common measures of physical fitness, 2) to investigate the possibility of predicting police officers' physical fitness using the index variables of body composition. Establishing the model of detecting the deficits in physical fitness by using body composition characteristics may be useful when the ability to perform a full fitness testing battery is not practical or feasible. This would be a non-invasive physical fitness-monitoring tool that could be used any time, regardless of fitness level, weather conditions or accessibility of testers.

Based on the purposes, the aims of this study were to determine the associations between the chosen index values of body composition and measures of physical fitness among police officers; to determine the possibility of predicting police officers' physical fitness by using these indices; and to determine whether the chosen body composition indexes as well as the approach to the study are valid. Therefore, the **Hg** was that it is possible to define a prediction model of physical fitness based on body composition characteristics of police officers. To reach the Hg, supporting hypotheses were: **H_1**) there will be a significant association between the characteristics of body muscularity, expressed as indexed calculation and physical performance; **H_2**) there will be a significant association between the characteristics of body fatness, expressed as indexed calculation and physical performance; **H_3**) there will be a significant internal and construct validity of chosen body composition indexes; **H_4**) there will be a significant causal relationship between body composition characteristics and individual physical ability.

7.1 ASSOCIATION BETWEEN BODY COMPOSITION AND PHYSICAL PERFORMANCE

According to the results, the main findings of this study suggest a small to moderate, but significant, inverse association of contractile and ballast tissue of body composition with investigated physical abilities, performance measures and performance indexes. The results of correlation analysis suggest that the body composition indexes have a specific effect on muscular force, muscular power, muscular endurance, aerobic endurance, COD, and various performance indexes. Moreover, indices of body muscularity and body fatness both were causally associated with physical fitness measures as well as with multidimensional performance indexes.

7.1.1 Correlations between body composition and muscular force and strength

The results of correlation analyses of the third sample showed that the DLFmax and BP1RM, strongly correlated ($p < .01$) with SMMI and moderately ($p < .01$) with BMI, while correlation was small ($p < .05$) with IH. This strongly suggest that when the requirement is an expression of the maximal muscular force, MPC who possess more muscle mass on each m^2 of their body size are more likely to produce higher forces. Although the main characteristic of skeletal muscles is the ability to contract and produce force (Blagojevic et al., 2016, p. 135; Nedeljković, 2016, p. 1), numerous differences related to dynamic and kinematic properties of DLFmax and BP1RM could affect the force production in these two tests. Therefore, the correlations between the BMI and SMMI and these two tests were slightly different between the tests. However, the quality of the muscle (SMMI) strongly correlated to both, maximal muscular force (DLFmax) and maximal muscular strength (BP1RM). Namely, 53.5% and 64.7% of the variance in DLFmax and BP1RM was explained by the differences

in SMMI. A small correlation between the IH and these tests further suggests that even when the task does not require from a person to overcome the weight of ballast tissue such as fat mass, the advances in PSMM over PBF significantly contribute to maximal muscular force and strength. However, only 20.5% and 22.8% of the variance in maximal muscular force and strength can be explained by the rule: the bigger the BMI based on PSMM, the higher are force and strength production of MPC. Since DLFmax and BP1RM test the maximal muscular force in static and dynamic conditions, an index of muscular force (MFi) was built combining these two conditions into one indicator of overall ability to express the force and strength. The correlation between the MFi and BMI, SMMI and IH indicate that the multifactorial space of muscular force production and its manifestation in a large measure depend on muscle quality. The variations in MFi were explained by the between-subject differences in BMI (50.1%), SMMI (66.6%) and IH (24.2%). This strongly suggests that MPC who have better muscle quality and lower share of PBF within the BMI, perform better in activities that require maximal muscle activation in either isometric or dynamic conditions.

The tasks performed by police officers may include carrying shields, arresting belligerents, crawl and drag, carry oxygen and fire hose or axe while climbing ladders or stairs, lifting and carrying. In that regard, studies showed a positive association between the measures of muscularity and muscle force and strength (Dawes et al., 2016; Dawes et al., 2017; Vaara et al., 2012; Winwood et al., 2012). Therefore, police agencies often use tests to estimate muscle strength, either statically or dynamically (Anderson & Plecas, 2000; Thomas et al., 2014; Dawes et al., 2017). For example, Dawes et al. (2017) found that handgrip strength and leg/back chain dynamometer strength (tests of maximal muscular force) significantly correlated to a specific physical ability test (physical agility course) of police officeres. Anderson & Plecas (2000) found that the handgun marksmanship is significantly associated with grip strength ($r = .38$) and forearm girth ($r = .28$) of the dominant hand. Furthermore, Dillern et al. (2014)

found a significant positive correlation between the physical ability index (bench press, hangs-up, standing long jump and 3000-m run) and arrest index (2 taekwondo and 2 self-defence tests), whereby bench press and hang-up test explained the most of the variance in physical ability index. These studies indicate the importance of maximal muscular force and strength for the occupational performance of police officers.

On the other hand, studies have shown that maximal strength and force depend on the development of muscle mass (Vaara et al., 2012; Windwood et al., 2012). When conducted the study on young Finnish men, Vaara et al. (2012) found that fat-free mass (kg) significantly ($p < .001$) correlated to maximal isometric leg extension, ($r = .36$), bench press ($r = .39$), and grip strength ($r = .44$), as well as with maximal strength index ($r = .52$). Windwood et al. (2012) investigated the associations between the maximal strength measures of novice strongman athletes and their body composition and found the correlations similar to the of this dissertation. They found that SMM correlated to 1 RM bench press ($r = .59$), squat ($r = .55$), dead lift ($r = .29$), power clean ($r = .50$), and system force ($r = .71$). The results from these two studies reinforce the construct and external validity of this dissertation as the correlations were higher when the maximal strength was measured in dynamic conditions, which was the case in this dissertation as well. This gives a clearer insight into why the measures of muscularity should be considered in evaluating, especially those officers whose occupational success in a large measure depends on muscular force and strength.

7.1.2 Correlations between body composition and muscular power

Multiple correlations occurred between the body composition and muscular power. Considering the lower-body muscular power (SLJ, ABL, RUN10m and RUN20m) and body size-independent indexes of body composition, a SMMI correlated ($p < .05$) only with SLJ. In contrast, BFMI

correlated ($p <$ .01) moderately with SLJ, ABL, RUN10m and RUN20m. However, considering the relative volume of fat mass and muscle mass, PBF and PSMM correlated moderately with SLJ, RU10m and RU20m, while correlations with ABL were large. Consequently, the correlations between the IH and SLJ and ABL were large, while correlations between the IH and RU10m and RU20m were medium. These results indicate that the amount of ballast tissue per each m^2 of body size moderately affect the lower-body muscular power, while the volumes of contractile (PSMM) and ballast bodily tissues (PBF) affect it strongly. Moreover, the ratio of PSMM and PBF relative to BMI (IH) affects the power of legs the most. Namely, 22.3% of the variance in between-subject differences can be explained by SMMI only in SLJ, while other indices of lower body muscular power did not share a significant amount of variance with SMMI. In contrast, the BFMI explained 39.8%, 46.6%, 31.3% and 37.6% of the between-subject variances in SLJ, ABL, RU10m and RU20m, respectively. Considering the volumes of muscular and fat tissue, the variances in SLJ, ABL, RU10m and RU20m were explained 45.1%, 51.4%, 33.9% and 40.9% by PBF, and 47.7%, 53%, 36.1% and 43.5% by PSMM, respectively. However, the IH shared 50%, 54.7%, 35.4%, and 43.1% of the common variance with SLJ, ABL, RU10m and RU20m, respectively. Note that neither body size-independent nor volume-independent indices of body composition correlated to SLJ and ABL better than the IH. Moreover, IH correlated to RU10m and RU20m better than the SMMI, BFMI and PBF.

