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Biological and Social Determinants of Maximum Oxygen Uptake in Adult Men

Stanisław B. Nowak, Andrzej Jopkiewicz, and Paweł Tomaszewski

Abstract

The maximum rate of O_2 uptake ($\dot{V}O_2$max) is one of the most important positive indicators of health. While the $\dot{V}O_2$max decreases with age, reducing the capacity for physical effort, it can be considerably upregulated through optimal environmental interventions, including systematic physical activity. This study seeks to determine variations in the cardiorespiratory function, estimated from the level of $\dot{V}O_2$max, in 798 employed men aged 20–59, according to biological (age, physical activity, body mass index (BMI), and limb muscle strength and agility) and social (place of residence, education, occupation, economic status, and smoking) predictors. We found that the variables abovementioned, with the exception of smoking and hand strength, were significant predictors of $\dot{V}O_2$max in univariate logistic regression, with age (OR = 0.52; 95%CI 0.47–0.57) and BMI (OR = 0.91; 95%CI 0.90–0.93) having the greatest effect on $\dot{V}O_2$max. The additional predictors, established in multivariate analysis, were the place of residence, education, and hand and arm strength. The multivariate model was fairly well-fitted (Nagelkerke r^2 = 0.54) and had a satisfactory prognostic value, with over 80% of cases classified correctly. Social variance in the $\dot{V}O_2$max makes it desirable to develop and implement the intervention programs with physical activity dedicated for men, especially men who are over the age of 50 years and have an excessive body mass, as this could reduce the risk of disorders and help improve the quality of life and workplace effectiveness of this group.

Keywords

Cardiorespiratory function · Health indicators · Maximum oxygen uptake · Physical activity · Quality of life

S. B. Nowak (✉)
Department of Physical Education, Kazimierz Pulaski University of Technology and Humanities in Radom, Radom, Poland
e-mail: snowak@uthrad.pl

A. Jopkiewicz
Department of Auxology, Jan Kochanowski University in Kielce, Kielce, Poland

P. Tomaszewski
Department of Biometry, Jozef Pilsudski University of Physical Education in Warsaw, Warsaw, Poland

1 Introduction

In today's era, the biology of the human body is increasingly at risk due to a lack of physical activity and the consequences thereof, in particular, resulting in overweight and obese condition. We are observing a steady shift from an active lifestyle in the external environment, which has been natural for the human race, toward a sedentary lifestyle in the enclosed spaces (O'Keefe et al. 2010; Malina and Litle 2008), even though the beneficial effect of aerobic exercise on the body is an evolutionary acquisition (Rowe et al. 2014). Endurance-based exercise, involving prolonged walking and running, has played a key role in human evolutionary history, and our species is distinguished from other primates in this respect (Mattson 2012).

Despite the fact that aerobic activity involves a high energy expenditure and fatigue, nature has programed the human body to feel pleasure during and after exercise, which is often expressed as a feeling of "runner's high". This is related to the activity of the reward brain center, resulting from an increase in the amount of endocannabinoids that lead to mood improvement. Thus, natural selection, through the endocannabinoid system, has helped motivate human beings to perform physical exercise, which in turn has not only ensured human survival but has also been crucial in anthropogenesis (Raichlen et al. 2012).

Today, the role of physical exercise as a predictor of survival has considerably decreased, and even the neurobiological rewards are not enough to encourage physical activity. Nonetheless, regular aerobic exercise is indisputably related to good health and longevity; whereas the opposite is true for a sedentary lifestyle, which leads to various health issues and premature mortality (Després 2016; Laukkanen et al. 2016; Arem et al. 2015; Gebel et al. 2015; Hupin et al. 2015; Blair 2009). A shift from a traditionally active lifestyle to a sedentary one is a global phenomenon. Types of physical activity requiring large energy expenditures (heavy physical labor and traveling on foot) have been replaced with low-energy forms of activity (office work and mechanized travel) (Katzmarzyk and Mason 2009).

The World Health Organization classifies physical inactivity as the fourth leading cause of global mortality and the primary cause of many chronic disorders (WHO 2009). The term physical activity transition has been coined to underline this harmful tendency, which is particularly dangerous to the health of children and youth (Katzmarzyk and Mason 2009). The yearly health costs resulting from a low level of physical activity are estimated to exceed $67 billion globally, and a sedentary lifestyle causes about 5 million deaths *per* year (i.e., almost 10% of the deaths not resulting from violence) (Ding et al. 2016). Hallal et al.'s (2012) analysis of the data collected from 122 countries shows that over 31% of adolescents and adults aged over 15 years are physically inactive. The inactivity is more common in wealthy countries and among women and elderly persons, and it factors in the development of noncommunicable diseases (Dumith et al. 2011). Age, sex, health, obesity, self-efficacy, and motivation are other factors associated with the level of physical activity. The evidence shows that the availability of a sport and recreation infrastructure close to one's place of residence has a positive causal relationship with the level of physical activity among both youths and adults (Smith et al. 2017; Bauman et al. 2012).

