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THE INFLUENCE OF ENVIRONMENTAL POLLUTION ON SOMATIC AND FUNCTIONAL DEVELOPMENT OF CHILDREN AND YOUNG PEOPLE FROM THE CRACOW REGION, POLAND[1]

by

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The study was conducted in the Cracow region; a group of 4098 young people was tested, including 2021 girls and 2077 boys aged 7–18, inhabiting the zone around Cracow which is one most severely polluted regions in Poland. The study involved checking the structural and functional traits, height, body mass and oxygen capacity. Motor abilities were measured indirectly through motor fitness tests. To determine how the level of environment pollution may impact upon biological development during the main periods of ontogenesis, the results were calculated for three age groups: 7–10, 11–14, 15–18. The participants were divided depending on the level of contamination in their place of abode : up to 80% above the Polish norm for protected areas, 80–150% above the norm and more than 150% above the norm. The results of earlier tests reveal that these groups did not differ significantly with the social and economical status of their families and motional activity of children (Ambroży 1997). The material was then analysed using basic statistical techniques so as to find the possible relationship between the high contamination level and reduced levels of: oxygen capacity, co-ordination abilities (especially those more complex ones) and those motor abilities, which were not correlated with somatic traits. No adverse effects of environment pollution on height, body mass and flexibility were found. Accordingly, the hypothesis of higher eco-sensitivity of functional traits rather than structural ones under the negative influence of natural environment could be proved.

Introduction

Poland, and particularly such regions as Silesia and Cracow are severely polluted areas. It is, therefore, not surprising that for a long period of time research was conducted to determine the impact of environmental conditions on the health of

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inhabitants. The research was conducted on a large scale, at several university research centres (School of Medicine in Krakow, State Department of Hygiene in Warsaw, Center of Oncology in Gliwice, School of Medicine in Zabrze, University of Mining and Metallurgy). The results have proved that environmental pollution would adversely affect the health and longevity of the population, particularly the male sex.

The attention of most researchers was focused on the relationships between the zones of pollution, based on very detailed maps of ecological threats (Grodzińska 1994, Turzański 1994) and widely understood health and mortality of the inhabitants of the given area (see: Gumińska 1989, Klonecki 1989, Krzyżanowski and Wojtyniak 1982, Rogowski and Rutkowski 1988).

In the consequence of such procedure, the results were scattered while the reasons and possible effects of a given phenomenon were too much detailed. The gravity of the problem is proved by the fact that till the end of the 80's such research was run, though on a different scale, in 27 localities and 60 polluted zones of Poland (Okólski 1981). It is worthwhile to mention, that the role of researchers from Cracow was far from minor (Gumińska 1986, 1989, Król 1983, Nikodemowicz 1983).

Though the research results are sometimes difficult to interpret, it seems worthwhile to tackle the problem anew. The zone around Cracow is of primary interest, because in some localities in this region the levels of environmental pollution are very high.

The scope of this research work should be supplemented with the analysis of motor development. The survey of earlier research works shows that this aspect was considered very rarely until now, although it becomes more important as the notion of dexterity becomes more general (Bouchard et al. 1988, Renson et al. 1977) when used in the definition of the "state of health" (Demel 1980), and also "health — related fitness" (Bouchard et al. 1989), whose basis is the harmonic (somatic, functional, motor and mental) development. In a way that also corresponds with the definition of health provided by WHO.

The main objective of the present work was to establish the relationship between the intensity of dust and gas pollution in the vicinity of Cracow (in small towns and villages) and the level of somatic, functional and motor development of children and young people aged 7–18.

Material and methods

The tested group consisted of 4098 children and young people (2021 girls 2077 boys) aged 7–18, living in seven villages and in four small towns in the south-east of the Cracow zone (the distance from the centre of Cracow being no more than 40 km).

Basing on the reports on pollution in the Cracow province, the chosen localities were placed in the zones of different pollution level, so they could be divided accordingly.

To meet the research objectives, the modified rankings method of homogenous group distinction was applied, already used by Mlekodaj and Piasecki (1990). Thus, on the basis of the gas and dust pollution data for specified localities in the years covered by the research (Grodzińska 1994, Turzański 1994); the localities were divided into three groups: those with relatively low, average and high level of environmental pollution.

