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ENDURANCE FITNESS AND PERSISTENCE FITNESS.
GENETIC CONTROL AND TRAINING POSSIBILITIES

physical fitness / population research / motorics / genetic factors / training effects, prognosis

The results indicate that endurance fitness is more susceptible to training than persistence. The latter is the more difficult to train, as more numerous muscle groups are concerned and the motor actions involved are more dynamic.

1. PROBLEM

The aspects of motorics in man have been the subject of discussion for more than half a century. International commissions founded at Olympic Congresses (cf. Larson and Michelman 1973) or appointed by the World Health Organization (cf. Shephard 1968) have reached certain conclusions which are neither obvious to all concerned nor consistent with each other. This indicates how difficult it is to measure objectively the different manifestations of human motorics and to set apart precisely their components. The major part of motor functions involved in various activities of life (nutrition, i.e. providing, preparation and consumption of food; employment; travelling; recreation; finding a partner and sexual intercourse; etc.) require various motor properties to be efficient. Prior to undertaking an analysis of the differences between endurance fitness and persistence fitness, it is necessary to specify their place among the overall manifestations of motorics as well as to determine their relationship to other aspects of motorics so far mentioned.

Some years ago (Wolanski 1958, 1963) I reflected on the meaning of physical fitness and suggested a definition close to that applied in physics, i.e. considering this trait as the relation between the results achieved and the subject’s predisposition. This time (cf. Wolanski and Parziko 1976) I want to add to the above concept the question whether man ought to strive for attainment of maximal fitness (to the limits of the body’s possibilities) or only try to achieve optimum fitness i.e. keeping some reserves, so as not to reach the limit entailing a risk for health and even for life. This question is, in a particular way, related to the problem of certain components of motorics; these components are the subject of the present analysis.

Considering motorics, attention has to be given to the relation of the organism to space and time. This relation is not simple. Some time ago the question arose whether time was an appropriate measure of speed in running (Mydlarski 1932). This is only one illustration of the fact that the speed of covering a certain distance ought to be referred to e.g., the stature and/or body weight of the runner, that the style of running should also be taken into account etc. Motorics is manifestation of the function of several organs and systems of the organism, and depends on their co-operation; in particular, motorics is related to (Table 1): nervous conduction, muscle cross-section and structure, lever system, and to a great extent the functions of the senses, e.g. feeling of balance, visual control, tactile and proprioceptive sensation, chronognosis (sensation of time, especially rhythm) etc. The above traits can be expressed in terms of some definite physiological structures and functions, among which prevail the structure and functions of the muscle, with its ability to overcome resistance, movement speed, energy cost, precision of movement realization, movement range and internal and external possibilities of movement realization (duration and effects of movement).

In connection with this list the need arises for the description of the most frequently mentioned (Hebbelinck 1984) components of motorics: strength, speed, agility (it is controversial to what extent the component of co-ordination is a distinct trait), endurance and persistence. There is no agreement as to what degree agility (fitness in gross motor functions, flexibility in movement) differs from co-ordination (fitness in fine motor functions, neuro-muscular effects); distinguishing between endurance and persistence is an even more controversial question. Not all investigators feel the necessity for distinguishing between these components! In English dictionaries or encyclopedias these notions are defined almost identically. However, long time ago some components of motorics have been distinguished intuitively. Most often these two have been referred to as „endurance”, with addition of the terms: „muscular” or „circulatory” (cf. Clarke 1959, p. 222). According to this approach, muscular endurance is defined as „ability to continue muscular exertion of submaximal magnitude; Example: chinning”. Circulatory endurance is interpreted as „moderate contractions of large muscle groups for relatively long periods of time, which require an adjustment of the circulatory and respiratory system to the activity; Example: distance running or swimming”. Several years later, the same author has extended these definitions by stating that: „muscular endurance” „is the lasting power of a single muscle or group of muscles”, and „circulatory-respiratory endurance — involves the continuous activity of the entire organism, during which major adjustments of the circu-
Endurance is a necessary division into aerobic and anaerobic endurance which enables dynamic work, and "local muscular endurance" which leads to exhaustion (Hebbelinck 1984).

