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THE ANTHROPOMETRIC PROFILE OF ADULT SWIMMERS FROM POLAND COMPARED TO THE CORRESPONDING DATA OF SWIMMERS FROM NORWAY

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ABSTRACT

The purpose of the research is to compare the somatic parameters of people practicing swimming in different conditions of the geographical environment – in Poland and Norway. The research material was collected by performing anthropometric measurements in a 112 person group of professional swimmers living in Poland and group 21 swimmers from Norway. The mean of the age in the group of Poles was 19.97 years (SD=3.31) and in the group of Norwegians it was 17.11 years (SD=1.05). A series of anthropometric measurements was performed in both research groups. Statistical analyzes were made using the Statistica 13.1 (StatSoft, USA). In summary of the results of the conducted research, it must be emphasized that these indicate differences in the somatic structure of swimmers living and training in Poland and Norway.
Keywords: Swimmers, Body build, Sport training, Environment, Genetics, Recruitment and selection in sports.

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INTRODUCTION

The selection process in competitive sports represents a social, psychological as well as pedagogical problem [1]. These concepts denote a system of comprehensive activities aimed at selecting such individuals who possess optimal somatic, motor and psychological conditions in order to achieve high sporting results in a given discipline or competition in the future [2]. Associated with them are a number of measurement and methodological issues, the aim of which is to reveal and evaluate the qualities that characterise a candidate's suitability for training at subsequent stages. At the same time, they make it possible to forecast the candidate's future performance [2]. Selection issues not only relate to the recruitment of individuals in the first stage of training, but also constitute a sequence of activities accompanying each stage of a sports career [3]. It is a continuous, dynamic and guided process whose criteria change and intensify as the sporting level increases. The essence of the problem is to select such candidates who, after several years of training, will be able to perform at the championship level. This need arises from the increasingly fierce international sporting competitiveness.

It is often the case that entering the recruitment of children and young people into the sport of swimming, we ask ourselves about the factors that determine the emergence of swimming talent and what to look for in order to identify a future outstanding swimmer among the many candidates. Body structure is one of the most important determinants of sporting success. An important feature of the body structure in the sport of swimming is a tall stature, as pointed out by the authors of numerous works. It is believed that the use of anthropological research methods such as the assessment of children's physique, rate of biological development, prediction of adult height and body type can greatly facilitate the accurate selection of children for qualified sports [4].

Genetic factors control the function and development of an organism, but the level at which development takes place and certain details of the dynamics of that development are dependent on elements present in the environment. The elements of the environment consist of those which enter into the organism as energy or building materials and those which, when acting on the organism, do not enter into its tissues. Both groups of factors produce changes in development such that an organism with an identical set of genes would develop differently with a different set of environmental factors. In this sense, environmental factors, depending on their sources of origin, are divided into natural and cultural modifiers [5]. From the current body of research, evidence exists to support the existence of the phenomenon of adaptation of human populations to the ecological conditions (biogeographical factors) in which they live [6,7]. Among other things, an inversely proportional relationship has been found between the average air temperature in a climate zone and the body weight of its inhabitants. The colder the climate zone, the greater the body mass in its inhabitants is observed [8]. Efforts have long been made to explain the differences in body proportions between inhabitants of warm and cold areas of the globe. Current knowledge allows us to conclude that individuals living in hot climates have developed: longer limbs (upper and lower) and longer limb segments, smaller body girths and lateral dimensions, thus making them more slender. In cold climatic zones, the opposite tendency is found (short limbs – long torso, etc.) [9]. This is also exemplified by the continuous process of adaptation in terms of somatic and functional characteristics that are important for the structure of human motor skills [6].

The present study compares a number of somatic characteristics of swimmers practising swimming under different environmental conditions – in Poland and in Norway.

SPORTS SWIMMING

SWIMMER'S MOTOR SKILLS

The primary objective for athletes in competitive swimming is to maintain a maximum swimming speed while optimizing energy expenditure for a specific race time. This capability relies on various factors such as muscular endurance, overall fitness, mastery of technique, and the swimmer's energy expenditure capacity [10]. When combined with an adequate level of muscular endurance, factors like aerobic capacity and energy cost of swimming become crucial limitations in sustaining a desired swimming speed over a given distance. Thus, it can be stated that sports performance in swimming, in addition to efficient technique, heavily relies on specific muscular strength, high aerobic capacity, and the accompanying specialized endurance.

SOMATIC CHARACTERISTICS OF SWIMMERS

Swimming is one of the few sports disciplines in which the athlete competes in an environment outside of his or her usual environment. The aquatic environment imposes certain requirements on the swimmer's organism and the process of adaptation finds its reflection in the swimmer's physique [7]. The record-holders in the particular swimming competitions are characterised by their specific body build: the backstroke swimmers are the tallest and slimmest, the breaststroke swimmers have a more athletic body build, while the classic style swimmers exhibit a strong build in the upper body, shoulders and chest [11].

BODY BUILD

The basic measures of body size are height and weight. They are both genetically determined, but body height is more strongly heritable. It has also been demonstrated that these traits are subject to variability. The results of cross-sectional studies [4] on the body build of boys and girls practising swimming sports at different ages indicate that the average body height of younger boys is approximately 10 cm above the average height of their peers, while that of older boys is approximately 7 cm higher. Similarly, younger girls practising swimming are taller than their Warsaw peers by about 8 cm, while older girls by about 5 cm. [12]. Bodyweight of Polish swimming championship class representatives was also found to be significantly higher, on average by 6 kg, compared to non-swimmers [13].

