# Relationship between motor abilities, physical activity, and cardiorespiratory endurance

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## Abstract

Cardiorespiratory fitness is a dimension of physical health associated with physical activity in a way that leads to many health benefits. The aim of this research was to determine the relationship between motor skills, physical activity (PA), and cardiorespiratory fitness (CRF). The sample consisted of 129 female students enrolled at the Faculty of Teacher Education, University of Zagreb - Department in Čakovec, with an average age of 21±0.12 years. The predictor set consisted of a variable body mass index (BMI), 7 Eurofit tests to assess motor abilities and three indices of PA of the Baecke questionnaire (sports, leisure and faculty index). The criterion variable for assessing CRF was the Beep test. The results were calculated by the regression stepwise method. Pearson's correlation coefficients between CRF and motor abilities, BMI, and physical activity index showed low to moderate correlations. Cardiorespiratory endurance significantly correlates negatively with the BMI, and positively with the sports and leisure time index and variables for assessing muscular endurance, agility, trunk strength and explosive leg power. However, regression analysis showed that significant predictors in explaining the variance in CRF were the variables bent arm hang (BETA=.20; p=.031), standing broad jump (BETA=.19; p=.043), sports index (BETA=.19; p=.020 and 10x5 m shuttle run test (BETA=-.17; p=.039) which explained 27% of the variance of the criterion variable. This research provides evidence that CRF is generally associated with BMI, TA in sports and leisure time, and motor abilities of energy regulation in female students. However, bent arm hang, standing broad jump, sports index and 10x5 m shuttle run were considered the most important predictors of cardiorespiratory endurance.

***Key words***

*cardiorespiratory endurance; motor abilities; physical activity*

## Introduction

Physical activity (PA) is any body movement made by skeletal muscles and involves energy expenditure, while cardiorespiratory fitness (CRF) is a property and is also defined as the ability of the vascular, respiratory, and muscular systems to supply oxygen during prolonged moderate or vigorous dynamic exercise (Zeiher, Ombrellaro, Perumal, & Neil, 2019). Regular physical activity, high levels of cardiorespiratory capacity, and maintaining a normal weight are known to strongly contribute to positive health outcomes. It is also known that moderate and high intensity physical activity is an important means of maintaining adequate cardiorespiratory capacity and normal body weight (Tammelin, 2013). Cardiorespiratory fitness is a dimension of physical health associated with physical activity in a way that leads to healthy benefits such as prevention of various diseases such as cardiovascular disease, lung, osteoporosis, colon cancer, high cholesterol,

high blood pressure, and prevention of obesity, anxiety, and depression (Laukkanen et al., 2001). Na et al. (2019) state that frequency, i.e., daily aerobic physical activity, has a more significant role in relation to maximum oxygen intake ($VO_{2max}$) in the prevention of cardiovascular diseases and alleviation of aortic stiffness in people with hypertension. There are a number of cross-sectional studies showing that low CRF in youth is associated with a higher cardiometabolic risk, including higher fasting glucose, abdominal obesity, triglycerides, and blood pressure, regardless of sociodemographic factors, diet, and physical activity (Andersen et al., 2006; Lobelo, Pate, Dowda, Liese, & Ruiz, 2010; Ruiz et al., 2006). In addition, longitudinal studies have shown that healthy CRF in childhood and adolescence is associated with a healthier cardiometabolic profile later in life (Ortega, Ruiz, Castillo, & Sjostrom, 2008). Some research shows that CRF is related to sex, age, anthropometric characteristics, and level of habitual physical activity (Koch et al., 2009; Takken et al., 2019). Although sex, age, body composition, and health status of an individual can significantly affect the level of cardiorespiratory fitness, physical activity has the greatest impact (Parikh & Stratton, 2011). Regular physical activity has long been one of the most important components of healthy living, especially today, when the younger population is preoccupied with advanced technology and increasing use of various motor and electric vehicles, while the COVID-19 virus has contributed to inactivity in the last two years.

This research aims to determine the relationship between cardiorespiratory ability and body mass index, motor skills and physical activity in faculty, sports, and leisure.