The difference between the SLJ and ABL reflects in the direction of force production. The ABL is a vertical jump and when conducted on a force platform (i.e. measure vertical and horizontal force), only the vertical force occurs. The SLJ requires a person to jump forward as far as possible. Based on a third Newton's law of action and reaction, one must apply the force in vertical and horizontal plane in order to jump forward. Therefore, the redundancy of muscle activation and force production is normally higher in SLJ than it is in ABL. Moreover, the coordination in SLJ is more complex, which further

increases the redundancy of neural signal and lowers the transfer of physical ability to performance. For that reason, an index of lower-body muscular power (LBMPi) was built to present the overall jumping ability of MPC. Comparing to SLJ and ABL, the LBMPi correlated lower with SMMI, but stronger with BFMI, PBF, PSMM and IH. The overall jumping ability of MPC was 57.9% explained by the IH, 55.7% by the PSMM, 53.5% by the PBF and 47.9% by the BFMI.

Since RU10m and RU20m are tests of anaerobic a-lactic power but at the same time different in dynamic, kinematic and kinetic from jumping tests, the index of straight running speed (SRSi) has been built. The correlations between the SRSi and body composition indexes were lower than between the LBMPi and these indexes, with 35.1%, 38.1%, 40.6% and 40% of the variance in SRSi being explained by BFMI, PBF, PSMM and IH, respectively. The discrepancy between the LBMPi and SRSi may be based on the aforementioned differences between the tests entering these performance indexes. For example, SLJ and ABL consist of one maximal jump that lasts less than a second, while RU10m and RU20m last longer and consist of several repeated movements. Moreover, both jumping tests required bilateral lower-body movements, while running tests requires alternated unilateral movement of high precision. This may cause an increase in complexity of the movement, which may affect the magnitude of correlation.

Considering the upper-body muscular power (PU10s, 10PullU and SU30s), SMMI correlated to PU10s ($p < .01$) and SU30s ($p < .05$), while BFMI correlated to PU10s ($p < .05$) and 10PullU ($p < .01$). Furthermore, PBF was associated ($p < .01$) with PU10s and 10PullU, while PSMM and IH were associated with all three tests for upper-body muscular power. The PU10s was conducted for 10 seconds and MPC completed in average 13.11 push-ups, while the average time to complete 10 pull-ups was 13.08 seconds. Thus, energetically PU10s and 10PullU tested the same ability – anaerobic a-lactate power. However, during the push-ups the coefficient of body weight that needs to be lifted is about 0.64 ± 0.04 (Ebben et al., 2011), comparing to pull-ups where the

weight of the whole body needs to be lifted. Therefore, a pull-up exercise requires higher engagement of the musculature, which may be the reason why body composition was more associated with 10PullU than with PU10s. The associations were even lower in SU30s where the coefficient of lifted body weight was lower and the duration was 30 seconds. Namely, 28.4% and 23.5% of the variance in PU10s and SU30s can be explained by the differences in SMMI, while 23.6% and 39.9% of the variance in PU10s and 10PullU can be explained by BFMI. Similar to lower-body power, volumes of fat and muscle tissue explained higher amount of common variance with performance than the body size-independent indexes. In that regard, 31.2%, 41.4% and 19.8% of variations in PU10s, 10PullU and SU30s can be explained by PSMM, respectively. In contrast, 29.4% and 42.3% of variation in PU10s and 10PullU can be explained by PBF. The shared variances are even higher when the PBF is adjusted to BMI because in that case 35.6%, 43.3% and 23.3% of the variance in PU10s, 10PullU and SU30s can be explained by the differences in IH, respectively.

To consolidate this multifactorial space, performances in upper-body muscular power tests were merged into an index of upper-body muscular power (UBMPi). All tests require the repetitive lifting of body weight, whereby the coefficient of the weight that needed to be moved is different. Moreover, muscle groups involved are different as well as the durations of the tests. Therefore, the UBMPi reflects an overall anaerobic power of upper body. The correlations between the UBMPi and body composition indices additionally reinforce the effects that certain body components may have on powerful repetitive performance of upper-body muscles. In that regard, 26.2%, 32.8%, 38.4% and 39.7% and 43.8% of the variance in UBMPi can be explained by the differences in SMMI, BFMI, PBF, PSMM and IH, respectively. Note that the IH correlated to UBMPi more than to other upper-body muscular power tests, indicating moderate construct and internal validity of building the indexes of body composition and physical performance.

The difference in correlation coefficients between the SMMI and BFMI could be due to higher cV% in BFMI. This means that the subjects were not disperse in SMMI, hence contractile potential was similar between them, while their body composition varied in ballast mass. In other words, MPC of the similar movement potential (engine) had to overcome different bodies (chassis), whereby increased amount of fat tissue negatively affects the outcome of maximal muscular effort of legs against the body weight. However, note that the correlation, although similar, was higher in ABL than in SLJ, RU10m and RU20m. Moreover, correlation in 10PullU was higher than in PU10s and SU30s. The explanation could be partially based on the form of the tests, because ABL and 10PullU were the only tests in purely vertical direction and technically less complex. The other lower-body power tests had a horizontal component and were more complex, while the other upper-body power tests were muscularly less engaging.   In that regard, the strength and consistency of the aforementioned correlations indicate low to moderate validity of body composition indexes. Since the IH contains the measures of body size, body volume, fat and muscular tissue, it seems that the muscular power, depends on the body as a whole, wherein, individually, the PSMM takes the most important role. Therefore, muscular MPC who possess a well-developed muscular system followed by the lower levels of PBF are the ones who are more powerful.

Dawes et al. (2016) investigated associations between the anthropometric characteristics and physical performance of 76 male police officers and found similar correlation coefficients as in this dissertation. Authors found that the PBF negatively correlated ($p < .001$, $r = -.566$) with vertical jump height, while lean mass correlated positively ($p < .001$, $r = .391$). A slightly higher correlation between the PBF and vertical jump in their study could be due to the difference in age and PBF as the mean age of their sample was 39.42 years and mean PBF was 16.89%. This is further supported by Dawes et al. (2017) where authors reported moderate correlation ($p < .001$, $r = -.32$) between the vertical jump and BMI, comparing to small correlation in this dissertation ($p < .05$, $r = -.194$). The

mean age of the subjects of Dawes et al. (2017) was 39.7 years, while more than 50% of the sample had mean BMI of 30.37 ± 3.96 kg/m² and the rest of the sample had a mean BMI of 26.15 ± 2.89 kg/m². This means that more than 50% of the sample were overweight or obese police officers, and therefore fat tissue was prevalent over the muscular tissue. Thus, the performance was more influenced by the ballast weight (chassis) of the fat mass, rather than by the skeletal muscle mass (engine).