Each group contains two or three villages and one town. While compared to the reference level taken to be the standard for protected regions (pursuant to the regulation by the Ministry of Environmental Protection, Natural Resources and Forestry in Poland), the level of gas and dust pollution in specific groups proved to be very high; accordingly the following criteria of division were established with respect to utalitarism :

1. The group with the relatively lowest level: up to 80% **above** the standard level ($120g * m^{-2} * years^{-1}$)
2. The group with an average level: between 80–150% **above** the standard level ($160g * m^{-2} * years^{-1}$)
3. The group with the highest level: from 150% **above** the standard level ($200g * m^{-2} * years^{-1}$)

It must be noted that in the studied areas, the **economical and cultural status, the condition of school work and physical activity of children and young people did not vary significantly** (Ambroży 1997), as analysed using Chi ^{2} test.

The following measurements were considered:

1. Somatic traits:

Body height and body mass

2. Functional abilities :

— eye-movement co-ordination (examined with the Piorkowski device),
— space orientation (with cross apparatus AKN-102),
— balance (test "flamingo balance" — Eurofit),
— speed of movement (test "plate tapping" — Eurofit)
— maximal oxygen uptake ($VO_{2\ max.}$)-predicted using the indirect method of Margaria et al. (1965). The heart rate was registered with a Sport Tester PE-3000.
— aerobic capacity (1000 m run)
— flexibility ("sit and reach" test-Eurofit)
— local static strength (grip strength)
— absolute static strength (throwing the medicine ball backwards)
— alactacid MAP (standing broad jump and 50 m run)

For each test the fundamental statistical characteristics ($\bar{x}$, SD) were calculated for given age and sex groups and environment pollution levels. To increase the number of people in analysed groups, the **weighted means were calculated for 3 age groups:** 7–10 , 11–14 and 15–18 (table. 1).

The significance was determined using t°-Student or C° Cochran-Cox tests according to variance differences. Inter-group differences were expressed in "Z" values, calculated as the normalised differences between groups 2 or 3 and group 1.

Table 1. Number of individuals in groups of sex, age and degree of enviromental pollution

n	Girls			Boys		
age	pollution					
	small	average	large	small	average	large
7–10	212	379	167	208	372	164
11–14	214	383	170	155	387	232
15–18	170	216	110	125	316	118

Results and discussion

Somatic traits

According to the results of previous research no distinct inter-group differences between the somatic development of children and young people were found. The differences were small, statistically insignificant and — what was quite unexpected — in the case of male sex better results were obtained for groups inhabiting more contaminated areas. In the female sex the body mass differences only were as expected (table. 2). This can be the consequence of obesity levels.

Motor abilities

Some very interesting observations can be made while analysing the level of development of co-ordination abilities, which show the efficiency of the central nervous system during the movement tests.

The data presented here (table. 3) and the results of ability tests (balance, eye — movement co-ordination and space orientation) show that the lowest level of development of co-ordination abilities was found in individuals who inhabited areas polluted with gas emissions and dust falls. However, it seems interesting that in this case the differences were more pronounced in the male sex; this tendency was also marked in the measurements of abilities involved in co-ordination processes and

Table 2. Statistical characteristics of somatic traits, flexibility and oxygen uptake of groups divided by the degree of environmental pollution (age groups: 7–10, 11–14 and 15–18 years)