## Methods

The sample consisted of 129 female students enrolled at the Faculty of Teacher Education, University of Zagreb – Department in Čakovec, average age 21 ± 0.12 years. The predictor set of variables consisted of the body mass index calculated as the ratio of body mass and square of body height expressed in meters, then 7 motor Eurofit tests to assess agility (10x5 m shuttle run), flexibility (sit and reach), speed of limb movement (hand tapping), repetitive torso power (sit-ups), static arm power (bent arm hang), balance (Flamingo test), explosive leg power (standing broad jump). Physical activity was examined with the Baecke questionnaire (Baecke, Burema, & Frijters, 1982), which assesses normal physical activity in the last 12 months and contains 16 questions that check physical intensity during work, sports activity, and leisure time. For the purposes of this research, workplace-related questions were reformulated only on physical activity in college. Physical activity at the faculty contains seven questions (faculty index), sports physical activity contains four questions, or seven if a person is engaged in another sport (sports index), while physical activity during leisure time contains seven questions (leisure index). The higher the value of an individual index, the better the level of physical activity (Baecke, Burema, & Frijters, 1982). The criterion variable was the Beep test or the 20m shuttle run test assessing aerobic endurance (Léger, Mercier, Gadoury, & Lambert, 1988), showing satisfactory reliability and validity in estimating maximal oxygen uptake ($VO_{2max}$) in children and adults (Léger & Lambert, 1982). To estimate the maximum oxygen uptake, the standard equation used was: $VO_{2max}$ (ml/kg/min) = 18.043461 + (0.3689295 x TS) + (-0.000349 x TS x TS), where TS is the total number of shuttles (Léger & Gadoury, 1989). Measurements were conducted in April 2021. The survey results were processed in IBM SPSS Statistics 23. Central and dispersive parameters were calculated for all variables: arithmetic mean (AS), standard deviation (SD), minimum (MIN) and maximum score (MAX), distribution asymmetry coefficient (SKEW), distribution curvature coefficient (KURT). The

skewness-kurtosis normality distribution test was used to determine whether the measurements were suitable for normal distribution. According to Tabachnick and Fidell (2013), kurtosis-skewness values should be between +1.5 and -1.5. Previously, the variables that showed deviations from the normal distribution were subjected to the normalization of the distribution by the procedure (log 10) which enabled further processing using regression analysis. The interrelationship between predictor and criterion variables was calculated with Pearson's correlation coefficient. To explain the variance of the criterion variable $VO_{2max}$, stepwise regression analysis was applied using the stepwise method.

## Results

Table 1. Descriptive and dispersive parameters of the predictor and criterion variable

| | Min | Max | AS±SD | Skew | Kurt |
|---|---|---|---|---|---|
| BMI | 14.60 | 35.29 | 23.06±3.75 | 0.88 | 0.98 |
| Flamingo (s) | 2.36 | 78.56 | 11.90±12.61 | 2.06 | 10.26 |
| Hand tapping (number) | 21.00 | 39.00 | 32.25±3.42 | -0.35 | -0.02 |
| Sit and reach (cm) | 43.00 | 103.00 | 74.75±11.60 | -0.07 | 0.01 |
| Standing broad jump (cm) | 70.00 | 220.00 | 159.81±23.05 | -0.49 | 1.37 |
| Sit up (30s) | 12.00 | 34.00 | 24.28±4.04 | 0.05 | -0.07 |
| Bent arm hang (s) | 1.00 | 72.00 | 18.68±16.17 | 1.48 | 2.35 |
| 10x5m (s) | 16.18 | 28.30 | 21.82±2.17 | 0.46 | 0.64 |
| Sports index | 1.50 | 4.25 | 2.61±0.61 | 0.47 | -0.05 |
| Faculty index | 1.88 | 3.38 | 2.58±0.26 | 0.30 | 1.042 |
| Leisure time index | 1.75 | 5.00 | 3.23±0.62 | 0.30 | -0.214 |
| $Vo_{2max}$ (ml/kg/min) | 19.60 | 33.30 | 23.71±2.95 | 1.06 | 0.97 |

Based on the research results shown in Table 1, the mean value of $VO_{2max}$ is 23.7 ml/kg/min. Furthermore, the highest average value (3.23) was obtained in the domain of leisure, while the lowest was in the domain of sports (2.61). The lowest result is visible in the sports index (1.58), and the highest in the leisure index whose value is the maximum of the possible (5). According to the asymmetry coefficients (Skew), the variables flamingo and bent arm hang show that most participants are grouped in the zone of lower results, and the roundness values (Kurt) of these variables show a homogeneous results distribution.