7.1.3 Correlations between body composition and muscular endurance

Upper-body muscular endurance (estimated from PU and SU test) was associated to both, fat mass indices and muscle mass indices, especially in PU test. Moderate to large correlations occurred between the body composition indices and PU and SU. Body volume and body size-independent fat measures, PBF, BFMI, and IH were negatively associated with PU by explaining 51.2%, 46% and 51.4% of the common variance, respectively. Conversely, indicators of contractile tissue such as PSMM and SMMI were positively associated with PU, explaining 50.4% and 34.1% of the common variance. Furthermore, variations in SU results significantly correlated to measures of fat and contractile tissue, whereby PBF, PSMM, BFMI, SMMI, and IH explained 42.9%, 42.1%, 39.5%, 30.8%, and 43.5% of the common variance, respectively. It seems that when the strength requirements were lower for repetitive overcoming of the body weight such as in SU test, the correlations were lower. The main functional characteristic of the muscle is its ability to contract and produce the movement of certain speed; and therefore strength (Blagojević et al., 2016, p. 135). In that regard, muscular endurance or repetitive strength refers to the ability of a muscle group to repeatedly contract over a period of time sufficient to cause muscular fatigue (Riebe et al., 2018, p. 101). In that regard, the correlation was higher between the PSMM and PU than between the PSMM and SU because the

requirements for the expression of muscular strength is higher in PU comparing to SU performance. Conversely, the correlations of fat indices were also stronger with PU than with SU results. These correlations and the fact that police officers tend to be fattier by time spent in service (Sorensen et al., 2002; Lagestad et al., 2014; Kukic et al., 2017) suggest that the maintenance of a good muscular status may be very important for the muscular endurance of police officers.

Although the evidence indicate the strength and direction of individual associations of BMI, PBF and PSMM to muscular endurance, studies have shown that BMI, PBF and PSMM can be misinterpreted when defining someone's body composition (Kyle et al., 2001; Rothman, 2008). For example, Kyle et al. (2001) found no changes over time in BMI, even though BFM and PBF significantly increased, while SMM, PSMM and FFMI significantly decreased. Minimal changes in BMI were reported after an applied exercise training and a casein-based diet regime, even though police officers significantly decreased PBF by 8% and increased lean body mass by 4 kg (Demling and DeSanti 2000). Furthermore, the study on athletes from National Football League (NFL) showed how the athletes can often be misinterpreted based on BMI because prevalence of obesity (BMI ≥ 30 kg/m^2) was 53.4%, while once adjusted to PBF, the prevalence decreased to 8.5% (Provencher et al. 2018). The reason for this discrepancy in results was due to NFL athletes having high amounts of SMM and low amounts of BFM. Although, the BMI is an indicator of body volume in relation to body height it does not give an information on the source of this volume (Provencher et al., 2018; Rothman, 2008). In contrast, BFM and SMM can easily be misinterpreted if used as absolute measures because bigger bodies (taller subjects) may naturally possess a bigger amount of BFM or SMM. Finally, PBF and PSMM are contrast tissues of human body, meaning that increase in PSMM will lead to decrease in PBF and vice versa (Kukic et al., 2018).

Thus, the IH that significantly ($p < .01$) correlated to PU and SU was developed in order to overcome the aforementioned misinterpretations, as it would indicate the ratio of PBF and PSMM independently of body size. The IH would indicate a muscularity regardless of how fatty an officer may be. Similarly, SMMI was used to extract muscle quality regardless of the PBF and PSMM. Developing a body size-independent indexes of body composition is based on the theory of geometrical similarities that assumes that all human bodies have the same shape and differ only in body size (Jaric et al., 2005). This means that all lengths are proportional to a characteristic length measured on a subject (e.g., body height), and all areas (e.g., SMM) are proportional to BH^2 (Jaric et al., 2005; Kukic et al., 2018).

Considering that the IH is calculated from PBF and BMI, assumingly it might improve the interpretation of PBF, BMI and PSMM, because the ones' BMI can be within the normal range, which does not necessarily mean that the level of PBF is in normal range (Kukic et al., 2018). For instance, police officers whose BMI is 24 kg/m² while PBF is 25%, often underperform on physical fitness assessment. Therefore, it would be wrong to rate his body composition or nutritional status as normal. Conversely, IH could also define the source of the body voluminosity, when the BMI is above 25 kg/m². Two officers may have the same BMI of 27 kg/m², even though their PSMM and PBF can be significantly different. One can possess 52% of SMM and 12% of BFM, while another officer can have 40% of SMM and 24% BFM. The potential for performance of these two officers is significantly different. Thus, building the body composition indexes that more closely define these differences in relation to officers' physical performance could be a valuable tool for police agencies as well as for practitioners.

Compared to SMMI, PSMM is more about the quantity of muscle mass in relation to body mass, while SMMI is a closer representation of a dry contractile mass, which is more important for policing jobs. There are instances when a police officer has a normal PSMM but followed by a very low BMI (i.e., PSMM

= 35% and BMI < 18.5 kg/m²). This could lead to lowered potential for muscular endurance, given that PSMM positively correlated to PU and SU. Conversely, although PBF leads to lower PSMM, SMMI could remain the same.

This is supported by studies on load carriage and military specific test (Lyons et al., 2005; Pihlainen et al., 2018). In a load carriage study, Lyons et al. (2005) showed that body composition index, calculated as lean body mass divided by (fat mass + external load), significantly correlated (r = -0.52, p < 0.01) with the metabolic demand of heavy load-carriage. The association of SMM and physical performance was higher as the task was more dependent on strength, suggesting that the lean muscle mass should be considered as a selection criterion for load carriage occupations (Lyons et al., 2005). The study on military specific performance showed moderate correlations between the SMM and a military specific test (r= -0.47). The SMM correlated 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). Moreover, SMM was included into best fit model of prediction, suggesting that better performance requires better SMM (Pihlainen et al., 2018).

7.1.4 Correlations between body composition and aerobic and anaerobic endurance

Body fat indices such as BMI, BFMI and PBF, as well as the indices of muscularity such as PSMM positively correlated to aerobic endurance of both, police officers and MPC. Considering the anaerobic endurance measured by the ShRun300 the magnitude of correlations were smaller for BFMI, PBF and PSMM, while the IH correlated the same as with the CT. The BMI was not associated with the ShRun300. Note that less seconds means better results, which is why correlations with BMI, BFMI and PBF were positive when results are in seconds, while in MPC the correlations were opposite because the result

was expressed in meters. This means that as bigger the body size and body volume are based on ballast tissue, the more time is needed to complete a 3.2 km or 300 m distance or more meters is covered for 12 minutes (CT). Conversely, PSMM correlated negatively to RUN and ShRun300m and positively to CT test, indicating that the relative amount of skeletal muscle mass in the body is highly important for aerobic performance of police officers (i.e. to overcome the negative effects of ballast tissue). It seems that the body composition indices, which are based on the ratio between the volume and size of the body such as BMI and BFMI, correlate the best with the running performance of police officers and MPC.

Although the BMI has been widely used in police studies (Dawes et al., 2018; Kukić et al., 2018; Kukić et al., 2018; Mitrović et al., 2015), it seems that the variations in RU and CT may be explained more precisely by the variations in BFMI than in BMI. The BMI explained 26.3% and 28.9% of the variance in running test of police officers and MPC, respectively, comparing to 42.4% (officers) and 42.9% (MPC) that was explained by the BFMI. On the other hand, relative volume of fat tissue (PBF) explained 39.3% and 41.9% of the variance in running of officers and MPC, respectively, comparing to 35.8% (officers) and 41.5% (MPC) of the variance explained by the relative amount of active tissue (PSMM). Finally, the IH explained 31.1% and 38.4% of the variance in aerobic endurance of police officers and MPC. The amounts of shared variance indicate that body size-independent body composition indices (BMI and BFMI) are more associated with aerobic endurance than the body volume-independent indices (PBF and PSMM). However, it also shows that increasing the amount of BFM relative to BH^2 (body size) lowers the running ability of police officers more than increasing the BM per se. This is highly important because BM can be increased either by increasing the amounts of BF or by increasing the SMM. In both cases increase in BM and therefore BMI may lead to lower performance in RU, but if the increase is based on BF, the impact will be immediate, much higher and will bring many other risks (Charles et al., 2008; Dawes et al., 2018;

Dawes et al., 2016). In contrast, development of SMM in general should be encouraged but only until the certain point, where excess SMM starts being a mechanical and metabolic burden (Mitrović et al., 2015; Kukić et al., 2018).