One of the best measures of functional efficiency is the maximal oxygen uptake ($\dot{V}O_2max$). Oxygen requirement of the working muscles is an objective indicator of the cardiorespiratory function (CRF) related to habitual physical activity. The $\dot{V}O_2max$ is an independent, diagnostic, and prognostic health indicator (Lee et al. 2010) that determines predispositions for prolonged aerobic exercise (Kenney et al. 2015; Araújo et al. 2013; Hawkins et al. 2007). Oxygen plays a key role in CRF as it is needed for the conversion of adenosine triphosphate into energy in the muscle cells. Consequently, the greater the oxygen uptake, the more energy can be produced.

$\dot{V}O_2max$ represents the highest rate at which oxygen can be transported and used during aerobic exercise. It denotes the maximum volume of oxygen that a person can process *per* minute. Except the highly trained athletes, the contemporary global population displays a lower $\dot{V}O_2max$ than it could have had (Powell et al. 2011; Sagiv et al. 2007). After the age of about 30 years, the $\dot{V}O_2max$ begins to decrease consistently by about 0.5–0.6 ml/kg/min *per* year, due primarily to evolutionary changes that take place in the cardiopulmonary system and in the muscles. A value approaching 50 ml/kg/min is considered satisfactory for middle-aged men. The lowest relative value of the $\dot{V}O_2$max, required for a full locomotive independence, is about 15 ml/kg/min.

Social determinants of health play a central role in morbidity and mortality among men and contribute to a heath-wise gender disparity (Leone and Rovito 2013; Lee et al. 2010, 2011). Men tend to undertake riskier health behaviors and are more likely to avoid prophylactic care than women do. These differences concern not only the men themselves but also their relatives and may have a negative effect on their participation in the job market (Giorgianni et al. 2013; Kwan et al. 2012; Evans et al. 2011). Therefore, the main aim of this study was to assess differences in CRF based on the $\dot{V}O_2$max of working men aged 20–59 years, according to social and biological predictors.

2 Methods

The study was conducted at several workplaces in the Swiętokrzyskie province in Poland during the spring of 2015. Participants consisted of a cohort of 798 men, stratified into 4 age groups: 20–29, 30–39, 40–49, and 50–59 years. The basic inclusion criterion was a combination of non-probability and random sampling, with priority given to randomly selected workplaces that employed mostly men and to divisions of the provincial vocational training center that conducted training for persons in various occupations who lived in both urban and rural areas and who had different levels of education. The inclusion criteria were a lack of health contraindications for performing a voluntary physical exercise workout. During a qualification interview, the participants were instructed about the scope of the study and were informed that they could opt out at any stage without providing a reason. All measurements were taken before noon, and the workouts were preceded by a warm-up.

The independent variables characterizing the social variation among the study participants were determined using a categorized interview, and they comprised of place of residence (large city, small city, or village), level of education (higher, secondary, or vocational), occupation (involving intellectual or physical labor), financial status (low, average, or good), and smoking habits (non-smoker, occasional smokers, or smokers over six cigarettes *per day*) (Table 1). The biological variables were age as a continuous categorized variable (20–29, 30–39, 40–49, or 50–59 years), BMI (kg/m^2) as a continuous and categorized variable (normal body mass, overweight, or obesity) according to the WHO (2008) classification, and the interview-based level of free-time physical activity categorized into low, moderate, or high. Physical activity was assessed on the basis of the number of days *per* week in which the participant performed at least 30 min of intense physical exercise (as a one-time exercise or a sum of the exercise periods for at least 10 min), i.e., the exercise that would create a feeling of tiredness. The applied measure of physical activity was the number of minutes spent on exercise in a week multiplied by the average intensity of exercise expressed in MET (metabolic equivalent). 1 MET corresponds to oxygen uptake during rest and amounts to 3.5 ml O_2/kg/min (Zhang et al. 2003; Araújo et al. 2017). Physical activity was stratified into three groups, according to the method of Lakoski et al. (2011): low (1–449 MET/min/week), moderate (450–749 MET/min/week), and high ($\geq$750 MET/min/week). In addition, several indices of motor ability were taken into account, such as static handgrip strength, static arm strength, dynamic leg strength, and overall agility (a component of speed, involving the coordination of body maneuverability), where:

- Static grip strength of the dominant hand was measured to an accuracy of 1 kg using a hydraulic manual dynamometer.
- Dynamic arm strength was measured based on the number of flexions and extensions of the arms performed within 30 s during exercise with a front support.