Table 2. Correlations between the predictor and criterion variables

| | BMI | Flam | tap | flex | stand bj | situp | benta h | 10x5 m | IS | IF | ILT | Vo 2max |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BMI | 1 | | | | | | | | | | | |
| FLAM | -.16 | 1 | | | | | | | | | | |
| TAP | -.16 | .20 | 1 | | | | | | | | | |
| FLEX | .16 | .02 | .19 | 1 | | | | | | | | |
| STAN BJ | -.38 | -.06 | .15 | .15 | 1 | | | | | | | |
| SITUP | .01 | .11 | .05 | .23 | .08 | 1 | | | | | | |
| BENT AH | -.60 | .18 | .20 | -.05 | .52 | .23 | 1 | | | | | |
| 10x5 m | -.16 | .19 | .12 | .09 | .37 | -.09 | .25 | 1 | | | | |
| IS | -.20 | .2 | .09 | .15 | .21 | .11 | .32 | .22 | 1 | | | |
| IF | -.07 | -.01 | -.06 | -.08 | .08 | .16 | .05 | .02 | -.08 | 1 | | |
| ILT | -.09 | .02 | -.06 | -.01 | .09 | .07 | .14 | .05 | .35 | .01 | 1 | |
| VO 2max | -.23 | .12 | .17 | .11 | .39 | .18 | .40 | .33 | .33 | .03 | .23 | 1 |

Table 2 shows the correlation coefficients of predictor and criterion variables. Significant associations of $VO_{2max}$ indicate a negative association with BMI (r = -.23) and a positive association with hand tapping (r = .17), standing broad jump (r = .39), sit-ups (r = .18), bent arm hang (r = .40), shuttle run 10x5m (r = .33), sports index (r = .33) and leisure time index (r = .23). Intercorrelations of predictor variables indicate low to moderate correlations. Thus, BMI shows low negative correlations with the sports index (r = -.20), standing broad jump (r = -.38), flamingo test (r = -0.16), hand tapping (r = -.16), and shuttle run 10x5 m (r = -.16) and moderately negative correlations with the bent arm hang (-.38). The sports index has a significant positive correlation with motor tests that are under the direct influence of the mechanism for energy regulation of movement; standing broad jump (r = .21), bent arm hang (r = .32), and shuttle run 10x5m (r = .22).

Table 3. Regression analysis for the cardiorespiratory endurance ($VO_{2max}$)

| R=.52; $R^2$=.27; Adj.R=.25 F(4.124)=11.60; p=.00; SEE=2.55 | B | SE | Beta | t | p |
|---|---|---|---|---|---|
| Bent arm hang | .03 | .01 | .20 | 2.185 | .031 |
| Shuttle run 10x5m | .23 | .13 | .17 | 2.083 | .039 |
| Sports index | .91 | .39 | .19 | 2.351 | .020 |

| | | | | | |
|---|---|---|---|---|---|
| Standing broad jump | .02 | .01 | .19 | 2.041 | .041 |

Based on the multiple correlation coefficient value (R = .52; p = .00), there is a statistically significant correlation between the predictor and criterion variables $VO_{2max}$ (Table 3). The value of the determination coefficient shows that the predictors explain 27% of the variance of the criterion variable, i.e., according to the corrected coefficient of determination 25% of the variance of the criterion variable. The bent arm hang has the highest partial impact (BETA = .22; p = .031), followed by the sports index (BETA = .19; p = .020), standing broad jump (BETA = .19; p = .041), and shuttle run 10x5 m (BETA = .17; p = .039).