Although the ShRun300 and CT test different bioenergetics system such as anaerobic lactic and aerobic, both tests estimate running endurance within these systems. The difference is in intensity of running while everything else remain the same. For that reason, in index of running endurance (REi) was build using these two tests because it represents the running ability of different intensity. The rationale behind it is that the components of body composition are similarly associated to straight running, regardless of intensity. The strength of correlation may vary but within the small range, which correlation coefficients of ShRun300 and CT proved to be true. However, the magnitudes of correlation between the REi and BFMI, PBF, PSMM and IH were higher comparing to these two tests. Namely, 44.1%, 44.7%, 45.2% and 43.5% of the variance in REi can be explained by the differences in BFMI, PBF, PSMM and IH, respectively. Moreover, IH correlated stronger to REi than to ShRun300 and CT, which further increases external and construct validity of this dissertation.

In a study on association between the anthropometric measures and physical performance in male law enforcement officers, Dawes et al. (2016) found that estimated BF negatively correlated ($p < .001$) with 1.5-mile run. Another study showed that low performers on specific physical agility test for patrol officers had higher ($p < .001$) BMI (30.37 kg/m²) comparing to BMI (26.15 kg/m²) of high performers (Dawes et al., 2017). Moreover, BMI was shown to have medium to large effect on physiological (blood lactate level) and perceptual demands (rating of perceived exertion) of state patrol officers when conducted the defensive tactics training (Dawes et al., 2018). Although the polygon for defensive tactics training was not the test of aerobic endurance, it certainly highly depended on it because in average it lasted for about 168 seconds. In addition, larger indices of adiposity such as BMI, WC, WHR and WHtR may significantly increase the levels of oxidative stress and decrease

levels of antioxidant defence among police officers (Charles et al., 2008). There is a plenty of evidence on negative effects of various BFM indices on aerobic performance and health of police officers, suggesting the importance of body fatness for both, health-related and performance-related physical fitness.

In contrast to measures of body fatness, studies on various athletes of both genders and on police officers (Dawes et al., 2017; Kukic et al., 2018; Mitrović et al., 2015) indicate that better performers normally possess leaner bodies with well-developed muscle mass and low amounts of fats. Increase in BM and BMI typically leads to a lower relative oxygen consumption (Mitrović et al., 2015; Dawes et al., 2017; Kukic et al., 2018), especially if based on excess BF. In contrast, SMM is actively involved in every movement, whereby muscles' metabolic capacity is higher as the PSMM increases (Bassett & Howley, 2000; Lyons et al., 2005). In that regard, given that the first sample of this study in average was overweight (mean BMI = 25.86 kg/m^2), with increased PBF (23.59%), police officers who opposed their ballast mass with higher volume of metabolically active, contractile tissue (PSMM) performed better in RU. However, this does not mean that SMM should be uncontrollably developed because at some point it may become biomechanically and physiologically ineffective. Namely, increase in the amount of SMM relative to body height overly increases BM, BMI and metabolic demands, which surpasses the metabolic capacity of the body. For example, study on three groups of police employees who were different only by SMMI, while PBF and age were the same, showed significant negative effect of highly increased SMM on running performance (Kukic et al., 2018). The authors concluded that the physical performance of police employees may be negatively impacted once BMI gets above 27.5 kg/m^2 due to increase in SMMI above 14.10 kg/m^2. In other words, highly muscular, or even hyper-muscular police officers, because of the hyper level of muscles as active metabolic consumption mass may have a lower level of metabolic efficiency during the locomotion endurance tasks, such as long running. According to that phenomenon and association of body size

and performance (Jaric et al., 2005; Markovic & Jaric, 2004), hyper-muscular body in police should be recognized as a whole body locomotion endurance negative effect. Therefore, highly increased SMM may become a disadvantage for aerobically demanding tasks (such as chasing suspect, running the stairs, etc.).

7.1.5 Correlations between body composition and COD

Both tests for COD correlated to BFMI, PBF, PSMM and IH, while only TT additionally correlated to SMMI ($p < .05$). A small correlation coefficient ($p < .05$) between the BFMI and PBF and IAT was followed by a non significant association of IAT and SMMI. This indicate that the performance of IAT among similarly muscular MPC may be hindered by an increased body fatness. Moreover, IAT was associated with PSMM ($p < .01$) stronger than with PBF ($p < .05$). This means that in similarly muscular MPC, those who have lower relative amounts of fat, in contrast have a higher relative amount of muscle mass and therefore they performed better in IAT. When the requirement is a fast lateral COD on a short distance, such as in TT, the importance of SMMI increases as well as the importance of PBF and PSMM. Namely, 22%, 24%, and 25.6% of the variance in IAT can be explained in differences in BFMI, PBF, and PSMM, while 23.7%, 23%, 28.3%, and 31% of the variance in TT can be explained by SMMI, BFMI, PBF and PSMM. Furthermore, 25.9% of the variance in IAT and 34.4% of the variance in TT can be explained by IH.

The IAT and TT were put through the factorial analysis to build one COD index (CODi). While on duty, police officers' COD activity would rarely be purely in a single direction. It would rather be a multi-directional activity. For that reason, CODi was built to represent the real activity as close as possible and then correlated with body composition indices. A small to medium correlation occurred between the CODi and body composition, whereby 24.2%, 28.8%, 30.5%, and 32.5% of the variance in CODi can be explained with the

differences in BFMI, PBF, PSMM, and IH, respectively. The remaining 67.5-75.8% of the variance depends on muscular power, reactive time, coordination (Pehar et al., 2018; Alvar et al., p. 371). Furthermore, the pattern of correlations (low or insignificant SMMI and PSMM higher than PBF, with IH being the highest) was the same as in muscular power. The explanation may lie in the duration of these tests because none of them lasted longer than 20 seconds, which depends on anaerobic power. Moreover, in TT that engages the leg muscles more and lasts shorter than IAT, the magnitudes of correlations are closer to those of lower-body muscular power. In that regard, it seems that the magnitude of correlation between the body composition indices and powerful performance (0-30 seconds) depends on the type and duration of activity.

7.1.6 Correlation between body composition and multidimensional performance indexes

Physical fitness defined as health-related or skill or performance-related normally consists of several components. For example, health-related physical fitness includes cardio-respiratory endurance, body composition, muscular endurance, muscular strength, and flexibility (Riebe et al. 2018, p. 2). In that regard, the most recent review study on characterization of the physical fitness of police analyzed 59 studies and showed what are the most frequent physical abilities that were tested (Marins et al., 2019). Namely, in 49 of 59 studies the aerobic capacity was investigated, followed by strength and muscular endurance that were reported in 29 studies, and body composition reported in 20 studies.

The process of evaluating the performance or occupational physical fitness for police officers can be demanding, considering the diversity of tasks and complexity of physical fitness related to it. Moreover, beyond the health related or general physical fitness tests, some police agencies additionally asses the occupational readiness, which include variety of tasks and physical abilities (Marins et al., 2018; Maupin et al., 2019). Therefore, multidimensional indexes

of physical performance that integrated a few physical abilities into one performance index were calculated for the purposes of this dissertation. This was done using the mathematical modeling by applying the techniques of multidimensional scaling (Dopsaj et al., 2012). For instance, a factorial analysis was used to create a new variable from RUN, PU and SU scores. The SPSS automatically name this new variable the FACT_bod, which was further used to calculate EPFS. Since EPFS represents the total score from all three tests it assumingly estimates the general physical fitness level. The same process was repeated for all investigated performance indexes; however, different variables were inserted in calculation (Page 51). Thus, muscle quality and performance index (MQPi) includes muscular force and power variables, running ability index (RAi) includes straight running speed, and COD. Finally, total physical performance index (TPPi) integrated all measured physical abilities.