Table 1 Characteristics of the study participants according to aerobic capacity ($\dot{V}O_2max$); numbers (%) of participants and means ±SD are provided for the qualitative and continuous variables, respectively

Variable	$\dot{V}O_2$max below median (<33.0 ml/kg/min) (n = 400)	$\dot{V}O_2$max above median (>33.0 ml/kg/min) (n = 398)	Total (n = 798)
Age (years)	44.5 ± 10.1	34.8 ± 9.9	39.7 ± 11.1
20–29	42 (10.5)	128 (32.2)	170 (21.3)
30–39	74 (18.5)	141 (35.4)	215 (26.9)
40–49	136 (34.0)	99 (24.9)	235 (29.5)
50–59	148 (37.0)	30 (7.5)	178 (22.3)
BMI (kg/m^2)[a]	27.1 ± 2.8	23.5 ± 2.2	25.3 ± 3.1
Normal	76 (19.0)	299 (75.5)	375 (47.1)
Overweight	275 (68.7)	96 (24.2)	371 (46.6)
Obese	49 (12.3)	1 (0.3)	50 (6.3)
Place of residence			
Village	76 (19.0)	136 (34.2)	212 (26.6)
Small city	92 (23.0)	82 (20.6)	174 (21.8)
Large city	232 (58.0)	180 (45.2)	412 (51.6)
Education			
Vocational	138 (34.5)	178 (44.7)	316 (39.6)
Secondary	144 (36.0)	125 (31.4)	269 (33.7)
Higher	118 (29.5)	95 (23.9)	213 (26.7)
Occupation			
Physical labor	205 (51.2)	272 (68.3)	477 (59.8)
Intellectual labor	195 (48.8)	126 (31.7)	321 (40.2)
Financial status			
Below average	52 (13.0)	79 (19.8)	131 (16.4)
Average	266 (66.5)	266 (66.6)	531 (66.5)
Good	82 (20.5)	82 (13.6)	136 (17.1)
Smoking			
Non-smokers	163 (40.8)	159 (39.9)	322 (40.4)
Occasional smokers	86 (21.5)	70 (17.6)	156 (19.5)
Smokers >6 cigarettes/day	151 (37.7)	169 (42.5)	320 (40.1)
Physical activity			
Low	272 (68.0)	234 (58.8)	506 (63.4)
Moderate	102 (25.5)	122 (30.7)	224 (28.1)
High	26 (6.5)	42 (10.5)	68 (8.5)
Static hand strength (kg)	43.1 ± 8.9	42.8 ± 9.5	42.9 ± 9.2
Dynamic arm strength (n)	13.5 ± 8.3	17.8 ± 8.4	15.7 ± 8.6
Dynamic leg strength (cm)	162.5 ± 36.0	183.6 ± 32.3	173.0 ± 35.8
Agility (s)	28.5 ± 3.3	27.6 ± 3.1	28.0 ± 3.2
$\dot{V}O_2$max (ml/kg/min)	27.5 ± 4.2	40.4 ± 6.5	34.0 ± 8.5
$\dot{V}O_2$max (l/min)	2.2 ± 0.3	2.8 ± 0.4	2.5 ± 0.5

[a]n = 796; two underweight persons were excluded from analysis

- Explosive strength of legs was measured based on a standing long jump (cm).
- Agility was measured based on a zigzag run within a 5 × 3 m area (three laps); the participants had to move around five poles (four in the corners and one in the middle), while the running time was measured to an accuracy of 0.1 s, with the better result from two attempts taken into account.

$\dot{V}O_2$max was determined indirectly using the Astrand test performed on a Monark LC6 cycle ergometer (Monark Exercise AB, Vansbro, Sweden). This test was divided into two stages: 3-min warm-up under a load of 50 W and 5–6-min exercise under a submaximal workload of 100–150 W, performed until the participant's heart rate, measured with a cardiometer, stabilized at 130–160 beats/min. The $\dot{V}O_2$max was then calculated using the Astrand and Ryhming (1954) tables, according to the heart rate, workload, body mass, and age. The participants' characteristics and $\dot{V}O_2$max levels are presented in Table 1.