SPECIFIC CHARACTERISTICS OF THE SOMATIC CONSTITUTION OF SWIMMERS

The first comprehensive anthropometric study of Polish swimmers was carried out in the mid-1950s by Drozdowski and Pawlaczyk (1958). They established that swimmers are characterised by a tall stature with a fairly heavy body weight; the torso is short - both in absolute size and in relation to the height of the body; the chest of swimmers is well and strongly developed and is characterised by a large amplitude at maximum inspiration and expiration; the shoulders are well-developed and, in juxtaposition with a fairly narrow pelvis, appear to be broad; the upper limb is shorter in absolute dimensions and in relation to body height compared to non-swimmers, and its musculature is clearly adapted to strenuous activity; the lower limb is longer and more muscular [14]. It was also highlighted that the swimmer's physique exhibited a strong development along the body axis, with a definite predominance of length elements over width elements. In addition, the streamlined body shape is also characteristic of the swimmer.

Matynia (1966), in his monograph on the morpho-functional principles of crawl swimming, acknowledges that a good swimmer should mainly be characterised by a large shoulder width, a narrow pelvis, and good muscularity of the limbs [15].

The tall stature of swimmers and their good musculature is further emphasised by Strokina (1964) in her opinion, a characteristic feature of swimmers is the even development of musculature in both upper and lower limbs [16]. The work of Strokina (1964) also confirms other morphological characteristics in swimmers, namely that they are characterised by a short torso, relatively short upper limbs, long lower limbs, a narrow pelvis and an average width of the shoulders. Gołąb (1967), on the basis of a study of participants in the 1965 Polish swimming championships, finds that, compared with non-swimmers, swimmers are taller, have a larger chest width and a smaller hip width; their body weight is heavier, and their arm and shin circumferences are large; more subcutaneous fat is deposited in the upper part of the body [17].

Distinct somatic differences are apparent in those traits that are strongly influenced by the breathing exercises implemented in swimming practice [18]. This is most noticeable in the development of the vital capacity of the lungs, the depth of the thorax, and the increase in the circumference of the thorax. This phenomenon may seem obvious in swimmers at a high level, however, it has also been observed in the early phase of swim training.

SELECTED ELEMENTS OF THE NATURAL ENVIRONMENT OF POLAND AND NORWAY

Poland's location is determined by its geographical coordinates: to the north (54° 50'N), to the south (49° 00'N), to the west (14° 07'E) and to the east (24° 09'E). The meridional extent of Poland is therefore 5° 50' (649 km) and the latitudinal extent is 10° 02' (689 km). Poland lies in the central part of Europe. Our country's climate is described as temperate warm transitional. This means that it has features of an intermediate climate between maritime and continental [19]. The distribution of air temperature shows considerable temporal and spatial variation. The average annual air temperature in our country is around 7.5°C [19].

Norway is one of the five northern European countries. The continental part of Norway stretches from 71° 08'N to 57° 59'N and from 5° E to 31° E. Despite its location at a latitude comparable to Alaska or southern Greenland, Norway's climate is much milder. Most of the territory lies in the temperate climate zone, with the west and south in the maritime temperate zone. The northern part is in the subpolar climate zone. During the winter, temperatures as low as -40° C persist.

RESEARCH OBJECTIVES

The aim of the study was to compare the somatic parameters of swimmers in different geographical environments of Poland and Norway. The following research questions were posed:

1. Are there differences in somatic constitution in swimmers living and training in Poland and Norway?
2. Which of the somatic parameters most significantly differentiate Polish and Norwegian swimmers?

MATERIAL AND METHODS

CHARACTERISTICS OF THE STUDY GROUP

The research material was collected by taking anthropometric measurements in a 112-person group of competitive swimmers living in Poland and in a group of 21 swimmers from Norway. The average age in the Polish group was 19.97 years, (SD=3.31) and in the Norwegian group 17.11 years (SD=1.05). The respondents represented the following sport levels: international master class, master class and 1st sport class.

The subjects and their parents were informed about the purpose of the study and the research procedures. Written consents from the parents of the underage swimmers to participate in the study were obtained. All procedures were in compliance with the Helsinki Declaration of Human Rights regarding research on human subjects. The Ethics Committee of the University of Physical Education in Wrocław approved the study design. (AWF-2018-219).

RESEARCH PROCEDURE

A series of anthropometric measurements were performed in both study groups. All measurements were taken by two persons. The height points of the test swimmers were measured with the upper limbs positioned parallel to the torso, the feet evenly weighted and the head positioned in the Frankfurt plane. Unilateral measurements were taken on the right side of the body.

Measurements were taken using: a linear compass, a large and small bowed calliper, a metric tape measure, an electronic calliper, manual dynamometer, and a scale. The following measurements were taken:

Measurements of body height and length of body sections taken by direct method (anthropometer):

- Body height (B-v) measured when the subject is maximally erect, head in the Frankfurt plane,

anthropometer positioned maximally to the base,
- suprasternal height (B-sst) measured without changing the position of the anthropometer after measuring the body height , the arrow is lowered to the jugular notch of the presternum,
- acromion height (B-a) the subject straightens the elbow and fingers, does not change the position of the shoulder during two consecutive measurements, the measurement is taken from the lateral-most edge of the acromion,
- radial height (B-r) measured from the upper edge of the head of the radius bone,
- styloid height (B-shape) measured from the lowest edge of the styloid process of the radius bone,
- dactylion III height (B-da III) measured from the pulp of the third finger,
- symphysion height (sy), the length of the lower limb (B-sy) measured from the edge of the pubic symphysis,
- trochanterion height (B-tro) measured from a point uppermost on the greater trochanter of the femur. It lies slightly lower than the symphysion. (functional length of the limb),
- tibiale height (B-ti) measured from the medial edge of the upper tibial epiphysis,
- sphyrion height (B-sph) measured from the ankle edge of the tibia,
- sitting posture height (Bs-v) measured from the surface on which the subject sits to the vertex point,
- arm span (da III-da III), the anthropometer placed parallel to the base and resting with its lower end on the wall at the height of the subject's shoulders, the subject touches the wall at the base of the anthropometer with the pulp of the third finger of one hand, the other limb extends along the device.