Considering the first sample, all three physical performance tests (PU, SU and RU) significantly correlated to body composition and consequently, the EPFS logically fallowed the similar course of events. The variance in EPFS can be explained by the differences in PBF (52.7%), PSMM (51.4%), BFMI (49%), SMMI (32.9%) or in IH (51.7%),. Furthermore, the variance in MQPi, which is calculated from muscular force, upper-body and lower-body muscular power, can be explained by SMMI (48%), BFMI (31.7%), PBF (42.2%), PSMM (46.5%), and IH (54%). The RAi is calculated from straight running speed and COD can be explained by BFMI (41.5%), PBF (44.7%), PSMM (46.9%), and IH (46.9%). The TPPi was calculated by an integration of all dimensions of the measured physical fitness, meaning that one index was made from MQPi, RAi, and REi. Thus, the TPPi would provide an integral insight into participant's ability to contract muscles, express strength, power, muscular endurance, aerobic and anaerobic endurance and COD. In that regard, the variance in TPPi, can be explained only by BMI (34.4%) or by SMMI (37.1%).

The EPFS correlated strongly to PBF, PSMM and IH, and moderately to BFMI and SMMI. Note that the correlations between the body composition

indices and individual physical ability tests such as PU, SU and RU were smaller than the correlations with EPFS. These results indicate that when the general fitness includes local muscular endurance and aerobic endurance, the overall performance depends on a good quality of SMM (PMI and FFMI), good relative amount of SMM and BFM (PSMM and PBF), as well as on its ratio within BMI (IH). On the other hand, the correlations of SMMI, BFMI, PBF, PSMM and IH to MQPi were higher than correlations to EPFS. A partial explanation certainly lies in the difference in samples, but part of the explanation could also lie in the dimensions included in MQPi. The MQPi depends on maximal muscle force and strength and on the ability of muscles to overcome the load of body weight, once powerfully or several times with maximum speed within a short period (0-30 s). Therefore, it moderately depends on the amount and quality of SMM but highly depends on the proportion of PBF and PSMM within the BMI. This is additionally proved by the correlations between the RAi and body composition because the only difference between the RAi and MQPi was that the RAi included only different types of running. The duration of the tests (RU10m, RU20m, IAT and TT) were in range of 1.65 – 21.14 s and the requirement was as fast as possible. Thus, the correlations between the RAi and body composition indexes were similar to those between the MQPi and body composition. The difference was that the SMMI did not correlate to RAi and the IH explained 7.1% of the variance less in RAi than it did in MQPi. Finally, the TPPi is moderately associated to only BMI and SMMI. Considering the complexity of the TPPi, whereby it consists of all dimensions of physical fitness, these correlations indicate that the ratio between the body size and body volume are in connection with overall physical performance. Moreover, the amount of muscular tissue per each m^2 of the body seems to be the key for TPPi.

7.2 DETERMINING MODELS OF PREDICTION

The multiple regression analysis established clear significant causal relationships between the measures of body composition and EPFS, and two prediction models were defined. Since the model based on the SEE includes four measures, IH, BMI, BFMI, and PBF, it was named 4M model, while the simplest prediction model included three measures BMI, PBF and BFMI and accordingly was named 3M model (Kukic et al., 2018). Both models defined in what degree and which body composition measures are associated to variability in EPFS. In that regard, 4M model explained 38.3% of the variance in EPFS and 3M model explained 37.9% of this variance. Considering the calculations of each variable (see Table 1) within the 4M model, the PBF represents the volume of fatness, while BMI, BFMI and IH represent a distribution BM and its fats on each m² of the body. This means that the performance of multiple tasks may be directly hindered by the relative proportion of ballast mass on each m² of the body. These findings suggest that both, body volume-independent (such as PBF) and body size-independent measures of ballast mass and active mass (such as BMI and BFMI) 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 police officers' physical fitness screening as well as in officers' physical preparation planning and programming (Kukic et al., 2018).

The regression analyses conducted on the second sample revealed significant causal associations between the indices of body composition and IAT among females in general as well as in FPO and FPC separately. In FPO and FPC combined, 37.1% of the variance in time to complete the IAT can be explained by the differences in SMMI and BFMI. However, when the sample of females was analysed separately the regression models included different body composition indices. In FPO, 42% of the variance in IAT can be explained in

differences in PBF; while in FPC, 35.1% of the variance can be explained by the within-group differences in BMI and PSMM. Although the BMI alone was not significantly associated to IAT of FPC, together with PSMM it indicates that the FPC who were more muscular; and therefore heavier, performed better on IAT. In contrast, FPO who were having higher proportions of ballast mass were slower on IAT.

The explanations could lie in the sizes and homogeneity of these two samples. Both samples were relatively small, different by age, by the level of physical fitness and amount of physical activity. The FPC were selected group of women who had to pass minimal physical fitness standards in order to enter the UCIPS. They also had classes of specialized physical education twice a week. In contrast, FPO were in average 12 years older, were not having obligatory physical activity, and in average had 4.38 kg/m² higher BMI. More importantly, FPC in average had 6.69% higher PSMM than FPO, with cV% being almost twice (1.6 times) lower. It is important to note that the FPC were in average 8.44 cm (5.15 – 11.74 cm) taller (p < 0.001) than the FPO but at the same time had 0.53 kg of SMM more and 5.02 kg of BFM less per each m² of body size. Therefore, when the sample is combined, which is likely to occur on larger samples, the body size-independent indexes of ballast and active tissue seem to be the ones to affect the COD the most among women. However, the generalisation of the results should be taken carefully, because the precision can be additionally increased depending on the sample's characteristics.

Considering the third sample, nine performance indexes were put through the regression analyses and for all nine a significant ($p < .001$) model of prediction was extracted from body composition indices. It seems that, the muscle force, upper and lower-body power, COD, aerobic-anaerobic endurance and total physical fitness of 95% of the sample to a certain degree significantly depend on body composition. However, the causality of relationship between the body composition indexes and manifestation of certain physical abilities varies depending on the type of activity that needs to be performed (Table 16).

Table 16. Shared variance for prediction models of physical performance**.**

Physical ability	Index	Activities included in index	Shared variance	Variables	Body composition indices
Force and strength related	**MFi**	Maximal isometric force and 1RM	44.4%	SMMI	Body size-independent muscle mass
Power related	**LBMPi**	Maximal vertical and horizontal jump	38.7%	BMI, IH, SMMI, PBF, PSMM	Body size-independent body mass; Body size-independent muscle mass; Body volume-independent fat and muscle mass
	UBMPi	Repetitions as fast as possible 10-30 s.	22.5%	SMMI, BFMI	Body size-independent muscle and fat mass
	CODi	Running forward with direction changes, 17-21 s; and lateral direction change, 10-15s.	19.3%	BMI, SMMI, PBF, PSMM, IH	Body size-independent body mass; Body size-independent muscle mass; Body volume-independent fat and muscle mass
	SRSi	Sprinting up to 4 s.	18.2%	BFMI, PBF, IH	Body size-independent fat mass; Body size and volume-independent fat mass
Aerobic and Anaerobic Endurance	**REi**	Maximal running for 12 min; and maximal running for 60-80 s.	28.3%	BFMI, PBF, IH	Body size-independent fat mass; Body volume-independent fat mass
Force, strength and power	**MQPi** **Calculated from MFi, LBMPi and UBMPi**	Maximal isometric force and 1RM; vertical and horizontal jump; Repetitions as fast as possible 10-30 s.	42.2%	IH, SMMI	Body size and volume-independent fat mass; Body size-independent muscle mass
Anaerobic power with variations in muscular engagement	**Rai** **Calculated from CODi and SRSi**	Running forward with direction changes, 17-21 s; and lateral direction change, 10-15s; Sprinting up to 4 s.	28.6%	BFMI, PBF, IH	Body size-independent fat mass; Body volume-independent fat mass
Force, strength, Power, Endurance	**TPPi** **Calculated from MQPi and REi, RAi**	All of the above	17.5%	IH, SMMI, BFMI, PBF	Body size and volume-independent fat mass; Body size-independent muscle mass; Body size-independent fat mass; Body volume-independent fat mass