## Discussion

This research has found an association between $VO_{2max}$ and BMI, motor skills, and physical activity in sports, faculty, and leisure. The average value of the participants' $VO_{2max}$ (23.70 ml/kg/min) in this research is lower compared to Indian female students (32.10) (Bandyopadhyay, 2013), as well as American 16-year-olds (34.2) (Gutin, Yin, Humphries, & Barbeau, 2005), Colombian 17-year-olds (32.70) (Ramos-Sepúlveda, Ramírez-Vélez, Correa-Bautista, Izquierdo, & García-Hermoso, 2016), and sedentary women aged 17-24 from Brazil (35.6) (Herdy & Uhlendorf, 2011). Norwegian women aged 20-29 show twice the average values (43.00) (Loe, Rognmo, Saltin, & Wisløff, 2013). The results of the participants in this research are consistent with medical students from India who are not engaged in sports (23.54) (Shete, Bute, & Deshmukh, 2014) and 64-year-old women (22.20) (Ogawa et al., 1992). The BMI shows a negative correlation with all tests that are directly influenced by the mechanism for energy regulation (standing broad jump, bent arm hang, shuttle run 10x5m), $VO_{2max}$ and sports index. Similar results were obtained in research conducted by Rausavljević (1995), which shows the negative impact of body weight and adipose tissue on the performance of motor tests that measure explosive power and the ability to solve complex motor tasks and endurance. Also, in a sample of healthy Israeli women (N = 181) aged 26–65 years, a significant negative correlation was obtained between BMI and $VO_{2max}$ (r = −.514) (Dagan, Segev, Novikov, & Dankneret, 2013). It seems that higher body fat mass can affect the result in the 20m shuttle run test. Goran, Fields, Hunter, Herd, and Weinsier (2000) stated that fat mass is partly metabolically inactive and constitutes an additional load to carry, increased fat mass will decrease $VO_{2max}$, and excess fatness has a detrimental effect on submaximal aerobic capacity. It is also possible that increased fat mass will increase the oxygen cost of running at any given speed relative to the total body mass (Olds, Ridley, & Tomkinson, 2007), and peripherally located fat mass (on the arms and legs) increases both rotational and translational kinetic energy (Cavanagh & Kram, 1989). Also, the results in the 20m shuttle run test can depend on psychosocial factors, e.g., motivation, effort, and self-efficacy (Tomkinson et al., 2017).

The results of the regression analysis show that 27% of the $VO_{2max}$ variance was explained by the bent arm hang, standing broad jump, and shuttle run 10x5m tests and the sports index. Similar results on a large sample of Lithuanian children (N = 15,200) aged 11 to 18 years were obtained in research (Venckunas, Mieziene, & Emeljanovas, 2018) in which the highest association of the 20m shuttle run test was obtained with standing broad jump and shuttle run 10x5m test, and each of them explains 10% of the variance of cardiorespiratory capacity, while the bent arm hang test showed a slightly smaller share of the variance of 7%. According to the determination coefficient (r

$^2$), the standing broad jump test shows 15%, the bent arm hang shows 16%, and shuttle run 10x5m shows 11% of the variance of the 20m shuttle run test. An explanation for the significant impact of these tests could be found in similar patterns of movement in shuttle run tests and the involvement of the same muscle groups (leg extensors) that are important for locomotion, especially when accelerating and slowing the whole body. Also, Zamparo, Zadro, Lazzer, Beato, and Sepulcri (2014) state that cardiorespiratory parameters increase in shuttle run tests of 180° direction change, which is more demanding, and are the same effective means of improving $VO_{2max}$. From the domain of physical activity, only the sports index showed significant predictive value in explaining the $VO_{2max}$ variance, and according to the correlation coefficient ($r^2$), 11% of $VO_{2max}$ variance can be explained by moderate to high intensity physical activity. The Baecke questionnaire showed satisfactory validity of the sports index and total physical activity compared to accelerometry, and it can be used to assess moderate to high physical activity in adults (Garcia, Osti, Ribeiro, & Florindo, 2013). A lower proportion of the total variance (5.7%) of $VO_{2max}$ and self-assessed physical activity are reported by Loe et al. (2013). In a large sample of 8,002 children aged 10–16 years, physical activity measured by the questionnaire accounted for 36% of the $VO_{2max}$-20mshutle run test variance (Newill, Duncan, & Sandercock, 2020). Similar correlation coefficients (r = .30) between cardiorespiratory endurance and moderate PA measured by accelerometers were obtained by the research carried out by Gutin et al. (2005). In the same research, the authors reported a higher correlation (r = .45) of $VO_{2max}$ and high-intensity PA. In the sample of women (N = 181) aged 26-65 only age, hours of training per week, and weekly caloric expenditure in physical activity were significantly associated with the cardiorespiratory fitness level (20% of the total CRF variance explained). In research by Dagan et al. (2013), on a sample of 123 women aged 60 to 91 years, the physical activity examined with the Baecke questionnaire was not significantly associated with $VO_{2max}$. The sample of Brazilian male students at the Faculty of Kinesiology did not show significant correlations between $VO_{2max}$ and physical activity domains, nor the overall result of the Baecke questionnaire due to homogeneity of $VO_{2max}$ values, because the average group value was high with small variations, which impaired the analysis (Florindo & Latorre, 2003).

