Acta Kinesiologica 17 (2023) Issue.2
DOI. 10.51371/issn.1840-2976.2023.17.2.7

Original Investigation

Macroregional Differences in Cardiorespiratory Fitness in Croatian Primary School Children

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Purpose: Cardiorespiratory fitness (CRF) is an important indicator of health. Previous studies have shown that regional affiliation and the socioeconomic development of the area significantly influence the development of CRF. The aim of this research was to identify whether there are any differences in CRF among primary school children based on the macro-region in which they live.
Methods: The study in-cluded 651 fourth-grade students from primary schools in the Republic of Croatia, aged 10.30±0.47 years. The sample of children was divided into three macro-regions of the Republic of Croatia (Continental, City of Zagreb, Adriatic). The CRF was assessed using the 20-meter shuttle run test.
Results: The results indicate that children living in the region encompassing the city of Zagreb have significantly better results (45.77) in terms of maximal oxygen uptake (VO_{2max}), which is used to assess CRF, compared to students coming from the Continental region (44.31). Students from the Adriatic macro-region have significantly better results (45.34) compared to those from the Conti-nental macro-region. There was no statistically significant difference observed between students from the city of Zagreb and the Adriatic macro-region.
Conclusions: There is a great need to introduce physical exercise programs that affect the development of cardiorespiratory capacity in the Continental part of the Republic of Croatia, where it has been observed that students have a significantly lower level of cardiorespiratory fitness. There is a need to continue research that evaluates aerobic capacity in children and young people, and it should be based on direct measurements of aerobic capacity, by means of which more relevant data would be obtained, primarily on the values of maximum oxygen intake.

Keywords: exercise physiology; physical fitness; relative age effects; students; young people.

Introduction

Cardiorespiratory fitness (CRF) measures the body's ability to deliver and utilize oxy-gen for energy transfer, supporting muscle activity during physical exercise[1]. Higher values of cardiorespiratory fitness in childhood and adolescence are strongly associated with the current level of health, but also with a great prediction of health in the future [2]. Low levels of cardiorespiratory fitness in adolescence increase the risk of mortality in adulthood [3]. Furthermore, it is associated with unfavorable cardiometabolic risk factors in both children and adolescents [4,5]. Aerobic capacity correlates with high levels of daily physical activity and is used as an indicator to assess children's health [6]. Physical activity, health, and quality of life are closely interconnected. The human body is designed for movement, and regular physical activity is necessary for its optimal functioning and disease prevention [7]. Cardiorespiratory fitness reflects the overall capacity of physiological systems (cardiovascular, respiratory, metabolic, and neuromuscular) during continuous and dynamic physical exercise involving large muscle groups at moderate to high intensity levels over extended periods. The usefulness of cardiorespiratory fitness lies in it being one of the indicators of the health index [8]. Aerobic capacity is directly linked to the integrated functions of numerous systems in the body, making it a reflection of overall bodily health [9]. It is an important clinical parameter for diagnosing and monitoring the current and future functional and metabolic health of obese youth, and it is compromised in overweight children and adolescents due to low levels of physical activity [10]. CRF may be a strong population health indicator and surrogate measure that could help researchers and public health officials understand the health of children and youth and how health varies across these populations [11]. A higher level of aerobic capacity during childhood and adolescence is associated with a lower body mass index and reduced body fat in later life [12]. Research has shown that maintaining an optimal level of aerobic capacity in obese individuals keeps them metabolically healthy and reduces the risk of developing cardiovascular diseases [13,14]. The American Heart Association states that cardiorespiratory fitness should be regularly assessed as the fifth clinical vital sign for predicting human health and longevity, alongside breathing, body temperature, pulse, and blood pressure [9].