The results were expressed as means ±SD or numbers and corresponding percentages. Relationships between the qualitative variables were assessed using a chi-squared test; Cramér's *V* was used as a measure of effect size. Groups with a $\dot{V}O_2$max below and above the median (Me) of 33.0 ml/kg/min were selected for the purpose of a logistic regression. Univariate and multivariate models of logistic regressions were used to assess the probability of the occurrence of a higher level of $\dot{V}O_2$max (dependent variable) according to the age, BMI, and social and physical variables (independent variables). Multivariate analyses were conducted using the backward stepwise procedure, with age and BMI analyzed in the categorized forms. For the independent variables, odds ratios (OR) with 95% confidence intervals (CI) were calculated, and the Nagelkerke r^2 was estimated as a measure of effect size. The statistical significance was assumed at $\alpha = 0.05$ for all analyses.

3 Results

Table 2 presents the odds ratios for the occurrence of a higher $\dot{V}O_2$max, estimated through the univariate logistic regression analysis. Significant predictors of the $\dot{V}O_2$max were found to comprise nearly all the variables, with the exception of smoking and static hand strength. The factors that had the largest effect on the $\dot{V}O_2$max were the age and BMI ($p < 0.001$), both with inverse correlations. An increase in BMI by 1 point correlated with a nearly twice as low probability of a higher $\dot{V}O_2$max (OR = 0.52; 95%CI 0.47–0.57), and an increase in age by 1 year correlated with a 10% lower probability of a higher $\dot{V}O_2$max (OR = 0.91; 95%CI 0.90–0.93). Among the oldest participants and the obese participants, the probability of a higher $\dot{V}O_2$max was over 14 times lower (OR = 0.07; 95%CI 0.04–0.11) and 100 times lower, respectively, compared to the younger participants and the participants with a correct body mass. Only 1 in 50 of the obese participants showed a higher $\dot{V}O_2$max, compared to about 75% of the participants with a correct BMI (Table 2). Furthermore, the variables of living in a city and performing intellectual labor correlated with a nearly twice as low probability of a higher $\dot{V}O_2$max (OR 0.5 and 0.49, respectively), compared to the participants that lived in rural areas and performed physical labor. In turn, a higher level of physical activity and better results in the arm flexion test (dynamic arm strength) and the standing long jump test (dynamic leg strength) increased the probability of a higher $\dot{V}O_2$max. For the persons who declared a high level of physical activity, the probability of a higher $\dot{V}O_2$max was nearly twice as high (OR = 1.88; 95%CI 1.12–3.16) compared to those who declared low levels of physical activity. An improvement in the results of the arm flexion test and the standing long jump test by one unit correlated with a 7% and 2% higher probability of a higher $\dot{V}O_2$max, respectively.

The multivariate logistic regression analysis conducted with the backward stepwise method

Table 2 Odds ratios of a higher $\dot{V}O_{2max}$ (> median $\dot{V}O_{2max}$) according to the biosocial variables studied, based on the univariate models of logistic regression (n = 798)

Variable	OR	95%CI	p	Nagelkerke r^2
Age	0.91	0.90–0.93	<0.001	0.25
20–29	1			0.24
30–39	0.63	0.40–0.98	0.04	
40–49	0.24	0.15–0.37	<0.001	
50–59	0.07	0.04–0.11	<0.001	
BMI	0.52	0.47–0.57	<0.001	0.48
Normal	1			0.41
Overweight	0.09	0.06–0.12	<0.001	
Obese	0.01	0.00–0.04	<0.001	
Place of residence				
Village	1			0.04
Small city	0.50	0.33–0.75	<0.001	
Large city	0.43	0.31–0.61	<0.001	
Education				
Vocational	1			0.01
Secondary	0.67	0.49–0.93	0.02	
Higher	0.62	0.44–0.89	0.01	
Occupation				
Physical labor	1			0.04
Intellectual labor	0.49	0.37–0.65	<0.001	
Financial status				
Below average	1			0.02
Average	0.66	0.44–0.97	0.03	
Good	0.43	0.27–0.71	<0.001	
Smoking				
Non-smokers	1			<0.01
Occasional smokers	0.83	0.57–1.22	0.36	
Smokers >6 cigarettes/day	1.15	0.84–1.56	0.38	
Physical activity				
Low	1			0.01
Moderate	1.39	1.01–1.91	0.04	
High	1.88	1.12–3.16	0.02	
Static hand strength	1.00	0.98–1.01	0.594	<0.001
Dynamic arm strength	1.07	1.05–1.09	<0.001	0.09
Dynamic leg strength	1.02	1.01–1.02	<0.001	0.12
Agility	0.92	0.88–0.96	<0.001	0.03