In my opinion, endurance (which for which I propose the term "endurance fitness") is related to working capacity, dynamics, and amount of work, and rather concerns aerobic "power" (oxygen debt); the latter (which I propose to refer to as "persistence fitness") is related to the causes of fatigue and duration of work, and it rather concerns anaerobic "power" (availability and utilization of nutrient reserves in the active tissues). Their distinction can most generally be argued by considering the energy cost of work (endurance) and the possibility of its continuation (persistence). Doubtless, the energy cost influences the possibility of work continuation, but viewing through the reserve exhaustion and/or production of metabolites and energy. However, the fatigue associated with production of metabolites in muscles is related to energy cost (aerobic) to not a greater extent than the effect of strength or speed manifestation, attained in the course of body displacement. Therefore, there is no tendency for identification of working capacity and energy cost of work performed, on the one hand, with muscular strength and/or speed of movements on the other.

Thus, in my opinion, (cardiorespiratory) endurance ought to be interpreted as a physical manifestation of motorics, expressed by muscle ability (determined by the overall state of the organism) to perform movements of considerable intensity (over 60% of maximal — voluntary intensity), lasting at least 60 sec, with full efficiency, i.e. without signs of its decrease. Persistence ("muscular endurance") expresses tissue tolerance to work-induced changes, including the concentration of lactic and non-lactic acid metabolites. Thus, it is the tissue adaptive capacity of prolonged realization of work. This is how I defined these notions some years ago (Wolanski and Parizkova 1976).

In my opinion, factor analysis applied in the past 2 decades aiming at learning more about the "structure of physical fitness" (Fleishman 1964, Meikota 1966, 1978) demonstrates that both above-described traits (endurance represented by the pulse frequency increase and step-test, as distinguished from persistence represented by the "hanging in arm-flexed position" test — Zara 1970) are uncorrelated latent factors, in the same way as strength is not correlated with speed or with agility of movements (Matsuura 1980, Reilly and Thomas 1980).

In this connection, endurance fitness and persistence fitness will be considered in the present paper consistently with the above explanation. Endurance fitness will be represented by the increase in the pulse rate at work and by maximal oxygen uptake (MOU, max $V_O_2$), and persistence fitness by the hanging in arm-flexed position test (per time), Knuas-Weber muscular test and Burpee squat-thrust test.

In my opinion, in the future these two groups of evidently "physical" tests ought to be extended with tests for "neuropsychical endurance" measuring psychical fatigue (psychic resistance) as distinguished from biological fatigue (physical resistance = persistence). Since motivation is an important element of the motor effects (work, sport), this component of motorics should also be measured.

2. MATERIAL AND METHODS

The results presented in this study are the result of several sets of examinations, performed between 1960–1967 in Polish villages of the Suwałki and Kurpie districts, between 1971–1972 in Polish settlements in low mountains and in villages situated close to an industrial region, between 1973–1974 in a Yugoslavian mountain town (Cetinje), industrial town (Ivangrad) and seaside towns (Kotor and Bar), and between 1975–1977 in a highly industrialized Polish area (Silesia). In these studies the maximal oxygen intake was evaluated by step-test in 2736 subjects, 14–85 years of age, and also in 183 families where parents and offspring were examined, in Polish rural areas only.

Another group of examinations, performed in Poland between 1976–1977, involved 1819 subjects aged from 5 to over 85 years. These studies were carried out in a highly urbanized area (Łódź — a big industrial city), a densely populated region of highly developed heavy and mining industries (Silesian Coal Basin — towns of Strzemieszyce, Slawkow, Bukowo and Olsztyn), in a slightly industrialized region (Belchatow Industrial Region — BOP), in villages with experimental coal mines (Lublin Coal Basin — LZW), and in a agricultural region (Suwałki district). In each case, the whole population of a given age or families, determined as a random sample were examined.

The methods of assessment used were reported in publications describing other traits in the investigated population and properties of the geographic regions studied as well (Wolanski and Pyzuk 1973, Wolanski 1975, Pawlak and Sarna 1982, Wolanski and Siniarska 1982, Ivanovic, Wolanski and Szemik 1984).

The population of Montenegro (Yugoslavia) represented a higher income level and better nutritional state, as compared with the Polish populations (Ivanovic and Wolanski 1974). Among the populations studied, people from the Pieniny and Bieszczady regions endured the greatest manual work load, and those from the vicinity of the Katowice steelworks (Silesian Coal Basin) endured a smaller work load, while the Montenegro population had the smallest manual work load. The inhabitants of the village of Wronow represented a specific case, being employed both at the Nitrogen Works and on their own farms, and thus seemed greatly overworked, especially in summer.