Cardiorespiratory fitness is influenced by many factors, including the regional environment factor, and it is believed that 50% of the variance in CRF can be attributed to hereditary factors [15]. Cardiorespiratory fitness can be improved in most people by regular physical activity of moderate to vigorous intensity [16]. In the Republic of Croatia, according to the data from the State Bureau of Statistics based on HR_NUTS 2021 - HR NUTS 2, it can be seen that the total gross domestic product (GDP) is higher in the city of Zagreb compared to the GDP of the Adriatic region and nearly twice as high as the Northern and Pannonian regions, which are included in the Continental macro-region in this study [17]. Some previous studies have found that in regions with lower socioeconomic status (SES), children tend to participate less in physical activity and have lower cardiorespiratory fitness levels. Depending on geographical, cultural, and socio-economic factors, unique lifestyles are developed, although the lives of young people in developed countries are generally characterized by the modern information era [18]. Many factors influence cardiorespiratory fitness, with regional environmental factors being particularly significant. The results of studies on the cardiorespiratory fitness of children and adolescents at different geographical latitudes are still inconsistent, and little is known about differences and temporal trends in cardiorespiratory fitness among children and adolescents at various latitudes within the same country [19]. In European countries, children and adolescents in northern and central countries tend to have better cardiorespiratory fitness than their southern counterparts[20]. Findings of increasing geographical disparities in cardiorespiratory fitness suggest a rise in geographical health disparities among the Japanese population [21]. The aim of this study is to determine whether there are differences in aerobic capacity among primary education students based on the macro-region in which they live.

Methods

Participants

The research used a sample of fourth-grade students from primary schools in the Republic of Croatia. The total sample size consisted of 651 students, stratified territorially into three macro-regions of the Republic of Croatia. According to the new NUTS-2 classification from 2021, the Republic of Croatia is divided into four statistical regions, whereas in the previous classification, it was divided into two. For the purposes of this study, the sample of participants was stratified into the Continental macro-region, which was formed by merging the Northern and Pannonian regions, the Adriatic region, and the city of Zagreb as a separate macro-region. The Continental macro-region is represented by students attending primary schools in the cities of Čakovec, Bjelovar, and Petrinja. The Adriatic macro-region includes the cities of Rijeka and Split, as well as students from primary schools in the city of Zagreb.

The research was conducted in the period from 05/07-06/10. during the 2021/2022 school year. All students involved in the research were in good health. Students who had established health problems were not included in the implementation of the research and, in agreement with the teachers, they were not granted consent to participate in the research. Students who signed parental consent to participate in the research were included in the study. After the distribution of the parents' informed consent, 30% of the students did not return the signed parental consent to participate in the study and they were excluded from further research. Given that the research in each class section was conducted for the duration of 2 school hours of physical education, students who did not perform one measurement were also excluded from the further procedure.

Testing

The research was conducted in sports school halls in the morning hours during the physical education class. Schools had to have a space with a minimum length of 22 meters, which was a prerequisite for conducting research. Before the actual procedure, the researchers described and demonstrated the test procedure. The process itself began with a dynamic warm-up and stretching exercises for the students lasting 10 minutes. After that, the students were divided into groups of 8 subjects. The measurement was performed in one attempt. Testing for the subject is complete when he fails to reach the finish line before the audio signal on two consecutive occasions, thereby shutting him off and the examiner entering his score on run intervals and levels into the prescribed form.

Body height was measured using a portable stadiometer (Seca® 213, Hamburg, Germany), and body weight was measured using a dual-frequency body composition analyzer (TANITA DC-360P) based on the principles of bioelectrical impedance.

Aerobic capacity was assessed using the multi-stage 20-meter shuttle run test (20MSRT Shuttle run test). In this field test, participants ran back and forth between two designated lines set 20 meters apart. The running speed started at 8.5 $km \cdot h^{-1}$ and increased by 0.5 $km \cdot h^{-1}$ every minute. Each stage lasted approximately 60 seconds, with the "speed" (duration of each interval) dictated to the participant by audible signals [22].

In epidemiological studies, indirect field tests are mainly carried out because they usually require low costs, short execution time and simplicity of simultaneous application to a large number of individuals [23]. A progressive increase in speed takes place at each level by reducing the interval of sound signals, and the number of intervals run increases in accordance with the increase in running speed. The speed of the last successfully completed phase is evaluated as the VO_{2max} index.

The maximum oxygen consumption (VO_{2max}, $mL \cdot kg^{-1} \cdot min^{-1}$) was calculated using the equation $VO_{2max} = 31.025 + 3.238(S) - 3.248(A) + 0.1536(A \cdot S)$, where S represents the speed in kilometers per hour at the end of the test, and A represents age in years [24]. This equation is suitable for boys and girls aged 8 to 19 years and can be calculated using an online calculator [25].