confirmed the correlation between the $\dot{V}O_2$max and age, BMI, education, and place of residence (Table 3). In addition, the dynamic arm strength was found to be a significant predictor of $\dot{V}O_2$max (OR = 1.04; 95% CI 1.02–1.07), and the static hand strength showed a negative correlation with the $\dot{V}O_2$max (OR = 0.96; 95% CI 0.94–0.99) in contrast to the results of the univariate analysis. The other variables were insignificant, and they were not included in the final model. They correlated strongly with the variables included in the model and were thus redundant: physical activity correlated with age ($\chi^2_{6,798} = 50.9$; p < 0.001; Cramér's $V = 0.18$) and education ($\chi^2_{4,798} = 40.3$; p < 0.001; Cramér's $V = 0.16$); occupation correlated with the place of residence ($\chi^2_{2,798} = 78.1$; p < 0.001; Cramér's $V = 0.31$); and financial status correlated with the level of

Table 3 Odds ratios of a higher $\dot{V}O_2$max, (> median $\dot{V}O_{2max}$) according to the biosocial variables studied, based on the multivariate analysis of logistic regression (n = 798)

Variable	OR	OR 95%CI	p	Nagelkerke r^2
Age				0.54
20–29	1			
30–39	0.74	0.41–1.30	0.29	
40–49	0.30	0.17–0.53	<0.001	
50–59	0.08	0.04–0.16	<0.001	
BMI				
Normal	1			
Overweight	0.12	0.08–0.17	<0.001	
Obese	0.01	0.00–0.04	<0.001	
Place of residence				
Village	1			
Small city	0.58	0.32–1.05	0.07	
Large city	0.52	0.32–0.85	0.01	
Education				
Vocational	1			
Secondary	0.47	0.29–0.76	<0.002	
Higher	0.38	0.22–0.65	<0.001	
Static hand strength	0.96	0.94–0.99	<0.004	
Dynamic arm strength	1.04	1.02–1.07	<0.002	

education ($\chi^2_{4,798} = 80.1$; $p < 0.001$; Cramér's $V = 0.22$). Overall, the estimated multivariate model was found to be fairly well-fitted (Nagelkerke $r^2 = 0.54$) and to have a satisfactory prognostic value as over 80% of the cases were correctly classified.

4 Discussion

In this study, we found that significant predictors of the aerobic capacity, based on $\dot{V}O_2$max using, comprised almost all of the variables studied, with the exception of static hand strength. A univariate analysis shows that the largest effect on the $\dot{V}O_2$max was exerted by the BMI, age, and, to a slightly lesser extent, the place of residence and education. These results are in line with the research conducted at the Cooper Clinic in Dallas, Texas, between 2000 and 2010 that investigated the modified and unmodified determinants of the cardiorespiratory function (CRF) (Lakoski et al. 2011). In that research, the strongest clinical factors were determined using a linear regression model. The BMI, age, gender, and physical activity have been found the most important factors related to CRF, accounting for 56% of the variation. Akin to the present study, the BMI was the strongest clinical risk factor related to CRF, alongside unmodified risk factors, such as the participant's age or gender. For the participants with a similar level of physical activity, those with a normal BMI had a higher CRF compared to obese persons. Overall, the data suggest that obesity may negate the benefits of physical activity, even in a healthy population of men and women.

The specifics of a steep decline in peek aerobic capacity in persons undergoing training have been described by Sagiv et al. (2007). Those authors demonstrate that the rate of the muscle strength and aerobic capacity decline, indexed as the peak $\dot{V}O_2$, are key from the viewpoint of quality of life and functional independence. The decline is not constant in healthy adults, as may be assumed from cross-sectional studies showing a 5–10% decline *per* decade of age in untrained persons, but rather, it appreciably increases each decade of age, especially in men. Fleg et al. (2005) have suggested that the rate of decline increases from 3–6% at 20–30 years of age to over 20% *per* decade after the age of 70, and it can also be indexed *per* kilogram of body mass or kilogram of lean body mass.