The cardiac function of the population of Pieniny, Kurpie and Wronow was evaluated by taking the pulse rate at work by palpation; the remaining population was examined by recording the cardiac activity on a Simplici-card electrocardiograph. Maximal oxygen intake (MOU) was read from an Astrand and Ryhming (1954) nomogram, multiplied by a correction factor related to
the subject’s age, and expressed as BTPS. Subjects performed submaximal work, stepping on and off a 40 cm high stool at a rate of 25 ascents and 25 descents per min, for a 5-min period. The final effect (max \( V_{\text{O}_2} \)) was expressed in ml \( \text{O}_2 \) per min and per 1 kg body weight.

In the Burpee squat-thrust test (BSTT) performance lasted 1 min in a four-motion cycle: normal erect posture, with arms stretched out and hands clapping once over the head; squat with front support; front prop up, with backward thrust of legs; squat with front support; return to starting position, with hands clapping once over the head. The number of cycles per 1 min was counted accurately to 1/4 of a cycle.

In the test of hanging in arm-flexed position (HAHF) the subject maintained a flat sitting position under a bar situated at the level of his chin. With arms flexed, the subject reached the bar so as to touch it with his chest, whereupon he straightened his body forward to form one line. Thus, he maintained his body weight on flexed upper extremities, with support on heels only. The duration of time elapsed between maintaining the described position and dropping from the bar was measured accurately to 1 sec.

The Kraus-Weber muscular test of the psoas and abdominal muscles (KWAT) was carried out in the dorsal position on a hard mattress. The subject put his hands on thighs, lifted his legs — with knees set straight — by about 15 cm over the mattress and tried to keep this position as long as possible; the time was measured exact to 0.1 sec.

The heritability of endurance and persistence applying above described tests was calculated in two ways: applying Fisher’s formula (1918):

\[
H = \frac{2r_{pp}}{1 + r_{pp}}
\]

and applying our own formula (Wolanski and Siniarska 1977, Wolanski 1984):

\[
\text{Her} = \frac{1}{3r_{ss} - r_{pp}}
\]

where: \( r_{pp} \) = parents-offspring correlation coefficient, \( r_{ss} \) = father-mother correlation coefficient, \( r_{ps} \) = sib-sib correlation coefficient.

The heritability thus calculated seems to express the intensity of genetic control of the development of the investigated traits; the value occurring in the denominator of the formula for Her is a measure of the trait’s eco-sensitivity (Eco), in our case, of the trait’s susceptibility to training.

3. RESULTS

3.1. Heritability of endurance and persistence

The results of the tests applied, as compared with the results obtained for other traits determined in the present Polish materials (Pawlak and Sarna 1982, Wolanski and Siniarska 1982), are recorded in Table 2.

The similarities in endurance and persistence fitness between parents and offspring are quite different, despite dealing with a large number of subjects and application of age- and sex-independent T-scores. The coefficients of correlation are, as compared with other traits, medium for KWAT and BSTT, less than medium for the pulse rate at work and HAFP, and very low for MOU (Fig. 1). A higher correlation is obtained for speed of movement, and an intermediate one for strength and reaction time.

The similarity in endurance and persistence fitness between siblings, as compared with other traits, is medium for HAFP and KWAT, and for endurance (pulse rate at work), and low for BSTT (Fig. 2). A correlation lower than that for BSTT is obtained only for the feeling of balance and movement accuracy. A correlation exceeding that for HAFP, KWAT and pulse rate at work, is obtained for movement speed and grip strength.

The heritability of endurance and persistence fitness, determined by Fisher’s and our own method, is — as compared with that of other motor traits — different depending on the test used. Heritability evaluated by both methods is of similar low value for endurance (pulse rate at work) and HAFP; a lower one is obtained only for grip strength. Heritability assessed by both methods is medium for KWAT. For the Burpee test (Fig. 3), it is high according to our own method, and less than medium, when evaluated by Fisher’s method. Consequently, the susceptibility of endurance and persistence fitness to training is also different. When measured by the value of Eco (Table 2), training susceptibility — as compared with that of other traits — is low for persistence evaluated by the Burpee test, less than medium for persistence assessed by KWAT, and medium for endurance (pulse rate at work) and persistence evaluated by HAFP (Fig. 4).

Therefore, the heritability of persistence measured by static tests (HAFP and KWAT) is similar to the heritability of endurance and muscular strength, whereas persistence evaluated by the dynamic Burpee test is highly inheritable similar to speed of movements. Thus the results of genetic studies suggest that endurance and persistence are not clearly set apart with respect to heritability, while they may largely differ in dependence on the muscle groups and nature of movement, involved in a given test.