Measurements of the length of body segments taken using the direct method (small bowed caliper):
- hand length (sty-da III) - the distance between the lowest point (at the top) of the styloid process of the radius bone and the pulp of the longest third finger (linear compass),
- length of the foot (pte-ap) - distance between the calcaneal tuber and the pulp of the longest toe (first or second).

Pomiary długości segmentów ciała wykonane metodą pośrednią (cyrkiel kabłąkowy mały):
- długość tułowia (sst-sy),
- długość ramienia (a-r),
- długość przedramienia (r-sty),
- długość kończyny górnej (a-da III),
- długość uda (sy-ti),
- długość podudzia (ti-sph),

Measurements of body diameters and widths of the epiphyses of long bones taken using the direct method (large bowed calliper):
- shoulder breadth (a-a) measured at the tops of acromions,
- upper body width (dl-dl) measured at the points most lateral on the skin where the deltoid muscle is present,
- thoracic width (thl-thl) measured at the costal arches in the axillary line at the level of the junction of the sternum shaft with the xiphoid cartilage,
- thoracic depth (xi-ths) measured between the xiphoidale point and the neurapophysis lying at the same height,
- thoracic depth at sst point - distance between sst point and the neurapophysis lying at the same height (large bowed caliper),
- pelvic width (ic-ic) measured between the most lateral points of the iliac crests,
- pelvic depth (sy-s) measured between the symphysion and sacrale (s) - the point located most posteriorly on the spinous processes of the sacrum (usually at the beginning of the posterior rugae),
- hip width (tro-tro) measured between the greater trochanter of the femur (tro) (most laterally),
- width at the height of the omphalion point (navel),
- depth at the height of the omphalion point (navel),
- depth at the height of the measurement of the greatest circumference of the hips.

Non-standard anthropometric measurements taken by direct method:
- width of the hand (mu-mr) measured between the heads of the second and fifth metacarpal bones (linear compass),
- width of the hand (mu-mm) measured between the heads of the first and fifth metacarpal bones (linear compass),
- width of the distal epiphysis of the forearm (spr-spu) the distance between the outermost points of the styloid process of the radius bone and the styloid process of the ulna (linear compass),
- ulnar epiphysis width (cm-cl) distance of the outermost points on the medial and lateral epicondyles of the radius bone (linear compass),
- knee epiphysis width (epm-epl) distance of the outermost points on the medial and lateral epicondyles of the femur (linear compass),
- ankle width (mlt-mlf) the distance between the most medial point on the medial malleolus and the most lateral point on the lateral malleolus (linear compass),
- width of the foot (mtt-mtf) measured between the heads of the first and fifth metatarsal bones (linear compass).

Body circumference measurements by direct method (metric tape):
- circumference of the head measured through the op and m points,
- circumference of the arm measured with the limb straight along the body, the tape running halfway down the arm,
- circumference of the "shoulder girdle" measured at the sst point, through the largest dimension of the shoulder muscles,
- waist circumference measured at the point of greatest indentation, at breathlessness,
- abdominal circumference at the height of the om point (navel),

- hip circumference measured through the largest protuberance of the buttocks,
- largest thigh circumference measured just below the gluteal sulcus, with both limbs equally weighted,
- largest circumference of the shin, measured through the greatest protuberance of the calf, with both limbs equally weighted.

Skin-fat fold measurement - direct method (caliper), measurement taken on the right side of the body:

- thickness of the subscapular fold, measured below the inferior angle of the scapula - horizontal fold.

Other:
Body weight (kg)
Anthropometric indices:

- BMI: The value of this parameter was determined by the quotient of body weight [kg] and body height (m^2), multiplied by 100%: body weight [kg]/body height [cm^2] × 100%,
- Quetel index 1: The value of this parameter was determined from the quotient of body weight [g] and body height (cm): body weight[g]/body height[cm],
- Roher index: The value of this parameter was determined by the quotient of body weight [g] and body height (cm^3): body weight [g]/body height[cm^3],
- Wertheimer index: [(B-sy)*1000000]/[(tl-tl)*(xy-ts)*(sst-sy),
- slenderness index: body height (cm (cm)/ $\sqrt[3]{masaciała(kg)}$, *[*body weight*],
- length/thickness ratio [H^2/U]. The value of this parameter was determined from the quotient of body height [cm^2] and maximum body transverse section [cm^2]: body height [cm^2]/[(6.9256 x body weight)+(3.5043 x body height)-377.156],
- WHR index: The value of this parameter was determined by dividing the waist circumference by the hip circumference: waist circumference/hip circumference,
- trunk length index. The value of this parameter was determined by the quotient of the scores (sst-sy) and (B-v), multiplied by 100%: [sst-sy]/[B-v] × 100%,
- intercondylar index. The value of this parameter was determined by the quotient of the scores (a-da III) and (B-sy), multiplied by 100%: [a-da III]/[B-sy] × 100%,
- upper limb spread index. The value of this parameter was determined by the quotient of the scores (da III-da III) and (B-v), multiplied by 100%: [da III-da III]/[B-v] × 100%,
- lower limb length index. The value of this parameter was determined by the quotient of the scores (B-sy) and (B-v), multiplied by 100%: [B-sy]/[B-v] × 100%,
- relative shank to lower limb length. The value of this parameter was determined by the quotient of the scores (B-ti) and (B-sy), multiplied by 100%: [B-ti]/[B-sy] × 100%,
- relative shank length to body height. The value of this parameter was determined by the quotient of the scores (B-ti) and (B-v), multiplied by 100%: [B-ti]/[B-v] × 100%,
- relative shank-to-torso length. The value of this parameter was determined by the quotient of the scores (B-ti) and (B-v)-(B-sy), multiplied by 100%: [B-ti]/[B-v]-[B-sy] × 100%,
- relative shank to thigh length. The value of this parameter was determined by the quotient of the scores (B-ti) and (sy-ti), multiplied by 100%: [B-ti]/[sy-ti] × 100%,
- upper limb length index. The value of this parameter was determined by the quotient of the scores (a-da III) and (B-v), multiplied by 100%: [a-da III]/[B-v] × 100%,
- the relative length of the forearm to the upper limb. The value of this parameter was determined by the quotient of the scores (r-da III) and (a-da III), multiplied by 100%: [r-da III]/[a-da III] × 100%,
- relative forearm length to body height. The value of this parameter was determined by the quotient of the scores (r-da III) and (B-v), multiplied by 100%: [r-da III]/[B-v] × 100%,
- the relative length of the forearm to the trunk. The value of this parameter was determined by the quotient of the scores (r-da III) and (B-v)-(B-sy), multiplied by 100%: [r-da III]/[B-v]-[B-sy] × 100%,
- the relative length of the hand to the upper limb. The value of this parameter was determined by the quotient of the scores (sty-da III) and (a-da III), multiplied by 100%: [sty-da III]/[a-da III] × 100%,
- relative arm-to-arm length. The value of this parameter was determined by the quotient of the scores (sty-da III) and (a-r), multiplied by 100%: [sty-da III]/[a-r] × 100%,
- relative arm to forearm length. The value of this parameter was determined by the quotient of the scores (sty-da III) and (r-sty), multiplied by 100%: [sty-da III]/[r-sty] × 100%,
- the relative length of the foot to the lower limb. The value of this parameter was determined by the quotient of the scores (pte-ap) and (B-sy), multiplied by 100%: [pte-ap]/[B-sy] × 100%,
- relative length of foot to thigh. The value of this parameter was determined by the quotient of the scores (pte-ap) and (sy-ti), multiplied by 100%: [pte-ap]/[sy-ti] × 100%,
- the relative length of the foot to the shin. The value of this parameter was determined by the quotient of the scores (pte-ap) and (ti-sph), multiplied by 100%: [pte-ap]/[ti-sph] × 100%,
- relative length of lower limbs to body height: [B-sy]/[B-v] × 100%,
- shoulder width index. The value of this parameter was determined by the quotient of the scores (a-a) and (sst-sy), multiplied by 100%: [a-a]/[sst-sy] × 100%,
- pelvic width index. The value of this parameter was determined by the quotient of the scores (ic-ic) and (sst-sy), multiplied by 100%: [ic-ic]/[sst-sy] × 100%,

- hip and shoulder index. The value of this parameter was determined by the quotient of the scores (ic-ic) and (a-a), multiplied by 100%: [ic-ic]/[a-a] × 100%,
- thoracic flattening index. The value of this parameter was determined by the quotient of the scores (xy-ts) and (tl-tl), multiplied by 100%: [xy-ts]/[tl-tl] × 100%,
- palm length-width index. The value of this parameter was determined by the quotient of the (mu-mr) and (sty-da III) scores, multiplied by 100%: [mu-mr]/[sty-da III] × 100%,
- hand length-width index. The value of this parameter was determined by the quotient of the (mu-mm) and (sty-da III) scores, multiplied by 100%: [mu-mm]/[sty-da III] × 100%,
- length-width index of the foot. The value of this parameter was determined by the quotient of the scores (mtt-mtf) and (pte-ap), multiplied by 100%: [mtt-mtf]/[pte-ap] × 100%,

The anthropometric profile of sports swimmers practising swimming in different conditions of the geographical environment was constructed on the basis of normalised values of arithmetic means of anthropometric parameters significantly differentiating Polish swimmers from Norwegian swimmers. The standardisation was based on the following formula:

$$Z = \frac{x_p - x_{gk}}{SD_{gk}}$$

where:
x_p – arithmetic mean of the measurement of a given parameter in a group of Polish swimmers,
x_{gk} – arithmetic mean of the measurement of the parameter in the group of Norwegian swimmers,
SD_{gk}– standard deviation for the measurement of a parameter in a group of Norwegian swimmers.

The standardised values of the individual parameters/indicators were plotted on a graph whose axis of ordinates (x) (point "0") determined the value of the arithmetic mean calculated for all parameters/indicators measured/calculated in a group of swimmers living and training in both Poland and Norway..

STATISTICAL METHODS

The following statistical tools were used to analyse the results: arithmetic mean, standard deviation, t-student test variance (p):

Statistical analyses were performed using Statistica 13.1 software (StatSoft, USA).

RESULTS

Comparison of morphological characteristics derived from measurements taken in a group of Polish swimmers and a group of Norwegian swimmers.

Tab. 1

Statistics of the measurement results for height features.