Parameter			girls			boys		
trait	age		pollution					
			Small	average	large	small	average	large
body height (cm)	7–10	$\bar{x}$	130.61	131.47	130.44	130.9	132.54	131.25
		SD	5.08	5.43	5.34	5.33	5.37	5.76
		Z		0.16	–0.03		0.31	0.06
	11–14	$\bar{x}$	151.79	152.76	152.48	152.74	154.44	153.56
		SD	5.88	6.41	6.53	6.97	6.95	7.21
		Z		0.16	0.11		0.24	0.11
	15–18	$\bar{x}$	161.85	162.77	161.41	169.61	172.75	171.17
		SD	6.15	6.4	6.03	6.86	6.79	6.87
		Z		0.15	–0.07		0.46	0.23
Body Mass (kg)	7–10	$\bar{x}$	26.96	28.19	28.14	27.69	28.64	29.58
		SD	4.71	4.93	5.34	3.82	4.44	4.4
		Z		0.25	0.24		0.23	0.46
	11–14	$\bar{x}$	41.33	44.38	43.34	44.68	43.81	44.13
		SD	6.46	7.93	7.52	7.04	7.53	7.11
		Z		0.42	0.29		–0.12	–0.08
	15 –18	$\bar{x}$	56.98	54.43	54.61	62.19	63.27	62.34
		SD	7.08	7.55	6.44	8.59	9	9.97
		Z		–0.35	–0.35		0.12	0.02
Flexi bility (cm)	7–10	$\bar{x}$	53.3	52.82	52.23	52.83	51.79	49.53
		SD	4.37	4.89	4.36	5.28	4.62	4.4
		Z		–0.1	–0.25		–0.21	–0.68
	11–14	$\bar{x}$	56.78	57.12	57.61	51.67	54.17	52.73
		SD	5.2	5.7	5.55	6.21	5.82	5.96
		Z		0.06	0.16		0.42	0.17
	15–18	$\bar{x}$	59.04	60.28	60.1	59.57	60.91	58.9
		SD	7.15	7.48	6.99	5.76	6.27	6.86
		Z		0.17	0.15		0.22	–0.11
oxygen uptake (ml*kg $^{-1}$)	7–10	$\bar{x}$	45.72	44.45	40.61	48.78	50.11	46.84
		SD	5.93	5.32	6.52	7.43	7.13	7.88
		Z		–0.23	–0.82		0.18	–0.25
	11–14	$\bar{x}$	48.79	45.6	39.6	54.5	49.7	51.02
		SD	5.19	6.05	4.79	8.04	8	7.44
		Z		–0.57	–1.84		–0.6	–0.45
	15–18	$\bar{x}$	45.33	44.8	42.7	51.21	51.68	48.41
		SD	6.79	7.57	6.76	9.24	9.17	9.25
		Z		–0.07	–0.39		0.05	–0.3

those involving the central nervous system (e.g. space orientation, eye — movement co-ordination); the differences were then correlated with IQ (Szopa et al. 1996).

It can be assumed that in this case the specific liability of male sex to environmental conditions was enhanced, too.

Table 3. Statistical characteristics of the coordinational abilities of groups divided by the degree of environmental pollution (7–10, 11–14 and 15–18).

Parameter			girls			boys		
trait	age		pollution					
			small	average	large	small	average	large
balance (sec)	7–10	$\bar{x}$	4.92	4.57	5.01	3.92	3.82	3.72
		SD	2.89	3.69	3.75	3	2.71	2.95
		Z		–0.11	0.03		–0.04	–0.07
	11–14	$\bar{x}$	4.93	4.63	4.96	5.32	4.66	5.1
		SD	3.37	3.41	3.65	3.66	3.35	3.38
		Z		–0.09	0.01		–0.19	–0.06
	15–18	$\bar{x}$	6.75	6.85	6.75	7.77	7.38	7.14
		SD	6.36	6.87	6.41	5.3	5.2	5.05
		Z		0.02	0		–0.07	–0.12
speed of move-ment (sec)	7–10	$\bar{x}$	12.49	12.73	15.48	10.98	11.86	12.07
		SD	1.45	1.19	3.48	1.66	1.71	1.93
		Z		0.18	1.21		0.52	0.61
	11–14	$\bar{x}$	9.52	9.13	10.53	6	7.49	6.92
		SD	0.92	0.87	1.44	0.48	1.39	1.22
		Z		–0.44	0.85		1.59	1.08
	15–18	$\bar{x}$	6.29	6.14	6.41	5.55	6.23	5.96
		SD	2.21	1.62	1.47	1.06	0.96	1.07
		Z		–0.08	0.07		0.67	0.39
space orienta tion (sec)	7–10	$\bar{x}$	140.26	142.15	119.37	128.48	144.11	157.62
		SD	41.91	37.75	38.19	30.34	37.88	43.17
		Z		0.05	–0.52		0.46	0.79
	11–14	$\bar{x}$	76.21	82.86	76.32	77.78	84.7	82.99
		SD	12.11	18.31	20.65	13.59	20.81	19.77
		Z		0.44	0.01		0.4	0.31
	15–18	$\bar{x}$	71.17	67.97	74.41	69.35	65.25	74.84
		SD	12.83	15.55	13.48	11.86	14.56	16.55
		Z		–0.23	0.25		–0.31	0.39
eye-mov. coordi nation (number)	7–10	$\bar{x}$	34.8	18.17	15.46	40.72	24.4	32.35
		SD	11.48	12.29	10.09	14.18	14.33	18.24
		Z		–1.4	–1.79		–1.14	–0.52
	11–14	$\bar{x}$	53.52	39.65	39.73	52.42	42.35	48.91
		SD	14.74	24.39	15.93	17.09	20.45	24.75
		Z		–0.71	–0.9		–0.54	–0.17
	15–18	$\bar{x}$	61.76	59.6	55.95	64.87	71.36	65.4
		SD	18.73	25.79	22.97	19.53	22.58	21.75
		Z		–0.1	–0.28		0.31	0.03