3.2. Development in ontogenesis and interpopulational differentiation

Endurance measured by MOU increases with age to about 20–25 years (with big inter-populational variation), whereupon it shows a regression (Fig. 5). In the period of peak development of MOU, the endurance is the lowest in populations of greatly industrialized Silesia and highest
in the inhabitants of Swedish cities and in the primitive tribe Masai (Sudan) — (di Prampero and Cerrettelli 1969, Shephard 1969); at older age (over 50 years), it is the highest in rural population and mountain raftsmen, and the lowest in populations of highly industrialized countries (Wolanski 1980, Shephard 1969). The regression rate of MOU is also different in agreement with the rule stating that the earlier the occurrence of the peak value of a trait's development, the more rapid the subsequent regression (Wolanski 1973, 1984).

Persistence measured by the Burpee test (BSTT) rises with age till the pubertal period, in girls from different populations until about 11 (Lodz) to 14 (Belchatow Industrial Region) years of age, and in boys until about 13 (Strzemieszycze) to 18 (Lodz) years of age (Fig. 6). The period of peak development is followed by a regression being most rapid in women from the Belchatow Industrial Region and men from Bukowno, and the slowest in inhabitants of both sexes in the Lublin Coal Basin. At about 45 years of age, the persistence once again reaches the level characteristic of 5 year old children.

The age-dependent changes in the results of the test in hanging in arm flexed position (HAFP) and of the test for abdominal muscles (KWAT) are less clear-cut. This is probably due to the fact that in this case the weight of child's body is changed; yet, the relation of muscle cross-section area and also strength of lever system between various body parts and body weight varies in the course of ontogenesis. Thus, in general, particularly in girls and mainly in tests of abdominal muscles, the persistence increases in the pre-school period, drops in the pubertal period, once more rises during adolescence and again diminishes in adulthood, particularly at old age.

Persistence evaluated by HAFP increases till the pre-pubertal period, and after a temporary drop it once again rises until adolescence (Fig. 7). The peak of development is attained earliest by women from Lodz and Bukowno (at about 16 years of age) and men from Slawkow (at about 15 years), and latest by women from Olkusz and Belchatow Industrial Region (at about 20 years) and men from Lodz and Suwalki district (after 20 years). The regression is most rapid in women from the Belchatow Industrial Region and Bukowno and in men from Lodz and Olkusz, whereas it is slowest in women from Olkusz and inhabitants of the Suwalki district of both sexes. Old women exhibit persistence typical of 7 years old girls, and old men typical of 12 years old boys.

Persistence measured by KWAT drops with age till the pubertal period and then increases. The peak value is attained earliest (at about 15 years of age) by women from Lodz and men from the Belchatow Industrial Region, and latest (after 50 years of age) by women from Bukowno and men from the Belchatow Industrial Region and Lodz (Fig. 7). The regression of this trait after the developmental peak is most rapid in women from Lodz and men from Strzemieszycze, whereas it is slowest in women from Bukowno and men from the Lublin Coal Basin. A value of the test typical of 5 years old children is attained for the second time at about 20 years of age and for the third time after 80 years of age, with big inter-populational differences in the dynamics of the progressive and regressive changes.

As compared with other traits investigated in the same materials, the endurance measured by MOU exhibits a peak value during adolescence, while persistence evaluated by the above-mentioned tests displays this peak value from puberty till adolescence; for movement accuracy and flexibility, the analogous period is earlier (Fig. 8). As compared with persistence, other traits: aim accuracy, movement speed of hands, static strength of muscles and endurance fitness (MOU), display a later peak of development.

Persistence evaluated by the above-mentioned tests is highest in the inhabitants of industrialized regions and lowest in rural populations (Table 3), probably on account of the nature of work and mode of life of these population groups. Urban population assumes an intermediate place between both above mentioned populations. The endurance is highest in urban populations and lowest in inhabitants of industrial regions.

4. DISCUSSION

In the present study it is of importance to specify whether the traits evaluated by a certain group of tests measuring „cardiorespiratory and muscular endurance” only represent distinct tests assessing the same component of human motorics or whether in fact they are different. In my opinion endurance fitness is only one of the several manifestations of motor activity in man. It exhibits a low correlation with some traits, e.g. with duration of short- and medium-distance races (100–1000 m), and a high one with other traits, e.g. with duration of 60-m dash. (Wolanski, Kozlowski and Fisrowicz 1973).

There is a strong correlation between the duration of 10–50 m dash, on the one hand, and static persistence (HAFP — stronger correlation) and dynamic persistence (BSTT — weaker correlation) on the other. Persistence fitness is also strongly corre lated with the duration of shuttle run and with explosive power, but not with grip strength (Fleishman 1964, Brudzynski 1985).