For example, for the controlled activities that largely depend on maximal force and strength of the muscles, such as isometric dead lift and 1RM bench press, the prediction of performance is relatively high. As the performance is less controlled, more complex and depends on ability of muscles to contract repeatedly, the prediction product decreases. Considering endurance, it seems that anaerobic lactic as well as aerobic running performance is causally associated with the ballast mass per each m² of body size. This means that the MPC who perform better in force and strength related activities are typically more muscular, while those who perform better in high intensity running are typically leaner. However, for the activities that are in-between the maximal force and aerobic running, the MPC who are lean and muscular with lower levels of fats perform better. In that regard, the prediction values of multidimensional physical performance indexes, such as MQPi, RAi and TPPi, additionally support this notion.

The MQPi consists of muscular force, strength and power and, as such, is highly associated with the SMMI as well as with the ratio of the PBF within the BMI. Since the result in MQPi depends on SMMi less than the result in MFi, the prediction value is slightly lower. Next to SMMI, the MQPi also depends on the balance between the PSMM and PBF relative to body size (IH), which could be the reason why it has higher prediction value than LBMPi and UBMPi. Therefore, MPC who have a good SMMI followed by a good IH are more likely to perform better in force, strength and power tasks. The result of the regression analysis for RAi is suggestive of an increase in construct validity because the prediction value is about 10% higher than in both, CODi and SRSi. The SRSi is an estimation of an anaerobic a-lactic power, while CODi is an estimation of an anaerobic lactic power. The SRSi is more related to fat indices, while the CODi requires acceleration, deceleration and change of direction, which is related to PSMM and IH. Thus, it seems that the overall ability of MPC to run fast and change direction depends on body composition more than it is the case with merely straight running speed or COD. Considering police tasks consisting of

maximal short run (i.e. on foot chase [Lockie et al., 2018a, Lockie et al., 2018b]), they are typically consisted of these two abilities.

Finally, the TPPi is the most complex index of physical performance as it integrates MQPi, REi, and RAi into one overall index of performance. This means that each of these three indexes in a certain amount contributes to the result in TPPi. However, the amount of contribution depends on physical abilities of each cadet, which are in small to large association with body composition. For example, those cadets who are stronger and more powerful are also more muscular, while those whose running endurance is higher possess lower amounts of fat. Since different abilities within TPPi require different body types, the prediction value is smaller than in particular physical abilities or ability-related performance indexes (Table 16). Nevertheless, SMM and BFM indices of body composition play a significant ($p < .001$) role in overall physical performance. The results suggest that 18% of the cadet's ability to be strong, powerful and resistant, at the same time, may require the SMMI, BFMI, PBF and IH to be within the certain range (Table 15).

A well-developed and balanced level of physical abilities is one of the main factors for success in physically demanding and risky duties (Dillern et al., 2014; Mitrovic et al., 2015; Pihlainen et al., 2018). However, negative associations between the non-functional body composition measures and certain physical abilities have been well established by several studies (Dawes et al., 2014; Dawes et al., 2016; Kukic et al., 2018, Orr et al., 2019). Moreover, BMI and BFM have been shown to negatively affect the health and increase the risk of injuries in police officers (Garbarino & Magnavita, 2015; Mitrovic et al., 2015). In that regard, the development, maintenance and monitoring of physical fitness is very important for effectiveness and general health status of police officers. Thus, body composition-based prediction could be a useful and justifiable physical fitness prescreening and monitoring tool. The findings of this dissertation identified the relations between the body composition indexes and physical abilities as well as the causality of relationship between these

indexes and multidimensional performance indexes. Therefore, the following prediction formulas were determined:

- **EPFS** = -48.21 + 5.02 • **BMI** + 3.24 • **PBF** + (-17.6 • **BFMI**), adj. R^2 = .369, SEE = 12.21, p < .001,

- **IAT_combined** = 25.23 + .35 • **BFMI** + (-.57 • **SMMI**), adj. R^2 = .342, SEE = 1.84, p < .001,

- **IAT_FPO** = 15.83 + .21 • **PBF**, adj. R^2 = .397, SEE = 2.07, p < .001,

- **IAT_FPC** = 35.48 + (-.14 • **BMI**) + (-.24 • **PSMM**), adj. R^2 = .229, SEE = 1.27, p = .049,

- **MFi** = -10.77 + 6.14 • **SMMI,** adj. R^2 = .439, SEE = 6.78, p < .001,

- **LBMPi** = 1233.89 + (**-50.83** • **BMI**) + 84.88 • **SMMI** + 17369 • **PBF** + (-19.10 •**PSMM**) + (-447.63 • **IH**), adj. R^2 = .358, SEE = 8.21, p < .001,

- **UBMPI** = 33.08 + 3.26 • **SMMI** + (-2.58 • **BFMI**), adj. R^2 = .211, SEE = 8.09, p < .001,

- **CODi** = -2420.97 + 107.39 • **BMI** + (-180.14 • **SMMI**) + (-36.65 • **PBF**) + 40.98 • **PSMM** + 889.23 • **IH,** adj. R^2 = .155, SEE = 15.45, p < .001,

- **SRSi** = 22.44 + 50.60 • **BFMI** + (-26.24 • **PBF**) + 383.45 •**IH**, adj. R^2 = .160, SEE = 15.33, p < .001,

- **REi** = 21.37 + 98.45 • **BFMI** + (-49.68 • **PBF**) + 669.43 • **IH**, adj. R^2 = .263, SEE = 14.33, p < .001,

- **MQPI** = 3.61 + 6.23 • **SMMI** + (-47.88 • **IH**), adj. R^2 = .411, SEE = 12.45, p < .001,

- **RAi** = 16.55 + 88.83 • **BFMI** + (-46.04 • **PBF**) + 647.27 • **IH**, adj. R^2 = .267, SEE = 14.39, p < .001,

- **TPPi** = 3.36 + 4.44 • **SMMI** + 29.28 • **BFMI** + (-16.09 • **PBF)** + 227.71 • **IH,** adj. R^2 = .145, SEE = 7.29, p < .001.

7.3 INTERNAL AND CONSTRUCT VALIDITY

This dissertation was investigating a novel approach in evaluating physical fitness. This approach utilized body composition components expressed as body volume and body size-independent indexes and integrated them into multidimensional models that would best predict physical performance. The majority of studies from police agencies that used anthropometric measurements or body composition components showed that certain variables such as waist circumference, waist-to-height ratio, BMI, PBF, or SMM correlated to either physical abilities or performance. However, none of these studies investigated the possibility of using the body as a whole (i.e. what our body is made of) to estimate physical abilities and physical performance (i.e. what our body can do). Therefore, the correlation analysis has been used to establish the internal validity of each variable that entered the prediction model (Table 17). Afterwards, the multiple regression analysis revealed if the used prediction models have higher construct validity than the individual body composition components. In that regard, an internal validity ranged from no significance to medium significance, while construct validity ranged from small to medium.