The results of maximum oxygen uptake measurements (table. 2.) reveal that the lowest aerobic performance was given by children and young people inhabiting regions severely polluted by dust falls and gas emissions. It may also seem interesting that those adverse effects were found in higher degree in female sex, which is generally regarded as less eco-sensitive, particularly with regards to somatic traits.

Table 4. Statistical characteristics of motor abilities of groups divided by the degree of environmental pollution (in 3 age groups: 7–10, 11–14 and 15–18 yrs)

Parameter			girls			boys		
test	age		small	average	large	small	average	large
st. long jump (cm)	7–10	$\bar{x}$	122.37	117.76	127.76	131.38	127.9	130.16
		SD	15.16	19.13	17.62	16.27	20.53	18.39
		Z		–0.27	0.33		–0.19	–0.07
	11–14	$\bar{x}$	164.98	156.63	158.37	164.13	167.14	168.89
		SD	18.56	21.88	19.57	23.52	26.46	20.53
		Z		–0.41	–0.35		0.12	0.22
	15–18	$\bar{x}$	182.34	162.8	174.8	200.73	204.31	199.17
		SD	23.6	26.6	22.24	24.26	24.77	25.66
		Z		–0.78	–0.33		0.15	–0.06
static strength (kG)	7–10	$\bar{x}$	11.56	9.78	12.4	14.94	14.77	15.91
		SD	2.04	2.66	3.51	2.67	2.99	3.46
		Z		–0.76	0.3		–0.06	0.32
	11–14	$\bar{x}$	23.48	19.83	25.07	29.26	28.55	32.8
		SD	4.7	5.05	6.16	6.32	6.88	6.43
		Z		–0.75	0.29		–0.11	0.56
	15 – 18	$\bar{x}$	32.39	25,94	30.34	53.88	59,86	56.48
		SD	6.63	6.54	6.14	11.34	10.71	11.36
		Z		–0.98	–0.32		0.54	0.23
medicine ball throw (m)	7–10	$\bar{x}$	3.3	2.85	2.75	3.61	3.64	3.84
		SD	0.6	0.68	0.68	0.78	0.96	1.15
		Z		–0.71	–0.87		0.03	0.24
	11–14	$\bar{x}$	6.73	6.28	6.04	7.78	7.65	7.63
		SD	1.04	1.45	1.19	1.49	1.86	1.91
		Z		–0.36	–0.62		–0.08	–0.09
	15–18	$\bar{x}$	7.33	8.1	7.74	8.16	11.92	8.9
		SD	1.52	1.47	1.34	1.96	2.62	1.51
		Z		0.51	0.28		1.64	0.43
50 m run (sec)	7–10	$\bar{x}$	9.98	10.69	10.56	9.52	10.71	10.74
		SD	0.56	0.97	0.79	0.43	1.04	0.93
		Z		0.92	0.85		1.62	1.8
	11–14	$\bar{x}$	8.74	8.94	9.3	9.14	8.36	8.74
		SD	0.51	0.77	0.72	1.74	1.06	0.61
		Z		0.31	0.91		–0.56	–0.34
	15–18	$\bar{x}$	8.28	8.73	8.18	7.9	7.54	7.77
		SD	0.98	1.58	0.99	2.12	0.72	0.64
		Z		0.35	–0.1		–0.25	–0.09
1000m run (sec)	7–10	$\bar{x}$	334.44	353.15	361.63	317.89	320.15	321.2
		SD	30.74	51.41	48.07	38.88	43.46	39.95
		Z		0.46	0.69		0.05	0.08
	11–14	$\bar{x}$	292.63	304.6	314.55	265.58	265.1	269
		SD	31.42	34.58	40.95	31.23	40.36	36.96
		Z		0.36	0.61		–0.01	0.1
	15–18	$\bar{x}$	291.88	296	301.58	225.98	229.63	228.95
		SD	21.82	29.53	33.16	29.97	31.17	30.17
		Z		0.16	0.35		0.12	0.1