The above-mentioned factor analysis affords important information about the different components of motorics (Table 4). Obviously, the results depend on the tests analysed. However, it can generally be stated that the first principal component (F 1) is formed by body size and weight, and to some extent by muscular strength as well. The second principal component (F 2) is formed by adipose tissue and/or static strength, the third principal component — by endurance fitness and overall physical fitness, the fourth principal component — by persistence, the fifth principal component — by agility, and the sixth principal component — by speed of movements. In our opinion it is of importance that the tests representing the cardiorespiratory system and energy changes, i.e. endurance fitness, form a separate principal component (latent factor), not correlated with that formed by the tests concerning long-term static efforts, i.e. persistence fitness.

An analysis of the age at the peak value of development of the traits measured by various tests also indicates
that the developmental peak is attained earliest by per-
sistence measured by the dynamic Burpee test, and later
by the static tests of persistence (HAFP and KWAT).
The peak of development is reached by MOU the latest,
being most representative of endurance fitness.

Only heritability sets apart the dynamic test for per-
sistence (Burpee squat-thrust test), and endurance
measured by an increase in the pulse rate at work and
persistence evaluated in hanging position (HAFP).

In the light of the present results it seems obvious that
within physical fitness two traits have to be distinguished.
One of them reflects the cardiorespiratory properties and
expresses the energy changes; I propose to refer to this
trait as endurance. The other trait corresponds to the
possibilities of work continuation and expresses tissue
tolerance to the metabolites formed during work; I pro-
pose to refer only to this trait as persistence fitness.
Factor analysis indicates that these two components of
motorics are evidently distinct from strength (particularly
the static one), agility and speed of movements. It seems
that the traits listed in order of decreasing importance for
physical fitness of the body assume the following sequen-
ce: body weight and static muscular strength; endurance
fitness and explosive power; persistence fitness; agility;
speed of movements.

The present results indicate that endurance fitness is
more susceptible to training than persistence. The latter
is the more difficult to train, as more numerous muscle
groups are concerned and the motor actions involved are
more dynamic.

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Table 1
Nominal traits of the organism with a potential effect on the motor properties, and expected „predetermination” of the components of motorics in man

<table>
<thead>
<tr>
<th>Nominal traits of organism</th>
<th>Component of motorics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nerve impulse conduction</td>
<td>speed</td>
</tr>
<tr>
<td>Cross-section and type of muscle</td>
<td>strength, speed, agility</td>
</tr>
<tr>
<td>Upper transposition</td>
<td>strength, agility</td>
</tr>
<tr>
<td>Aerobic and anaerobic power</td>
<td>endurance</td>
</tr>
<tr>
<td>State of vestibular organ</td>
<td>agility</td>
</tr>
<tr>
<td>State of visual organ</td>
<td>co-ordination, agility, speed</td>
</tr>
<tr>
<td>State of taction (inc. proprioceptive) organ</td>
<td>co-ordination, agility, speed</td>
</tr>
<tr>
<td>Chronognois (feeling of time, rhythm)</td>
<td>co-ordination, agility, persistence</td>
</tr>
<tr>
<td>Continued work capacity</td>
<td>persistence</td>
</tr>
</tbody>
</table>

Table 2.
Correlation coefficients of somatic and psychomotor traits in combinations: parents – offspring (r_{po}), sib-sib (r_{ss}), husband-wife (r_{pp}), heritability index H (Fisher), ecosensitivity (Eco) and heritability (Her) estimated by an own method. Correlation coefficients significant at level 0.05*, and 0.01**