Variable	Poland			Norway			Difference
	N	Mean	SD	N	Mean	SD	
B-v (body height) [cm]	112	184,2	60	21	182,1	62	2,1
B-sst (suprasternale height) [cm]	112	150,7	54	21	148,5	50	2,2
B-a (shoulder height) [cm]	112	152,2	58	21	150,1	55	2,1
B-r (radiale height) [cm]*	112	117	48	21	114,7	46	2,3
B-sty (stylion height) [cm]**	112	89,8	37	21	86,6	48	3,2
B-da III (dactylion height) [cm]**	112	69,9	34	21	65,8	49	4,1
B-sy (lower limb length) [cm]	112	94,8	42	21	93	37	1,8
B-tro (hip height) [cm]	112	94	58	21	92,1	38	1,9
B-ti (knee height) [cm]*	112	50	32	21	51,7	23	-1,7
B-sph (foot height) [cm]	112	8,1	9,13	21	8,2	6,62	-0,1
Bs-v (sitting height) [cm]	112	96,3	33	21	95,5	38	0,8
da III-da III (arm span) [cm]	112	188,9	80	21	187,2	79	1,7

N – Group size
SD – Standard deviation
* Statistical significance of differences at $p \leq 0,05$ level
**Statistical significance of difference at $p \leq 0,01$ level

As shown, swimmers from Poland outperformed their Norwegian counterparts in almost all height parameters. They were taller (B-v), characterised by a longer torso (Bs-v), longer arm span (da III-da III), longer lower limb (B-sy). Additionally, the shoulder height (B-a), anthropometric points of the upper limb (radiale height (B-r), stylion height (B-sty), dactylion height (B-da III)), and hip height (B-tro) were higher. The exceptions were lower knee height and lower foot height. Swimmers from Poland were characterised by a shorter lower leg compared to swimmers from Norway.

Tab. 2

Statistics of measurement results for length features.

Variable	Poland			Norway			Difference
	N	Mean	SD	N	Mean	SD	
sty-da III (hand length) [cm] **	112	19,9	10	21	18,9	9	1,0
pte-ap (foot length) [cm] **	112	27,4	13,5	21	26,4	9,1	1,0
sst-sy (trunk length) [cm]	112	55,9	31	21	55,5	35	0,4
a-r (arm length) [cm]	112	35,2	23	21	35,4	21	-0,2
r-sty (forarm length) [cm]	112	27,2	24	21	28,1	21	-0,9
a-da III (upper limb length) [cm] *	112	82,3	40	21	84,3	40	-2,0
sy-ti (thigh length) [cm] **	112	44,9	34	21	41,3	30	3,6
ti-sph (shank length) [cm] *	112	41,9	31,54	21	43,5	21	-1,6

N – Group size
SD – Standard deviation
* Statistical significance of differences at *p≤0,05* level
**Statistical significance of difference at *p≤0,01* level

Swimmers from Poland were characterised by larger dimensions for the hand (sty-da III), foot (pte-ap), trunk (sst-sy) and thigh (sy-ti). In contrast, swimmers from Norway were characterised by a longer upper limb (a-da III) including the length of the arm (a-r) and forearm (r-sty), as well as a longer shank (ti-sph).

Tab. 3

Statistics of measurement results for width and depth dimensions.

Variable	Poland			Norway			Difference
	N	Mean	SD	N	Mean	SD	
a-a (shoulder width) [cm] **	112	40,6	32	21	36,2	22	4,4
dl-dl (upper body width) [cm] **	112	48,4	24	21	46,5	19	1,9
thl-thl (thorax width) [cm] **	112	30,6	19	20	32,4	25	-1,8
xi-ths (thorax depth) [cm]	112	22	19	21	21,9	32	0,1
thorax depth at the sst point [cm]	112	15,1	14	21	14,7	20	0,4
ic-ic (pelvic width) [cm] **	112	29	20	21	24,8	29	4,2
sy-s (pelvic depth) [cm] **	112	19,4	11	21	18,6	19	0,8
tro-tro (hip width) [cm] **	112	34,5	25	21	30,4	26	4,1
mu-mr (hand width) [cm]	112	8,7	4,87	21	8,6	5,53	0,1
mu-mm (hand width) [cm]	112	10,9	5,72	21	10,6	5,38	0,3
spr-spu (width of the distal forearm epiphysis) [cm]	112	5,9	3,53	21	5,9	2,66	0
cm-cl (width of ulnar epiphysis) [cm]	112	7,4	4,99	21	7,3	3,53	0,1
epm-epl (width of knee epiphysis) [cm] **	112	10	4,89	21	9,5	6,17	4,4
mlt-mlf (ankle width) [cm] *	112	7,6	3,81	21	7,4	3,50	1,9
mtt–mtf (foot width) [cm]	112	10,2	5,60	21	10,2	5,81	-1,8
width at omphalion (navel) point **	112	29,4	20	21	28,0	18	0,1
depth at the omphalion (navel) point	112	18,6	15	21	18,7	19	0,4
depth at the height of the measurement of the largest hip circumference	112	22,4	15	21	22,1	18	4,2

N – Group size
SD – Standard deviation
* Statistical significance of differences at *p≤0,05* level
**Statistical significance of difference at *p≤0,01* level

Polish swimmers surpassed their Norwegian counterparts in almost all width and depth parameters. The exceptions were width of the thorax (thl-thl), width of the hips (tro-tro), and depth at the height of the omphalion (navel) point. It can be inferred that swimmers from Poland tended to exhibit greater width measurements of the upper torso.

Tab. 4

Statistics of morphological measurements results in terms of body circumferences.