The differences were rather significant (0.39–1.84 SD), particularly in the puberty period (over 9 ml * kg $^{-1}$).

In the case of boys these differences were less marked — but still significant (0.25-0.45SD), which probably is due to their physical activity which makes the influence of exogenic agents less visible (Mleczko 1991, Szopa 1990). It can be thought, that the observed pattern of differences for the female sex is the representation of negative results of environmental effects, while in the case of male sex these differences are less marked (but not eliminated) due to the influence of physical activity factor.

It follows from table 2, that the relationships between the environment pollution and the flexibility of examined population are similar (and therefore minimal) to those obtained for somatic traits.

Motor abilities involve complexes of functional traits. In some of them the energetic and somatic components play a major role. Therefore, it could be expected that the previously obtained relationships between somatic development and the quality of the environment will to a large extent reflect the results of the present research. Considering the results of this study, this assumption seems reasonable.

It follows from the data (table. 4) relating to the strength abilities i.e. static and explosive ones, that the closer the connection with the body mass (static local strength), the weaker the environmental effect producing lower level of individual development. It is worth noting that in boy groups the differences are inconsistent and coincide with the environmental gradient, while in girl groups one could observe a marked the tendency for weaker results in worse environmental conditions.

Results of MAP — based tests (long jump and absolute strength ability — medicine ball throw), either display no variability or are definitely lower in polluted environment (with the exception of medicine ball throw in the age group 15–18). The differences of 50 m run results follow the similar pattern.

It seems that energetic anaerobic and aerobic performance (alactacid MAP and VO_{2max}), involving also the above abilities, is susceptible to the impacts of environmental pollution, particularly in the case of girls (differences between groups in some age groups are more significant than in case of $VO_{2\ max}$), though here the influence of relatively greater body mass, also fat mass, must not be ignored. These facts may result from the effects of Pb and Cd on enzymes engaged in respiratory chain in mitochondria.

Definitely lower results of endurance ability tests (1000m run) were recorded for girls, particularly in younger age groups (in case of boys there was no such variability), where the influence of pollution is explicit and coincides with the environmental effect gradients: severe pollution — lower performance. It is quite understandable considering the variability patterns for two basic features: $VO_{2\ max.}$ and body mass.

With regards to various methodology and established environmental indices, it is difficult to refer thus obtained results to data found in literature. It seems, however, that there is some justification in genetic research showing, among others, quite weak genetic control over functional traits especially in the female sex (review see Bouchard et al. 1997, Szopa et al. 1996); also in study over trainability of particular functional traits (Bouchard 1986, Bouchard et al. 1988, 1989, Szopa and Prus 1997) and considerable eco-sensitivity of energetic base of physical effort ($VO_{2\ max.}$, alactacid MAP, several biochemical parameters etc.), as mentioned in earlier sections.

The results allow to formulate a quite probable thesis that in the first place the air pollution adversely affects the enzymatic base of physical effort (particularly aerobic) — which is demonstrated in a low degree in case of psycho-motoric traits and in no degree in case of somatic traits. It can also be compensated by extensive physical exercise.

Conclusions

1. The adverse effects of environment pollution were very distinct in studied population, especially as far as their aerobic performance and co-ordination abilities were concerned and slightly less explicit in case of more complex motoric abilities. In case of structure-functional traits the environmental effects were not to be traced.

2. Except for co-ordination abilities, more significant variability of somatic, functional and motor development was noticed in girls. It could be due to the compensating influence of more extensive physical activity of boys.

3. Basing on the research results, the thesis can be formulated that functional traits are the first to respond to environmental effects. They are much more sensitive indicators of negative impacts of environmental pollution than somatic traits.

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