## Conclusions

The low average values of the female students' $VO_{2max}$ in this research can be explained by the COVID-19 pandemic because organized forms of indoor exercise were prohibited in the year prior to the testing, followed by a lack of contact classes in Kinesiology at the faculty, i.e., all classes were conducted online. Also, their movement in the social environment was reduced, and thus the time spent in sedentary activities was certainly increased. We can assume that only highly motivated individuals engaged in moderate to high intensity physical activity. On the other hand, the results in the 20m shuttle run test can depend on other parameters, such as mechanical efficiency, anaerobic capacity, agility, fat mass, as also motivation and effort. All of this may have affected the results of the association between $VO_{2max}$ and the body mass index, motor ability, and physical activity level in this research.

The testing of motor and cardiorespiratory fitness should be conducted throughout higher education in order to obtain feedback about their status and, finally, education about the consequences of an inactive lifestyle, as well as motivation to increase physical activity from moderate to high intensity.

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# Povezanost motoričkih sposobnosti, tjelesne aktivnosti i kardiorespiratorne sposobnosti

## Sažetak

Kardiorespiratorna sposobnost je dimenzija tjelesnoga zdravlja povezana s tjelesnom aktivnošću tako da dovodi do mnogih zdravstvenih beneficija poput prevencije različitih kroničnih nezaraznih bolesti. Cilj ovoga istraživanja bio je utvrditi povezanost motoričkih sposobnosti, tjelesne aktivnosti i kardiorespiratorne sposobnosti. Uzorak ispitanika činilo je 129 studentica Učiteljskog fakulteta Sveučilišta u Zagrebu – Odsjeka u Čakovcu, prosječne dobi 21 ±0,12 godine. Prediktorski skup činile su varijable indeks tjelesne mase, zatim 7 Eurofit testova za procjenu motoričkih sposobnosti (agilnost – trčanje 10 x 5 m; fleksibilnost – pretklon u sjedu; brzina frekvencije pokreta – taping rukom; repetitivna snaga trupa – podizanje iz sjedu u 30 s; statička snaga ruku – izdržaj u visu zgibom; ravnoteža – flamingo test; eksplozivna snaga nogu – skok u dalj s mjesta) te tri indeksa tjelesne aktivnosti Baeckeova upitnika (indeks sporta, slobodnoga vremena i fakulteta). Kriterijsku varijablu za procjenu kardiorespiratorne sposobnosti činio je Beep test. Rezultati su izračunati regresijskom *stepwise* metodom. Pearsonovi koeficijenti korelacije između kardiorespiratorne izdržljivosti i motoričkih sposobnosti, indeksa tjelesne mase te indeksa tjelesnih aktivnosti pokazale su niske do umjerene povezanosti. Kardiorespiratorna izdržljivost značajno negativno korelira s indeksom tjelesne mase, a pozitivno s indeksom sporta i slobodnoga vremena te varijablama za procjenu statičke snage ruku, agilnosti, repetitivne i eksplozivne snage nogu. Međutim, regresijska analiza je pokazala da su značajni prediktori u objašnjenju varijance kardiorespiratorne sposobnosti varijable izdržaj u visu zgibom (BETA = .28; p = .00), indeks sporta (BETA = .21; p = .01) i trčanje 10 x 5 m (BETA = -.20; p = .02) kojima je objašnjeno 23 % varijance kriterijske varijable. Ovo istraživanje pokazuje da je kardiorespiratorna sposobnost općenito povezana s indeksom tjelesne mase, tjelesnim aktivnostima u sportu i slobodno vrijeme te motoričkim sposobnostima energetske regulacije kod studentica. Međutim, izdržaj u visu zgibom, indeks sporta i trčanje 10 x 5 m smatrani su najvažnijim prediktorima za kardiorespiratornu izdržljivost.

***Ključne riječi***

*kardiorespiratorna sposobnost; motoričke sposobnosti; tjelesna aktivnost*

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