Variable	Poland			Norway			Difference
	N	Mean	SD	N	Mean	SD	
head circumference [cm]	112	56,7	16	20	56,9	19	-0,2
arm circumference [cm] *	111	32,1	23	21	30,7	18	1,4
circumference of the "shoulder girdle" at sst [cm] **	112	115,8	60	21	112	42	3,8
waist circumference [cm]	112	80,1	51	21	78,4	50	1,7
abdominal circumference at the om point [cm] *	112	83,2	52	21	80,7	55	2,5
hip circumference [cm] *	112	96,6	43	21	92,9	38	3,7
largest thigh circumference [cm] **	112	56,8	40	21	53	23	3,8
largest circumference of shank [cm]	112	37,4	23	21	37,1	17	0,3

N – Group size
SD – Standard deviation
* Statistical significance of differences at *p≤0,05* level
**Statistical significance of difference at *p≤0,01* level

The group of swimmers from Norway was characterised by smaller body circumferences. The only dimension found to be slightly larger was that of the head circumference. Thus, in general, the swimmers from Poland seemed to have larger body circumference measurements.

Tab. 5

Statistics of the results of morphological measurements of body weight and skin-fat folds.

Statystyki wyników pomiarów morfologicznych w zakresie masy ciała oraz fałdów skórno-tłuszczowych.

Variable	Poland			Norway			Difference
	N	Mean	SD	N	Mean	SD	
body weight [kg] *	111	78,74	8,11	21	73,97	6,82	4,76
thickness of subscapular fold [mm]	111	10,57	3,07	20	9,72	2,33	0,84

N – Group size
SD – Standard deviation
* Statistical significance of differences at *p≤0,05* level
**Statistical significance of difference at *p≤0,01* level

The swimmers from Norway were characterised by a lower body weight as well as a smaller value of the skinfat fold measurement under the scapula. This allows to conclude that less fatness around the upper limb girdle was another morphological feature that distinguished swimmers from Norway from swimmers from Poland.

Comparison of morphological characteristics resulting from the calculation of anthropometric indices performed in a group of Polish and Norwegian swimmers

Tab. 6

Statistics of values of weight and height indices as well as indices describing body build.

Variable	Poland			Norway			Difference
	N	Mean	SD	N	Mean	SD	
BMI: body weight [kg]/body height [m^2]*100 *	111	23	1,76	21	22	1,85	1
Quetelet 1: body weight [kg]/body height [cm^2]*100 *	111	427	36	21	406	33	21
Rohrer: body weight [kg]/body height [cm^3])	111	1,26	0,10	21	1,23	0,12	0,03
Wertheimer: (B-sy)*1000000/(thl-thl)*(xy-ts)*(sst-sy)	112	25,52	3,39	20	23,74	4,02	1,78
slenderness: (body height [cm]/) * $\sqrt[3]{masa\ (kg)}$ *[mass]	111	0,64	0,06	21	0,61	0,05	0,03
Length/thickness ratio [H2/U] *	111	4184	217	21	4302	222	-118
WHR: (waist circumference/hip circumference)	112	0,83	0,04	21	0,85	0,05	-0,02

N – Group size
SD – Standard deviation
* Statistical significance of differences at *p≤0,05* level
**Statistical significance of difference at *p≤0,01* level

The results indicate that both groups were characterised by a normal body build in terms of body mass index (BMI) values. The swimmers from Norway obtained lower values of the Quetelet 1 and Rohrer indices. In contrast, the higher slenderness index of the Polish swimmers indicates that they are characterised by a slender and very strong body build. A comparison of Wertheimer index values suggests that Polish swimmers had a greater ratio of lower limb length to trunk volume. The group of swimmers from Norway showed higher WHR values, suggesting that the difference between waist circumference and hip circumference in the Norwegians was smaller than in the Poles.

Tab. 7

Statistics concerning body segment ratios.

Variable	Poland			Norway			Difference
	N	Mean	SD	N	Mean	SD	
trunk length (sst-sy/B-v*100)	112	30	1,38	21	30	1,61	-0,15
interlimb length (a-da III/B-sy*100) *	112	87	3,46	21	91	3,66	-3,82
upper limbs spans (da III-da III/B-v*100)	112	103	2,40	21	103	2,86	-0,26
length of lower limb (B-sy)/(B-v)*100	112	51	1,41	21	51	1,58	0,41
shank to lower limb length ratio (B-ti/B-sy*100) **	112	53	2,66	21	56	2,04	-2,86
shank length to body height ratio (B-ti/B-v*100) **	112	27	1,34	21	28	0,91	-1,24
shank to trunk length ratio (B-ti/(B-v)-(B-sy)*100 *	112	56	3,53	21	58	2,99	-2,07
shank to thigh ratio (B-ti/sy-ti*100) **	112	112	12,35	21	126	10,45	-13,39
upper limb length (a-da III/B-v*100) **	112	45	1,39	21	46	1,82	-1,60
forearm to upper limb ratio (r-da III/a-da III*100)	112	57	1,88	21	58	1,48	-0,84
forearm length to body height ratio (r-da III/B-v)*100) **	112	26	1,12	21	27	1,39	-1,31
forearm to trunk length ratio (r-da III/(B-v)-(B-sy)*100 **	112	53	2,89	21	55	3,73	-2,27

hand to upper limb ratio (sty-da III/a-da III*100) **	112	24	1,28	21	22	0,87	1,79
hand to arm length ratio (sty-da III/a-r*100) **	112	57	3,84	21	53	2,67	3,20
hand to forearm length ratio (sty-da III/r-sty*100) **	112	74	6,94	21	67	4,21	6,29
foot to lower limb length ratio (pte-ap/B-sy*100)	112	29	1,34	21	28	1,10	0,56
foot to thigh length ratio (pte-ap/sy-ti*100) *	112	62	5,48	21	64	4,20	-2,57
foot to shank length ratio (pte-ap/ti-sph*100)	112	66	4,06	21	61	3,27	4,91
lower limb length to body height ratio (B-sy/B-v*100)	112	51	1,41	21	51	1,58	0,41

N – Group size
SD – Standard deviation
* Statistical significance of differences at *p≤0,05* level
**Statistical significance of difference at *p≤0,01* level

As can be seen, swimmers from Norway surpassed their Polish counterparts in almost all body segment aspect ratios. The exceptions were relative arm to upper limb length (sty-da III/a-da III*100), relative arm to shoulder length (sty-da III/a-r*100), relative arm to forearm length (sty-da III/r-sty*100), relative foot to lower limb length (pte-ap/B-sy*100), and relative foot to shank length (pte-ap/ti-sph*100). The higher values of the interlimb lengths (a-da III/B-sy*100) recorded among the Norwegian swimmers suggest that the characteristic of this group was greater upper limb length compared to lower limb length.