Data analysis

During the data analysis of morphological measurements and the assessment of aerobic capacity, descriptive statistics were used to obtain basic statistical indicators, including Mean (AS), Standard Deviation (SD), Minimum result (MIN), Maximum result (MAX), Kurtosis (KURT), Skewness (SKEW). The normality of the data distribution was tested using the Kolmogorov-Smirnov test, while the homogeneity of variance was assessed using Levene's test. Significance of differences between subgroups based on macro-regional membership and aerobic capacity was tested using univariate analysis of variance (ANOVA). For variables that showed statistically significant F-values indicating differences between group means in further analysis, the Scheffe post hoc test was applied. In cases where Levene's test indicated significant differences in variances, the ANOVA Welch F test, which does not assume equal variances, was used to determine differences between group means, and the Mann-Whitney U test was applied. Statistical significance was tested at a significance level of $P < .05$. Data processing was performed using STATISTICA version 14.0.0.15 by TIBCO Software Inc.

Results

Table 1. The number of participants according to gender, age, and macro-region.

Gender	Number	Percentage	Age (years)
Girls	316	48.5 %	10.30 ± .47
Boys	335	51.5 %	10.34 ± .49
Total	651	100 %	10.38 ± .50
Region	**Number**	**Percentage**	
Continental	202	31.0 %	
City of Zagreb	221	34.0 %	
Adriatic	228	35.0 %	
Continental	651	100 %	

The results in Table 2 display descriptive values of the analyzed variables. It is evident that boys and girls show similar values for body height. Similar results can be seen for weight.

Table 2. Descriptive indicators of morphological characteristics and aerobic capacity in the sample of fourth-grade students.

Variables	Mean±SD	MIN	MAX
Height (cm) - Male (*n*=335)	147.50 ± 6.85	124.60	167.50
Height (cm) - Female (*n*=316)	148.37 ± 7.58	128.10	174.00
Height (cm) - Total (*n*=651)	147.92 ± 7.23	124.60	174.00
Weight (kg) - Male	41.62 ± 10.42	21.90	82.60
Weight (kg) - Female	40.40 ± 9.36	25.30	74.30
Weight (kg) - Total	41.03 ± 9.93	21.90	82.60
Maximum Oxygen Uptake (VO_{2max}, $mL·kg^{-1}·min^{-1}$) - Male	45.79 ± 4.33	37.90	58.30
Maximum Oxygen Uptake (VO_{2max}, $mL·kg^{-1}·min^{-1}$) - Female	44.50 ± 2.95	40.00	54.50
Maximum Oxygen Uptake (VO_{2max}, $mL·kg^{-1}·min^{-1}$) - Total	45.16 ± 3.78	37.90	58.30
Distance Run (meters) - Male	542.33 ± 323.72	60.00	1520.00
Distance Run (meters) - Female	428.92 ± 210.35	80.00	1260.00
Distance Run (meters) - Total	487.28 ± 280.19	60.00	1520.00

Table 3 presents the results of the analysis of variance (ANOVA) showing statistically significant differences between groups defined by the macro-region they live in for variables assessing aerobic capacity or cardiorespiratory fitness (*P*= .01).

Table 3. Results of the analysis of variance (ANOVA) to determine differences in aerobic capacity level based on the macro-region.

Variables	ANOVA F	*P*	ANOVA Welch F	Welch *P*
Aerobic capacity - VO_{2max}	8.41	.01*		
Aerobic capacity - Distance run			7.83	.01*

Maximum Oxygen Uptake - Vo_2max; F = Coefficient of Analysis of Variance; *P*= Level of statistical significance; at the level of *P*= .05* F-Welch F value; *P*= Welch value; *at the level of error *P* < .05.

The results of the Scheffe post hoc test are shown in Table 4. The variable analyzed evaluates aerobic capacity based on the results of maximum oxygen uptake (VO_{2max}) and was found to be statistically significant. The results indicate that students living in the Continental macro-region of Croatia have significantly lower levels of aerobic fitness compared to students living in the city of Zagreb (*P*= .01). Similarly, it is evident that students living in the Continental macro-region have significantly lower aerobic fitness levels compared to students living in the Adriatic macro-region of Croatia (*P*= .02). The Scheffe test results between students living in the city of Zagreb and those living in the Adriatic macro-region do not show significant differences in aerobic capacity (*P*= .48) based on the values of maximum oxygen uptake (VO_{2max}).

Table 4. Results of the Scheffe post-hoc analysis to determine differences in aerobic capacity between groups based on the macro-region.