<table>
<thead>
<tr>
<th>Trait</th>
<th>r_{po}</th>
<th>r_{ss}</th>
<th>r_{pp}</th>
<th>H</th>
<th>3r_{ss}-r_{po}</th>
<th>Eco</th>
<th>Her</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grip strength</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>right hand</td>
<td>0.15**</td>
<td>0.30**</td>
<td>0.06</td>
<td>0.28</td>
<td>0.75</td>
<td>5.00</td>
<td>0.20</td>
</tr>
<tr>
<td>left hand</td>
<td>0.13**</td>
<td>0.27**</td>
<td>0.08</td>
<td>0.24</td>
<td>0.68</td>
<td>5.23</td>
<td>0.19</td>
</tr>
<tr>
<td>Back lift strength</td>
<td>0.28**</td>
<td>0.23**</td>
<td>0.22**</td>
<td>0.46</td>
<td>0.41</td>
<td>1.46</td>
<td>0.68</td>
</tr>
<tr>
<td>Explosive power of upper extrem. (med. ball throw)</td>
<td>0.17**</td>
<td>0.16**</td>
<td>0.13**</td>
<td>0.30</td>
<td>0.31</td>
<td>1.82</td>
<td>0.55</td>
</tr>
<tr>
<td>lower extrem. (vertical jump)</td>
<td>0.20**</td>
<td>0.23**</td>
<td>0.15**</td>
<td>0.35</td>
<td>0.49</td>
<td>2.45</td>
<td>0.41</td>
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<td>Simple reaction time</td>
<td></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>hand</td>
<td>0.17**</td>
<td>0.18**</td>
<td>0.16**</td>
<td>0.29</td>
<td>0.37</td>
<td>2.18</td>
<td>0.46</td>
</tr>
<tr>
<td>foot</td>
<td>0.16**</td>
<td>0.17**</td>
<td>0.16**</td>
<td>0.28</td>
<td>0.35</td>
<td>2.19</td>
<td>0.46</td>
</tr>
<tr>
<td>Movement speed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>right hand</td>
<td>0.34**</td>
<td>0.33**</td>
<td>0.33**</td>
<td>0.53/</td>
<td>0.65</td>
<td>1.91</td>
<td>0.52</td>
</tr>
<tr>
<td>left hand</td>
<td>0.36**</td>
<td>0.30**</td>
<td>0.35**</td>
<td>0.54</td>
<td>0.64</td>
<td>1.50</td>
<td>0.67</td>
</tr>
<tr>
<td>feet (max.)</td>
<td>0.45**</td>
<td>0.46**</td>
<td>0.59**</td>
<td>0.57</td>
<td>0.93</td>
<td>2.07</td>
<td>0.48</td>
</tr>
<tr>
<td>feet (cycling)</td>
<td>0.39**</td>
<td>0.29**</td>
<td>0.36**</td>
<td>0.57</td>
<td>0.45</td>
<td>1.15</td>
<td>0.87</td>
</tr>
<tr>
<td>Persistence (hanging in arm flexed pos.)</td>
<td>0.17**</td>
<td>0.25**</td>
<td>0.15*</td>
<td>0.30</td>
<td>0.58</td>
<td>3.41</td>
<td>0.29</td>
</tr>
<tr>
<td>Abdomen muscles (persis.)</td>
<td>0.26**</td>
<td>0.25**</td>
<td>0.15**</td>
<td>0.46</td>
<td>0.49</td>
<td>1.88</td>
<td>0.53</td>
</tr>
<tr>
<td>Persistence (Burpee test)</td>
<td>0.23**</td>
<td>0.17**</td>
<td>0.31**</td>
<td>0.35</td>
<td>0.28</td>
<td>1.22</td>
<td>0.82</td>
</tr>
<tr>
<td>Endurance (pulse increase under work)</td>
<td>0.18</td>
<td>0.25</td>
<td>0.26</td>
<td>0.29</td>
<td>0.87</td>
<td>3.16</td>
<td>0.32</td>
</tr>
<tr>
<td>Endurance (max V\textsubscript{O2})</td>
<td>0.12</td>
<td>-0.22</td>
<td>0.20</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Table 3.
Maximal (best = max), average (a) and minimal (worst = min) values of some psychomotor traits in 5 populations recognized as rural, urban and industrial in Poland

<table>
<thead>
<tr>
<th>Trait</th>
<th>Rural</th>
<th>Urban</th>
<th>Industrial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spine flexibility</td>
<td>min</td>
<td>min</td>
<td>max</td>
</tr>
<tr>
<td>Turning balance</td>
<td>a</td>
<td>min</td>
<td>max</td>
</tr>
<tr>
<td>Standing balance</td>
<td>min</td>
<td>a</td>
<td>max</td>
</tr>
<tr>
<td>Hand movement accuracy ( proprioceptive feel)</td>
<td>min</td>
<td>max</td>
<td>max</td>
</tr>
<tr>
<td>Space orientation</td>
<td>min</td>
<td>—</td>
<td>max</td>
</tr>
<tr>
<td>Throw at a target for accuracy</td>
<td>a</td>
<td>max</td>
<td>min</td>
</tr>
<tr>
<td>Agility run (shuttle run)</td>
<td>max</td>
<td>min</td>
<td>a</td>
</tr>
</tbody>
</table>