Tab. 8

Statistics of the values of the body width ratios.

Variable	Poland			Norway			Difference
	N	Mean	SD	N	Mean	SD	
shoulder widths [a-a]/[sst-sy]*100**	112	73	6,43	21	65	5,99	7,39
pelvic width [ic-ic]/[sst-sy]*100**	112	52	4,20	21	45	6,32	7,27
iliac-acromial width [ic-ic]/[a-a]*100*	112	72	5,82	21	68	7,71	3,24
fFlattening of the thorax [xy-ts]/[tl-tl]*100*	112	72	6,63	20	69	7,47	3,49

N – Group size
SD – Standard deviation
* Statistical significance of differences at *p≤0,05* level
**Statistical significance of difference at *p≤0,01* level

The results presented conclusively show that all body width aspect ratios were smaller in Norwegian swimmers. It can therefore be concluded that another morphological feature of Norwegian swimmers appears to be a narrow pelvis in relation to both shoulder width and torso length.

Tab. 9

Statistics on the values of the length and width indices of the hand and foot.

Variable	Poland			Norway			Difference
	N	Mean	SD	N	Mean	SD	
hand width (mu-mr/sty-da III*100) **	112	44	2,61	21	46	2,61	-1,73
hand width (mu-mm/sty-da III*100) *	112	55	2,78	21	56	2,78	-1,69
foot width (mtt-mtf/pte-ap*100) **	112	37	2,03	21	39	2,17	-1,56

N – Group size
SD – Standard deviation
* Statistical significance of differences at *p≤0,05* level
**Statistical significance of difference at *p≤0,01* level

All indices for hand and foot were lower in Polish swimmers. This may indicate that a morphological trait of Polish swimmers was slimmer hands (ratio of hand width to hand length (mm-mu/sty-da III*200) and ratio of hand width to hand length (mr-mu/sty-da III*100)) as well as slimmer feet.

ANTHROPOMETRIC PROFILE TAKING INTO ACCOUNT THE CHARACTERISTIC SOMATIC FEATURES OF SWIMMERS LIVING AND TRAINING IN POLAND AND NORWAY

The anthropometric profile was constructed on the basis of standardised values of arithmetic means of anthropometric parameters and indices significantly differentiating groups of swimmers in Poland and Norway. The profile illustrates the set of morphological characteristics that statistically differentiate the Polish and Norwegian swimmer groups and the extent of differences occurring across these characteristics. Swimmers from Poland had a more developed upper torso in the width dimension (shoulder width (a-a), upper body width (dl-dl)). They were also characterised by wider hips (tro-tro) and greater pelvic width ((ic-ic) and pelvic depth (sy-s)).

The anthropometric profile indicates that the Polish swimmers' feature was shorter upper limbs (a-da III) not including arm length (sty-da III). The shorter upper limb length in swimmers from Poland was revealed in the smaller values of the ratios of relative upper limb length (a-da III/B-v*100), relative forearm length to body height (r-da III/B-v*100) and to trunk (r-da III)/(B-v)-(B-sy)*100). Polish swimmers, on the other hand, were characterised by longer arm dimensions, as manifested by higher values of the indices of relative arm length to upper limb (sty-da III/a-da III*100) and relative arm length to shoulder (sty-da III/a-r*100) and to forearm length (sty-da III/r-sty*100).

Another characteristic of Polish swimmers was longer lower limbs. At the same time, the shorter shank (ti-sph) in the group of Polish swimmers was expressed in lower values of the ratios of relative shank length to lower limb (B-ti/B-sy*100), to body height (B-ti/B-v*100), to trunk (B-ti)/(B-v)-(B-sy)*100), and to thigh (B-ti/sy-ti*100). The value of the inter-limb index (a-da III/B-sy*100) calculated for the group of Polish swimmers highlighted another characteristic of this group, shorter upper limbs in relation to the lower limbs. Nevertheless, it should be emphasised that Polish swimmers were characterised by longer and more slender long arms and feet.

Differences between swimmers from Poland and Norway became evident at body circumferences. Larger body circumference measurements were found in the group of Polish swimmers (arm circumference, hip circumference, thigh circumference (largest), abdominal circumference at the om point and 'shoulder girdle' circumference at sst).

Swimmers from Poland represent individuals distinguished from swimmers from Norway by their higher body weight and BMI. In addition, the values of the Quetelet 1, Wertheimer and slenderness indices combined with the interpretation of the shoulder width, pelvic width and hip/shoulder indices allow the classification of swimmers from Poland as slimmer than their peers from Norway with a torso developed in an athletic direction.

DISCUSSION

The aquatic environment imposes certain requirements on the swimmer's organism with the process of adaptation also finding its expression in the physique [7].

The analyses carried out revealed a number of differences occurring in the somatic constitution of swimmers living and training in different environmental conditions.