It seems that the validity of prediction models is higher for the activities that are better controlled and in higher degree depend on the intensity of muscle contraction such as MFi and MQPi. When the physical performance is more complex and muscularly less demanding the validity seems to decrease such as in TPPI and RAi. However, the purpose of this dissertation was not to find the replacement to widely used physical tests of physical fitness, but to offer an additional approach to evaluation of physical fitness. Using the body composition to estimate the physical fitness of police officers to a certain degree is quick, safe and non-invasive procedure. Although police officers do need to be able to overcome physical demands of the tasks as well as army officers, it has been reported that some recruits and officers died during the physical

fitness assessment (Web Page 1, Web Page 2, Web Page 3). Moreover, considering that unfit officers may have higher proclivity of injuries during physical activities such as physical assessment, an invasive and safe assessment of medium validity could be considered credible.

Table 17. The internal and construct validity of the prediction models.

Prediction model	Variables within the model	Internal validity		Construct validity	
		Pearson's coefficient r		Regression analysis R^2	
EPFS	BMI	-.136	Non-significant	.379	Medium
	BFMI	-.490	Small		
	PBF	-.527	Medium		
Female-IAT	SMMI			.371	Medium
	BFMI				
FPO-IAT	PBF			.420	Medium
FPC-IAT	BMI			.315	Medium
	PSMM				
MFi	SMMI	.666	Medium	.444	Medium
LBMPi	BMI	-.169	Non-significant	.387	Medium
	IH	-.579	Medium		
	SMMI	.195	Non-significant		
	PBF	-.535	Medium		
	PSMM	.575	Medium		
UBMPi	SMMI	.262	Small	.225	Medium
	BFMI	-.328	Small		
CODi	BMI	-.040	Non-significant	.193	Small
	SMMI	-.171	Non-significant		
	PBF	.282	Small		
	PSMM	.305	Small		
	IH	.325	Small		
SRSi	BFMI	.351	Small	.182	Small
	PBF	.381	Small		
	IH	.400	Small		
REi	BFMI	.441	Small	.283	Medium
	PBF	.447	Small		
	IH	.435	Small		
MQPi	IH	-.540	Medium	.422	Medium
	SMMI	.480	Small		
RAi	BFMI	.415	Small	.286	Medium
	PBF	.447	Small		
	IH	.469	Small		
TPPi	IH	-.019	Non-significant	.175	Small
	SMMI	.371	Small		
	BFMI	.153	Non-significant		
	PBF	.081	Non-significant		

A given medium validity relates only to possibility of predicting the physical performance. However, studies had shown that body composition is also associated with the amount and type physical activity, hypokinesia, lifestyle and diet (Demling and DeSanti, 2000; Dopsaj et al., 2017; Kukic and Dopsaj, 2017). Therefore, next to predicting physical performance, with more research that would focus on these other factors, body composition might give an insight into more than just physical performance.

8. CONCLUSIONS

Body composition, cardiorespiratory fitness, muscular strength, muscular endurance, and flexibility are the main factors of health-related physical fitness (Riebe et al., 2018, p. 1). On the other hand, performance-related physical fitness mainly depends on components such as agility, power, running speed, anaerobic endurance, and coordination (Riebe et al., 2018, p. 2). Thus, the level of physical fitness of police officers, in general, is assessed by tests such as different types and intensities of running, jumping, push-ups, sit-ups, etc. Therefore, the purpose of this dissertation was to investigate the associations between the novel index values of body composition and common policing measures of physical fitness and to investigate the possibility of predicting the officers' 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. Moreover, when the time and geographical position of some countries does not permit for a more comprehensive assessment, the body composition-based prediction could be a useful and justifiable physical fitness prescreening and monitoring tool. For instance, countries that have very high heats during the summer, or extremely cold winters may not have technical conditions to conduct the physical assessment for hundreds of officers. In that regard, this approach might provide a moderately accurate insight in officers' physical fitness, even when the physical test cannot be conducted. 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 police officers to an optimal physical fitness.

This dissertation was conducted fulfilling several tasks that were formulated through one general hypothesis and seven supporting hypotheses. The hypotheses were statistically tested using a Pearson's correlation analysis

to find if the body composition indexes share a significant amount of variance with physical abilities and physical performance of police officers. Afterwards, the regression coefficient of determination was used to determine the possibility of predicting physical performance from body composition. Led by the results of these statistical analyses, the following can be concluded about the hypotheses:

General hypothesis:

H_g – It is possible to define a physical fitness prediction model based on body composition characteristics. **It can be concluded that Hg is true.**

Physical fitness was defragmented to its main elements, body composition, physical abilities, bioenergetics, muscle characteristics, physical performance and the role of each of them was explained. Body composition components were presented as index variables and thorough background was given for this approach. Physical abilities were also thoroughly explained and they were joined into multifactorial and multidimensional physical performance indexes to reflect parts of physical fitness or total physical fitness. Chosen body composition indexes were correlated to each physical ability and to performance indexes and showed small to medium power of correlation. Body composition indexes were also tested for prediction power on thirteen physical performance indexes and all of them were statistically significant, with small to medium power of prediction. Therefore, the prediction of physical fitness constituents as well as total physical fitness, using body composition indexes is possible. However, practitioners should be cautious when using this approach because the power of prediction differs among constituent of physical fitness. This is well presented in Tables 16 and 17.

Supporting hypotheses:

H₁ – There will be a significant association between the characteristics of body muscularity, expressed as indexed calculation and physical performance. **It can be concluded that H₁ is true.**

Indicators of muscular status (SMMI or PSMM) correlated to all physical abilities and to all physical performance indexes (Tables 7 and 9). Moreover, SMMI or PSMM were included in 8 out of 13 prediction models, while three more models included IH (proportion of PSMM and PBF relative to BMI). Muscular force, strength, power and muscular endurance as well as performance indexes that included these physical abilities were highly associated with either SMMI or PSMM. Thus, the muscular status was associated to physical abilities.

H₂ – There will be a significant association between the characteristics of body fatness, expressed as indexed calculation and physical performance. **It can be concluded that H₂ is true.**

Indicators of body fatness (BFMI and PBF) did not correlate only to DLFmax, BP1RM, SU30s and TPPi, while IH as an indicator fatness relative to BMI did not correlate only to TPPi. It should be noted that DLFmax is a maximal isometric contraction and the result depends largely on neuromuscular activity, because the ballast mass does not need to be moved. The BP1RM is conducted laying down on the back and moving only hands loaded with the weight on a barbell. Therefore, the success in lifting this weight depends on muscular activity of upper-body, while fat mass does not have any impact on bench press performance. Thus, BFMI and PBF are significantly associated to physical abilities estimated by tests that require whole body

mobility, which is known to be the case in police officers. In that regard, they were associated with physical performance indexes.

H₃ – There will be a significant internal and construct validity of chosen body composition indexes. **It can be concluded that H₃ is partially true.**

The validity is summarized in Table 17. It ranges from small to medium, depending on physical performance that was predicted. It seems to be higher for the activities that are better controlled and in higher degree depend on the intensity of muscle contraction such as MFi and MQPi. When the physical performance is more complex and muscularly less demanding the validity seems to decrease such as in TPPI and RAi. Therefore, predicting complex multidimensional physical performance such as TPPi, hence overall physical fitness, might need further clarifications for its utilization. However, models that are more valid could be used as they have practical value.