**Strength and power**

<table>
<thead>
<tr>
<th>Trait</th>
<th>Rural</th>
<th>Urban</th>
<th>Industrial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grip strength</td>
<td>max</td>
<td>min</td>
<td>a</td>
</tr>
<tr>
<td>Back-lift strength</td>
<td>max</td>
<td>—</td>
<td>min</td>
</tr>
<tr>
<td>Upper extremity explosive power (ball throw)</td>
<td>a</td>
<td>min</td>
<td>max</td>
</tr>
<tr>
<td>Lower extremity explosive power (vert. jump)</td>
<td>min</td>
<td>a</td>
<td>max</td>
</tr>
</tbody>
</table>

**Speed**

<table>
<thead>
<tr>
<th>Trait</th>
<th>Rural</th>
<th>Urban</th>
<th>Industrial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple reaction time of hands and feet</td>
<td>max</td>
<td>a</td>
<td>min</td>
</tr>
<tr>
<td>Hand movement speed</td>
<td>max</td>
<td>a</td>
<td>min</td>
</tr>
<tr>
<td>Legs movement speed</td>
<td>min</td>
<td>a</td>
<td>max</td>
</tr>
</tbody>
</table>

**Persistence fitness**

<table>
<thead>
<tr>
<th>Trait</th>
<th>Rural</th>
<th>Urban</th>
<th>Industrial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burpee squat thrust test</td>
<td>min</td>
<td>a</td>
<td>max</td>
</tr>
<tr>
<td>Abdomen muscles persistence</td>
<td>min</td>
<td>a</td>
<td>max</td>
</tr>
<tr>
<td>Hanging in arm flexed position</td>
<td>min</td>
<td>a</td>
<td>max</td>
</tr>
</tbody>
</table>

**Endurance fitness**

<table>
<thead>
<tr>
<th>Trait</th>
<th>Rural</th>
<th>Urban</th>
<th>Industrial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximal oxygen uptake (aerobic power)</td>
<td>a</td>
<td>max</td>
<td>min</td>
</tr>
</tbody>
</table>

Table 4.
Principal components (latent factors) identified by various authors using different tests connected with human physical fitness and/or psychomotor efficiency. Principal components according to Krapkova 1973, Żara 1970 and Havlíček 1972 after Mekota 1978.

<table>
<thead>
<tr>
<th>Author and tests used</th>
<th>F 1</th>
<th>F 2</th>
<th>F 3</th>
<th>F 4</th>
<th>F 5</th>
<th>F 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fleishman 1964, strength</td>
<td>static</td>
<td>persist.</td>
<td>static</td>
<td>strength</td>
<td>agility</td>
<td>+ speed</td>
</tr>
<tr>
<td>Fleishman 1964, agility etc</td>
<td>agility</td>
<td>balance</td>
<td>strength</td>
<td>grip</td>
<td>explos.</td>
<td>power</td>
</tr>
<tr>
<td>Žara 1970, general</td>
<td>body w. + VC</td>
<td>agility</td>
<td>body w.</td>
<td>strength</td>
<td>explos.</td>
<td>persistence</td>
</tr>
<tr>
<td>Havlíček 1972, general</td>
<td>agility</td>
<td>body w.</td>
<td>flexib.</td>
<td>flexib.</td>
<td>strength</td>
<td>+ flexib.</td>
</tr>
<tr>
<td>Krapkova 1973, artis. gymnastics</td>
<td>flexibil.</td>
<td>run</td>
<td>throw</td>
<td>jump</td>
<td>run</td>
<td>flexib.</td>
</tr>
<tr>
<td>Mekota 1975, track and field</td>
<td>run</td>
<td>throw</td>
<td>jump</td>
<td>run</td>
<td>run</td>
<td>run</td>
</tr>
<tr>
<td>Matsuuraru 1980, general</td>
<td>body w. + statura</td>
<td>adipose tissue</td>
<td>static stren. + VC</td>
<td>endurance</td>
<td>strength</td>
<td>low extr.</td>
</tr>
<tr>
<td>Reilley and Thomas 1980, general</td>
<td>body w. + streng.</td>
<td>adip. tis. + VC</td>
<td>static streng. + VC</td>
<td>endurance</td>
<td>strength</td>
<td>low extr.</td>
</tr>
<tr>
<td>Brudzynski 1985, general</td>
<td>body w. + streng.</td>
<td>agility</td>
<td>persistence</td>
<td>speed</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

MOST FREQUENT SEQUENCE (and Important for motorics in man?)