Swimmers from Poland were taller, characterised by a longer torso (Bs-v) and had a more developed upper torso in the width dimension (shoulder width (a-a), upper body width (dl-dl)). They were also characterised by wider hips (tro-tro). Pelvic width and depth ((ic-ic), (sy-s)) also tended to be of greater dimension compared to the Norwegian swimmers.

Gołąb (1967), on the basis of a study of participants in the Polish swimming championships, concluded that swimmers are tall, characterised by a smaller hip width and a larger chest width [17]. The work of Wieczorek and Witkowski (1992) pointed out that swimming workouts cause an increase in width parameters, which results in the formation of a "typical for swimmers V" body silhouette [18].

Analysis of the results showed that Polish swimmers have shorter upper limbs (a-da III) than Norwegians (not including arm length (sty-da III)). The shorter upper limb length in the group of Polish swimmers is revealed by a lower value of the ratios of relative upper limb length (a-da III/B-v*100), relative forearm length to body height (r-da III/B-v*100) and to torso (r-da III)/(B-v)-(B-sy)*100).

On the basis of a study by Drozdowski and Pawlaczyk (1958), it was found that swimmers tend to have shorter upper limbs both in absolute dimensions and in relation to height than non-swimmers, and their musculature is clearly adapted to strenuous activity. Experts emphasise that a key role in the propulsive force generated by the upper limb is played by the movement of the forearm and hand [14,20].

Another morphological feature characterising swimmers from Poland was longer lower limbs compared to their peers from Norway. However, the shorter lower extremity (ti-sph) observed in the group of Polish swimmers was expressed in lower values of the ratios of relative shank length to lower limb (B-ti/B-sy*100), to body height (B-ti/B-v*100), to trunk (B-ti)/(B-v)-(B-sy)*100), and to thigh (B-ti/sy-ti*100). The value of the interlimb index (a-da III/B-sy*100) calculated for the group of Polish swimmers highlighted another characteristic of this group, namely shorter upper limbs in relation to the lower limbs. Nevertheless, it should be emphasised that Polish swimmers were characterised by longer and more slender hands and feet.

Confirmation of the results obtained can be found in the work of Strokina (1964) [16]. The author suggests that the body build of swimmers is characterised by long lower limbs, a narrow pelvis, relatively short upper limbs and a large shoulder width. A study by Drozdowski and Pawlaczyk (1958) showed that Polish swimmers have a longer and more muscular lower limb than non-swimmers [14].. Other scientific studies also

note that swimmers with longer upper limbs and lower limbs perform better in swimming [21].

The differences between swimmers from Poland and swimmers from Norway became most pronounced in body circumferences. Swimmers from Poland were characterised by larger body circumference measurements (arm circumference, 'shoulder girdle' circumference at sst point, waist circumference, abdominal circumference at om point, hip circumference, thigh circumference (largest) and shank circumference (largest)). Both groups were characterised by a narrow pelvis in relation to both shoulder width and trunk length. All body width aspect ratios were greater in the group of Polish swimmers.

Analysis of the results also showed that both groups had a normal body build in terms of body mass index (BMI) values. The swimmers from Norway obtained lower values of the Quetelet 1 and Rohrer indices. On the other hand, the higher slenderness index in the group of Polish swimmers indicates that they too are characterised by a slender and very strong body build. A comparison of Wertheimer index values suggests that Polish swimmers had a greater ratio of lower limb length to trunk volume. The group of swimmers from Norway had higher WHR values, thus suggesting that the difference between waist circumference and hip circumference in Norwegians was smaller than in Poles. Moreover, swimmers from Poland were characterised by higher body weight and exhibited greater adiposity around the upper limb rim (subscapular fold thickness).

To summarise the results of the study, it must be emphasised that they indicate the existence of differences in the somatic constitution of swimmers living and training in Poland and Norway. This raises the question of whether the differences in somatic constitution between Poles and Norwegians are reflected in sports results. On the basis of swimmers' ranking lists administered and updated by FINA, one may think that swimmers from Poland present a higher sporting level. Their ranking places include 91st and 100th in the 50m freestyle, 77th in the 50m backstroke, and 30th and 93rd in the 100m backstroke. A similar situation occurred in the backstroke competition, in which a higher level of sportsmanship is displayed by swimmers from Poland, as they ranked 77th for the 50m competition, as well as 30th and 93rd for the 100m competition. In the butterfly style competition, swimmers from Poland ranked 26th for the 50m event and 55th for the 100m event. On the other hand, no Norwegian representative has been ranked among the top 100 swimmers in any of the rankings mentioned.

The above considerations suggest that the somatic constitution of swimmers constitutes one of the factors for achieving success. According to many authors [22,23] on the other hand, it is the effective swimming technique, a motor habit driven to perfection, that makes it possible to achieve the best results. This raises the question of whether success in swimming is determined by factors of the external environment (training process, sports infrastructure, material conditions of the athlete, etc.) or by motor potential (genetics), which is subject to development in the aforementioned environment. The answer lies beyond the interpretation of the results of the present study. Nevertheless, the differences in somatic constitution between swimmers living and training in the vastly different environments of Poland and Norway warrant further, deeper research into the environmental determinants of recruitment and selection in the sport of swimming.

CONCLUSION

A group of Polish swimmers was found to have morphological characteristics that predispose them to a greater extent than Norwegian swimmers to achieve success in the swimming sport. Among these are: greater body height, slim body shape, broad shoulders, narrow pelvis, relatively short upper limbs, long lower limbs, longer hands and feet. The presence of these features is matched by their sporting level (determined by FINA ranking lists), in which they outperform their Norwegian colleagues.

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