The effect of social determinants on the $\dot{V}O_2max$ has been shown in a study that compared the population of Tsimané Indians living in Bolivian Amazonia to a highly industrialized Canadian population, a part of the Tsimané Health and Life History Project carried out between 2002 and 2010. The Indians have a considerably higher $\dot{V}O_2max$ and, notably, a lower rate of decline than the Canadians do. The Indians' $\dot{V}O_2max$ is consistent with a high physical activity stemming from farming and contract work (Gurven et al. 2013; Pisor et al. 2013). Living in a rural environment, even the alpine one, and leading a farming-based lifestyle may not be sufficient for a better CRF and physical fitness. Physical activity always needs to have an optimal volume and intensity (Beall et al. 1985). Nonetheless, a lower socioeconomic status of rural population is usually accompanied by a higher level of physical activity and aerobic capacity when compared to better off urban population. This has been confirmed by studies such as the one conducted by Muthuri et al. (2014) among African children, in whom a higher level of physical activity translated into a higher aerobic capacity. That study also demonstrates that a lower education and living in a rural environment associates with a higher $\dot{V}O_2max$ in men than women. However, the effect of various environmental factors, and rather their aggregation as a single factor can never be solely responsible, should be taken into account when considering different social predictors.

Physical activity improves $\dot{V}O_2max$ and consequently health. However, different forms of physical activity promote different physiological changes and different levels of health-related benefits (Pimentel et al. 2003). The type, level, volume, and frequency of physical activity are important considerations. According to the recommendations of the US Department of Health and Human Services (2008), adults should perform 500–1000 MET min/week of moderate-to-intense activity. This volume of activity, which corresponds to 150–300 min of fast walk or 75–150 min of jogging, provides major health benefits. The present study confirm the benefit of physical activity on $\dot{V}O_2max$ as physically active persons had nearly twice as high a probability of achieving a higher level of $\dot{V}O_2max$ compared to persons with low physical activity. However, in multivariate analysis, physical activity appeared an insignificant predictor of $\dot{V}O_2max$, due likely to its correlation with age and education. Nonetheless, it should be noted that even a low level of physical activity is better than no activity at all, and it may result in health benefits if it is appropriately distributed over time (Powell et al. 2011). Hagströmer et al. (2015) have emphasized that all forms of physical activity, including everyday activities, influence health. They have also demonstrated that the risk of mortality among persons who spend 10 h a day in a sedative lifestyle is over 2.5 times greater than among those who limit their sedative lifestyle to 6.5 h a day. Everyday physical activity for more than half an hour may decrease the risk of death by as much as 50%. Post-training changes in $\dot{V}O_2max$ are nonlinear and depend on the exercise intensity and duration and on the frequency and length of a training program.

Huang et al. (2016) have determined the duration and parameters of the optimal aerobic training for healthy older persons who lead a sedentary lifestyle. Such persons should participate in a 30–40-week health improvement training program, carried out in 3–4 training sessions a week. Each session should last 40–50 min and have an intensity amounting to 66–73% of the heart rate reserve. The CRF decreases linearly, and its decline increases after the age of 45 years in both men and women. Maintaining a correct body mass, level of physical activity, and not smoking all distinctly contribute to a higher CRF (Jackson et al. 2009).

A decrease in cardiorespiratory function is due primarily to a sedentary lifestyle, which in turn contributes to increased BMI. Undertaking a physical activity is therefore important for health and quality of life in every stage of ontogenesis, and it appears to be indispensable in older age. The present study, conducted in a large cohort of working men, confirms these issues. A limitation of this study is the use of an indirect method of assessing $\dot{V}O_2$max based on the subject's submaximal heart rate. That caused an arbitrary enforcement of the age-specific decline in CRF, which could introduce inaccuracies. In addition, a cross-sectional study design revealed just the cohort effects, whereas, as suggested by Nussey et al. (2008), changes in $\dot{V}O_2$max could be better explained in longitudinal research due to the issues related to inter-individual heterogenicity and individual aspects of aging.

In conclusion, age and body mass index have the largest effect on cardiorespiratory function, estimated from the level of $\dot{V}O_2$max, in working men aged 20–59, which was confirmed in multivariate analysis using the backward stepwise method. We submit that it would be socially desirable to implement an intervention program involving recreational physical activity dedicated to middle-aged men with overweight or obesity, as that could reduce the risk of illness and improve quality of life and occupational effectiveness.

Conflicts of Interest The authors declare no conflicts of interest in relation to this article.

Ethical Approval All procedures performed in the study were in accordance with the ethical standards of the institutional national and/or research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The study was approved by the Bioethics Committee of the Faculty of Medicine and Health Sciences of the Jan Kochanowski University in Kielce, Poland.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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