<table>
<thead>
<tr>
<th>Trait</th>
<th>F 1</th>
<th>F 2</th>
<th>F 3</th>
<th>F 4</th>
<th>F 5</th>
<th>F 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>muscle mass</td>
<td>muscle mass</td>
<td>static</td>
<td>streng. + adipose tissue</td>
<td>endurance</td>
<td>(+ general)</td>
<td>fitness</td>
</tr>
</tbody>
</table>
Fig. 1. Parents-child mean correlation coefficients for endurance and persistence fitness, and for numerous other motor traits in Man

Fig. 2. Sib-sib mean correlation coefficients for endurance and persistence fitness, and for numerous other motor traits in Man
Fig. 3. Heritability index as calculated by Fisher (1918) method (H) and by Wolanski and Sniarska (1984) method (Her) for endurance and persistence fitness and for some other motor and somatic traits in Man.

Maximal oxygen uptake in ml/kg/min

Fig. 4. Ecosensitivity index (Eco) as calculated by Wolanski and Sniarska (1984) method for endurance and persistence fitness and for some other motor traits in Man.
Fig. 5. Maximal oxygen uptake (MOU) per 1 minute and per 1 kg of body weight in some Polish and Yugoslavian populations with comparison with Sweden, Canadian, USA and Masai populations (data by Ivanović, Wolanski and Kozioł 1984, Wolanski 1975, di Prampero and Cerretelli 1969, Shephard 1969) in age 5 to 70 years in milliliters of O₂ in BTPS.

Fig. 6. Burpee squat-thrust test (BSTT) in cycles per 1 minute in numerous of Polish rural, under industrialization, industrialized and urban populations in age 5–65 years (by Elzanowska and Sniarska 1982).

Fig. 7. Hanging in arm flexed position (HAFP) in seconds in numerous of Polish rural and other populations in age 3–80 years (by Elzanowska and Sniarska 1982).
Fig. 8. Kraus-Weber muscular test of the psoas and abdominal muscles (KWAT) in seconds in numerous of Polish rural and other populations in age 3–80 years (by Elzanowska and Siniarska 1982)

MOU — endurance

— grip strength

— back-lift strength

hand movm. speed — — accuracy (throw)

reaction time — — HAIF - persistence

— — space orientation

legs movm.speed — — explosive power (jump)

BSTT—persistence — — balance

— — agility run

— — movement accuracy (far)

— — spine flexibility

— — movement accuracy (close)

Age in years

4 6 8 10 12 14 16 22 27 35 45 55

Fig. 9. Age at maximal (peak) value and high fitness of endurance, persistence and some other motor traits in Man (solid lines in men and broken lines in women, triangle = peak value)
IZDRŽLJIVOST I USTRAJNOST. GENETSKA KONTROLA I MOGUĆNOST TRENIRANJA (VJEŽBANJA)

Učinjen je pokusaj razgranicačenja pojmov izdržljivosti i ustrajnosti. Na temelju citirane literature autor smatra da se izdržljivost odnosi na radni kapacitet, dinamiku i količinu rada, a pobliže na tzv. aerobnu „snagu” (dug kisik), dok je ustrajnost povezana s uzrocom umora i s trajanjem rada i više se odnosi na anaerobnu „snagu” (dostupnost i iskorištavanje hranjivih rezervi u aktivnim tkivima). U svrhu utvrđivanja mogućih genetskih razlika između dvije takoj definirane sposobnosti uspoređen su rezultati velikog broja istraživanja, provedenih od 1960 godine u Poljskoj i Jugoslaviji, na ispitnicima u dob dijete i mladeža. U stranama je otkriveno da djeca i mladež u usredotočenu vježbu su utisle u sljedeće rezultate: u među gotovo u usredotočenu vježbu su utisle u sljedeće rezultate:

1. Najveća utjecaj na izdržljivost ima genetska faktore
2. Ustrajnost je pod utjecajem genetskih faktora
3. Ustrajnost i izdržljivost su pod utjecajem genetskih faktora

U svijetu dobivenih rezultata čini se izvan svake sumnje da je potrebno unutar fizičke spremnosti razlikovati dvije osobine. Jedna odražava kardiovaskularna svojstva i izražava energetne promjene; autor predlaže da se ta osobina imenuje kao izdržljivost. Druga odgovara mogućnostima nastavljanja rada i izražava toleranciju tkiva na metabolite proizvedene tokom rada; autor predlaže da se ta osobina nazove ustrajnoću. Razmatrani rezultati ukazuju na to da je izdržljivost znatno više podložna procesu treninga od ustrajnosti. Ustrajnost je već manje podložna procesu treninga što je više miješčnih grupa uključeno, to što su motoričke akcije više dinamičkog karaktera.