AEROBIC CAPACITY -VO_{2max}	Mean±SD (mL/kg/min)	Scheffe *P*-value
Continental - City of Zagreb	44.31 ± 3.58 - 45.77 ± 3.81*	.01
Continental - Adriatic	44.31 ± 3.58 - 45.34 ± 3.79*	.02
City of Zagreb - Adriatic	45.77 ± 3.81 - 45.34 ± 3.79	.48

Mean = mean value; SD = standard deviation; * at the level of *P* < .05.

Table 5 shows the results of the Mann-Whitney test for differences in the distance covered by the surveyed students according to the macro-region they live in. Significant differences are evident between participants living in the city of Zagreb, who have better results compared to those from the Continental region. Additionally, it can be noticed that participants from the Adriatic region have significantly better results than those from the Continental region.

Table 5. Results of the Mann-Whitney test to determine differences in the distance covered between groups based on the macro-region.

Aerobic capacity - distance covered(m)	Distance covered (Mean±SD)	U	Z	*P*
Continental- City of Zagreb	425.45 ± 266.17 – 527.06 ± 294.93*	17148.50	-4.12	.01
Continental-Adriatic	425.45 ± 266.17 – 503.51 ± 269.37*	18312.00	-3.67	.01
City of Zagreb -Adriatic	527.06 ± 294.93 – 503.51 ± 269.37	24540.50	0.48	.63

Mean = mean value; SD = standard deviation; U= *U* value; Z= Z value; *P*= *P* value; * at the level of *P*=.05.

Discussion

In line with the research objective, which aimed to determine differences in aerobic capacity among the surveyed students based on the macro-region they live in, the analysis of variance revealed significant differences between the examined subgroups. Students living in the region encompassing the city of Zagreb demonstrated significantly better results (45.77) in maximum oxygen uptake (VO_{2max}), used to assess CRF, compared to students belonging to the Continental region (44.31). Additionally, participants from the Adriatic macro-region exhibited significantly better results (45.34) compared to those from the Continental macro-region. There was no statistically significant difference between students from the city of Zagreb and the Adriatic macro-region. When examining the results concerning the differences in the distance covered by the examined students, the same differences were observed. Students from Zagreb and the Adriatic region covered significantly more meters than students from the Continental region. This result was expected, considering the high correlation between the distance covered and maximum oxygen uptake (VO_{2max}).

In line with this, it is evident that in this research, participants from the southern region of Croatia achieved better or equal results compared to those living in the central and northern areas of the country. Conversely, opposite results were obtained in a study conducted on Chilean children. Significant geographical differences in cardiorespiratory fitness were observed, with the highest values of maximum oxygen uptake (VO_{2max}) in the northern and central regions of the country[26], while the southern regions showed lower levels of cardiorespiratory and motor fitness. Authors attributed these significant geographical differences to risk factors related to economic development or climate. Zhang et al. [19] observed similar differences in a study of Chinese children aged 10. They found that boys in northern China had lower aerobic capacity compared to participants living in southern or central regions. Similar differences were observed in 11-year-old girls, while there were no significant differences in 10-year-old girls. The study also showed that as age increases, CRF decreases, and the decline is smaller in the central region of China compared to the northern and southern regions. After comparing the results of the 20-Meter Shuttle Run Test for children and adolescents in 50 countries [11], it was discovered that aerobic capacity in children and adolescents exhibits different trends in developed and developing countries. In developing countries, children and adolescents living in central and northern regions tend to have better results in the 20-Meter Shuttle Run Test compared to those in southern regions. Welk, Saint-Maurice, and Csányi [27] found in their study of Hungarian students that there is a statistically significant difference in aerobic capacity between regions, with regions showing better socioeconomic status also demonstrating better results in aerobic capacity. When looking at the results of differences in aerobic capacity, it is evident that students living in economically developed regions, primarily referring to the city of Zagreb and the Adriatic region, have better results than students residing in the Continental region of Croatia, classified as a less economically developed region. Possible reasons for this could be the fact that in Zagreb and in Rijeka and Split, which represent the Adriatic macro-region, students have better conditions for physical activity, and the parents' attitudes toward physical activity are more pronounced in upbringing compared to cities in the Continental macro-region. The obtained results align with previous research worldwide, where it has been demonstrated that socioeconomic conditions significantly influence the development of aerobic capacity. Certainly, the influence of climate conditions should not be disregarded, as it can be a strong predictor in the development of aerobic capacity. Most interpretations of differences in physical fitness focus on climate, genetic, and ingrained socio-cultural differences [18]. It has been demonstrated that children living in areas with higher air temperatures tend to have better aerobic capacity results [28]. The reason for this can be attributed to the fact that they have more opportunities to engage in outdoor physical activities in nature. The results of maximal oxygen consumption (VO_{2max}) show values of 45.79 $mL \cdot kg^{-1} \cdot min^{-1}$ for boys and 44.50 $mL \cdot kg^{-1} \cdot min^{-1}$ for girls. These results are higher than the suggested thresholds to avoid the risk of cardiovascular diseases. Ruiz et al.[5] mention a range of up to 41.8 $mL \cdot kg^{-1} \cdot min^{-1}$ for boys and 34.6 $mL \cdot kg^{-1} \cdot min^{-1}$ for girls. Ruiz et al.,[5] state that results below 42.0 $mL \cdot kg^{-1} \cdot min^{-1}$ in boys and 35.0 $mL \cdot kg^{-1} \cdot min^{-1}$ in girls are dangerous.