H₄ – There will be a significant causal relationship between body composition characteristics and individual physical ability. **It can be concluded that H₄ is true.**

The prediction models of nine physical performance indexes included direct indicator of muscularity status, while two more included IH. However, considering the results from Table 14, the prediction models with the lowest SEE include the SMMI or PSMM in all performance indexes. The strongest model of prediction included only SMMI, indicating that the highest validity of body composition prediction models occurs in predicting muscular force and strength. Although the lowest validity of prediction occurred in TPPi, the SMMI and IH still were among the predictors. Therefore, skeletal muscles as an active component of body composition seem to be an important factor in physical performance.

Only prediction model for MFi did not include any indicator of body fatness, which may be because none of the tests from this index included a whole body motion. In contrast, all other prediction models included either BFMI, PBF or IH. Whenever the weight of the body (whole or partial) had to be moved throughout the space, the ballast mass had a negative effect on the result. In other words, fat mass hinders the performance produced by skeletal muscles. This was evident in all performance indexes, regardless of length and intensity, as IH as an indicator of ratio between skeletal mass and fat mass correlated to all physical abilities and performance indexes. It did not correlate only to TPPi but it was included in model of prediction. Thus, the amount of body fats was causally physical performance of police officers.

Considering the aforementioned fulfilment of hypotheses the final conclusion could be that the screening of general physical fitness by using body composition indexes is possible. According to results, health-related physical fitness (typically estimated from PU, SU and RUN), muscle quality and power as well as the ability of FPO to change the direction while running fast share moderate amount of variance with body composition. Additionally, studies have shown that the amount of physical activity, training and diet affect body composition. This means that next to physical performance, body composition indicate the lifestyle, dietary habits and level of physical activities that an officer might have. Thus, precise utilization of body composition such as indexed approach might be a useful tool for police agencies as well as for strength and conditioning professionals working with police officers.

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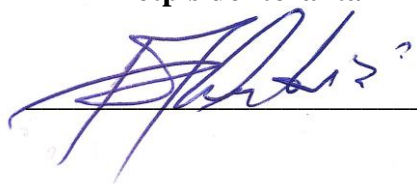
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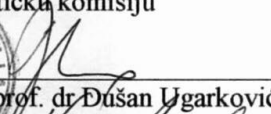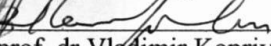
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UNIVERZITET U BEOGRADU
FAKULTET SPORTA I FIZIČKOG VASPITANJA

Saglasnost Etičke komisije Fakulteta sporta i fizičkog vaspitanja Univerziteta u Beogradu za realizaciju projekta „Efekti primenjene fizičke aktivnosti na lokomotorni, metabolički, psiho-socijalni i vaspitni status populacije R Srbije" (br. 47015)

Na osnovu uvida u plan projekta „Efekti primenjene fizičke aktivnosti na lokomotorni, metabolički, psiho-socijalni i vaspitni status populacije R Srbije" (br. 47015, rukovodilac doc. dr Milivoj Dopsaj), a koji je odobren od Ministarstva za nauku i tehnološki razvoj R Srbije u okviru ciklusa nacionalnih naučnih projekata za period 2011-2014. godine, Etička komisija Fakulteta sporta i fizičkog vaspitanja Univerziteta u Beogradu iznosi mišljenje da se, kako u koncipiranju tako i u planiranju realizacije istraživanja i primene dobijenih rezultata, polazilo od principa koji su u skladu sa etičkim standardima, čime se obezbeđuje zaštita ispitanika od mogućih povreda njihove psiho-socijalne i fizičke dobrobiti.

U skladu sa iznetim mišljenjem Etička komisija Fakulteta sporta i fizičkog vaspitanja Univerziteta u Beogradu daje saglasnost za realizaciju istraživanja planiranih projektom „Efekti primenjene fizičke aktivnosti na lokomotorni, metabolički, psiho-socijalni i vaspitni status populacije R Srbije" (br. 47015, rukovodilac doc. dr Milivoj Dopsaj) a koji je odobren od Ministarstva za nauku i tehnološki razvoj R Srbije u okviru ciklusa nacionalnih naučnih projekata za period 2011-2014. godine.

Za Etičku komisiju

red. prof. dr Dušan Ugarković

van. prof. dr Vladimir Koprivica

127

Attachment 5: Copy of the published paper

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

Filip Kukic[1]; Milivoj Dopsaj[2,3]; Jay Dawes[4]; Robin Orr[5] & Aleksandar Cvorovic[1]

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 per-formance (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 ≤ 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.

[1] Police Sports Education Center, Abu Dhabi, United Arab Emirates.
[2] Department for Analysis and Diagnosis in Sport, Faculty of Sport and Physical Education, University of Belgrade, Serbia.
[3] Institute of Sport, Tourism and Service, South Ural State University, Chelyabinsk, Russia.
[4] Health Sciences Department, University of Colorado-Colorado Springs, United States of America.
[5] Tactical Research Unit, Bond University, Australia.

BIOGRAPHY OF THE AUTHOR

Filip Kukić is younger son of Svetlana and Vladimir. He was born on 13th February 1989 in Apatin, a small town from North Serbia where he spent childhood and early adolescence. Filip and his Brother were raised in a working family of a mother who was a high school teacher and father who was craftsman working in various fields. During the elementary school Filip started practicing Karate, did it for two years, and then he transferred to flatwater kayak (1998) where he successfully competed for next 10 years.

These 10 years, probably played the most significant role in shaping of what Filip is today and will be for life. Filip competed nationally and internationally as a member of Serbian national team, but more importantly, he met and was trained by multiple World champion and Olympic vice champion Milan Janić. Moreover, he "lived" and trained with world vice champions Mićo and Stjepan Janić as well as with multiple Olympic champion Nataša Janić. Finally, he competed with competitors who today are World champions and Olympic vice champions such as Marko Novaković, Marko Tomicević and Milenko Zorić. This was the period when Filip was taught to work hard and be persistent in it for a bigger goal. Somewhere along the way, during these 10 years, Filip spent two years competing professionally and for the Serbian national team in Rowing.

In September 2008, he enrolled the studies at Faculty of Sport and Physical Education, University of Belgrade, where he graduated in 2012 and gained BSc of Sport and physical Education. His BSc degree thesis was in Biomechanics and Motor Control, mentored by Prof Duško Ilić and Vladimir Mrdaković. In October 2012 he started Master studies and graduated in

February 2014. Master thesis was also from Biomechanics and Motor Control, with same mentors. From September 2010 to February 2014, Filip was a student assistant at the Department of Biomechanics.

During the Autumn 2011, he started his firs paid job as a personal trainer in a local fitness center. In December of the same year he started working in Profex - Academy of healthy living. He spent more than two years in Profex working as a trainer and one year as a trainer and diagnostician. At the time he graduated Mater degree, he got a job in Abu Dhabi Police to be physical education instructor with police officers. Six months after he started working as an instructor, he got promoted into a trainer supervisor. The next year, 2015, Filip applied for PhD studies at Faculty of Sport and Physical Education, got accepted and enrolled in November.

Currently, Filip is employed in Abu Dhabi police on developing and implementing strategies of physical fitness improvement of police employees. His current research is related to associations between body composition and physical fitness and physical performance. Some of his experimental studies are on the effect of planned exercise programs on changes in body composition and physical abilities in male and female police officers. He authored and co-authored different posters and communications in international journal and conferences. He has been collaborating in research projects with the members of Faculty of Sport and Physical Education, Belgrade; University of Criminal Investigation and Police Studies, Belgrade, Serbia; Tactical Research Unit of Bond University, Gold Coast, Australia; Health Department of Colorado Springs, University of Colorado Springs; Department of Health and Human Performance, Oklahoma State University, Stillwater, OK, USA; and Department of Kinesiology, California State University, Fullerton, CA, USA.