The results of cardiorespiratory capacity research were obtained based on CRF assessment using a multi-stage progressive 20-m shuttle run test. To predict maximum oxygen consumption, a predictive equation can be used, which is recognized as one of the best indicators of aerobic fitness[29]. Given that the comparison of our research with previous research is based only on the use of the 20m shuttle run test and no attention was paid to the predictive equations used in these studies, it can be believed that there are differences in these analyzes of the obtained results. In our research, a predictive equation according to [22] was used, which showed a good adequacy for the assessment of maximum oxygen intake in school-aged children[29]. while comparative studies[26,27] used equations created according to the FITNESGRAM standard and which were developed based on BMI results and gender of the subjects. The strength of this research lies in the fact that it is the first major study on the population of primary school students examining CRF with respect to the macro-regional division in the Republic of Croatia. However, there are some limitations to the study. The sample of participants used in this research was not entirely representative, as it was drawn from larger urban centers. Additionally, nearly 30% of students did not receive parental consent to participate in the study, which may be attributed to the choice of the 20-meter shuttle run test. Some students or their parents, who personally perceived themselves as having increased body weight or being overweight, did not want to participate in this research, which could ultimately have influenced the CRF results. This is just an assumption that can be argued based on the fact that other measurements conducted, as well as the questionnaire, did not require a high physical load, except for the mentioned test for assessing CRF. Furthermore, a limitation is that the performance in the 20-meter shuttle run test (20MSRT Shuttle run test) is highly influenced by motivation, and therefore, some results may have been lower than the participants' actual capabilities.

Practical Applications

The analyzed research results will contribute to the development of optimal programs and strategies aimed at increasing physical activity levels among students with the goal of improving aerobic capacity as a factor in enhancing the health of young people. The results have practical implications in the field of public health, as well as for actions aimed at increasing cardio respiratory capacity and reducing obesity, which is a significant health issue in the Republic of Croatia.

Conclusions

It is extremely important to provide children in the Republic of Croatia with access to organized physical exercise throughout the country, and not only for children in larger urban centers. Also, it is important to start introducing an additional program of physical exercise that affects the development of cardiorespiratory capacity, especially in schools in the continental part of the Republic of Croatia, where it was observed that students have a significantly lower level of cardiorespiratory fitness. Schools as institutions can be places where cardiorespiratory fitness monitoring would be carried out systematically and continuously, and based on these results, specific strategies can be defined for launching public health actions with the aim of raising the level of physical fitness and physical activity among children and young people, regardless of the region to which they belong.

Acknowledgments

The authors gratefully thank the pupils for their cooperation during the study.

Ethical Committee approval

The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board of University of Zagreb, Faculty of Teachers Education (Reg. No.:251-17-22-1, date of approval 17.01.2022.).

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Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Topic

Sport Science.

Conflicts of interest

The authors have no conflicts of interest to declare.

Funding

This research received no external funding.

Declaration if used ChatGPT

We don't used ChatGPT.

Author-s contribution

Conceptualization, M.B. and L.R.; methodology, I.P.; software, I.P.; validation, M.B., L.R..; formal analysis, M.B.; investigation, L.R.; resources, I.P.; data curation, I.P.; writing—original draft preparation, L.R; writing—review and editing, M.B; visualization, L.R.; supervision, I.P.; project administration, L.R.; funding acquisition, L.R. and M.B.; All authors have read and agreed to the published version of the manuscript.

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Received: 28.11.2023
Accepted: 18.12.2023.
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