# The methodology of studies and evaluation of physical fitness in flying personnel

Colonel Prof. Dr. K. KLUKOWSKI,
Ass. Prof. M. KLOSSOWSKI Ph.D. (Poland),
Polish Air Force Institute of Aviation Medicine.

## Introduction

Among all factors affecting pilot's health, systematic motor activity is essential. It is reflected by the level of aptitude and physical capacity. The PAF Institute of Aviation Medicine within its diagnostic-certification activity considers periodic and long-wave studies of flying personnel's physical capacity in the aspect of preventing circulatory system diseases and defining the optimal level of ability to work in aviation.

We estimate pilot's physical capacity during periodic and circumstantial qualifying examinations and duing their stay in Military Training Centres, depending on the needs of aviation-medical certification. In the estimation of physical capacity we consider $VO_2$ max level (the level of maximal oxygen uptake), the features of circulatory system effort adaptation (depending on the value of changes in arterial blood pressure and heart rate) and the kind of changes in electrocardiogram after physical effort. The proper adaptation of the circulatory system and the lack of pathological changes in electrocardiography determine whether the study can be accepted or not. In each case the individualisation of effort loads is used. The person who examines candidates decides when to finish the test.
In this we have not presented the interpretation of electrocardiogram since the criteria of positive effort trial are consistent with WHO recommendations.

1. **The selections of submaximal effort loads in testing of the maximal oxygen intake**

During mass examinations, when the time is limited and there are a lot of subjects, it is difficult to determine during the first examination the optimal range of standard loads. In this case, using relative loads related to individual physical capacity of each subject seems more profitable. The original Astrand-Rhyming trial is based on the selection of effort load causing that the heart rate reaches values 120-170/min (1). In the PAF Institute of Aviation Medicine, the method of determining relative loads during exercises with a cycloergometer has been worked out. It is based on the heart rate obtained during the first, initial load - its value is 1 W/kg of body weight (3). The accepted methodology of examination is mainly based on dosing loads on an electromagnetic ergometer ELEMA-SCHONANDER. Since there is a need to carry out identical studies in Military Training Centres, which are equipped with worse apparatus, the described method has been adapted to exercises with a bicycle ergometer MONARK, with mechanical breaking.
Within the proposed system of effort examination the heart rate can be measured in four ways :
a) using a phonendoscope and a stop-watch,
b) using an electronic pulse measurer, attached to an ear lobe,
c) recording the electrocardiogram from selected leads from the chest ($CM_5$, Nehb, $V_5$, $V_6$),
d) using the SPORT-TESTER set (a belt with electrodes and watch-measurer).

Table I presents the methodology of effort loads selection on a bicycle ergometer with an electromagnetic breaking and the possibility to regulate the load every 10 W.

**Tab. 1 : The methodology of effort loads for men, depending on body weight and the initial response to effort on electromechanically steered bicycle ergometer.**

## ELECTRIC ERGOMETER

| WEIGHT (KG) | WORKLOAD I (WATT) | WORKLOAD II | | |
|---|---|---|---|---|
| | | VARIANT I (HR < 110) | VARIANT II (110 < HR < 120) | VARIANT III (HR > 120) |
| TO 55 | 50 | 110 | 80 | REMAIN INITIAL WORKLOAD |
| 55 - 60 | 60 | 120 | 90 | |
| 61 - 65 | 60 | 120 | 100 | |
| 66 - 70 | 70 | 130 | 100 | |
| 71 - 75 | 70 | 140 | 110 | |
| 76 - 80 | 80 | 150 | 110 | |
| 81 - 85 | 80 | 150 | 120 | |
| UP 85 | 90 | 150 | 130 | |
| TIME | 3 MIN. | 6 MIN. | 6 MIN. | 3 MIN. |

Table 2 presents the methodology of effort loads selection on ergometer with mechanical breaking and regulation of loads in scale every 0.5 kg (25 W).

Tab. 2 : The methodology of effort loads selection for men, depending on body weight and the initial response to effort on a mechanical bicycle ergometer (MONARK)

## MONARK ERGOMETER

| WEIGHT (KG) | WORKLOAD I (WATT) | WORKLOAD II | | |
|---|---|---|---|---|
| | | VARIANT I (HR < 110) | VARIANT II (110 < HR < 120) | VARIANT III (HR > 120) |
| TO 55 | 50 (1.0) | 110 (2.0) | 80 (1.5) | REMAIN INITIAL WORKLOAD |
| 55 - 60 | 60 (1.0) | 120 (2.0) | 90 (1.5) | |
| 61 - 65 | 60 (1.0) | 120 (2.0) | 100 (1.5) | |
| 66 - 70 | 70 (1.5) | 130 (2.5) | 100 (2.0) | |
| 71 - 75 | 70 (1.5) | 140 (2.5) | 110 (2.0) | |
| 76 - 80 | 80 (1.5) | 150 (3.0) | 110 (2.0) | |
| 81 - 85 | 80 (1.5) | 150 (3.0) | 120 (2.5) | |
| UP 85 | 90 (1.5) | 150 (3.0) | 130 (2.5) | |
| TIME | 3 MIN. | 6 MIN. | 6 MIN. | 3 MIN. |

The principle of carrying out the test is as follows : during the first, three minutes initial period of working with any ergometer, the load amounts to approximately 1 W/Kg of body weight. Depending on the obtained heart rate (HR) during the last fifteen seconds of the third minute of work, three different variants of proper effort load applied :

- variant I : approximately doubling the load to about 2 W/kg of body weight; it is used if HR is not bigger than 110/min,
- variant II : increasing the load to about 1.5 W/kg of body weight; it is used if HR is about 110-120/min,
- variant III : leaving the initial load if HR has not reached 110-120/min.

When variant I or variant II is applied, the work lasts (with the 3 minute initial period) 9 minutes, when variant III is applied - it lasts 6 minutes. In pilots who have performed 6 minutes'effort test, the physical capacity ($VO_2$ max) is decreased and they need a more thorough going over so that other deviations in their hygienic condition can be excluded.

It was proved that such methodology of effort loads selection can be applied in healthy men aging 20-54. Regardless the accepted load variant, the effort heart rate does not exceed 170/min during the so called "steady state". The effort heart rate values in 70 percent amount for 130-150/min. Arterial blood pressure does not exceed "safe" values (2.6).

The obtained effort heart rate values (in variant I and II - 9 minutes, in variant III - 6 minutes of work) are written in Astrand-Rhyming nomogram. To simplify the use of it, particular values have been specified and presented in table 3.

Tab. 3 : The predicted maximal oxygen uptake ($VO_2$ max) depending on heart rate during a submaximal effort trial (according to Astrand-Rhyming nomogram)

| HR | WORKLOAD (WATTS) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 | 130 | 140 | 150 |
| 120 | 2.2 | 2.4 | 2.7 | 3.0 | 3.2 | 3.5 | 3.8 | 4.0 | 4.3 | 4.5 | 4.8 |
| 121 | 2.2 | 2.4 | 2.6 | 2.9 | 3.2 | 3.4 | 3.7 | 3.9 | 4.2 | 4.4 | 4.7 |
| 122 | 2.2 | 2.3 | 2.6 | 2.8 | 3.1 | 3.4 | 3.6 | 3.9 | 4.1 | 4.4 | 4.6 |
| 123 | 2.1 | 2.3 | 2.6 | 2.8 | 3.1 | 3.4 | 3.6 | 3.8 | 4.1 | 4.3 | 4.6 |
| 124 | 2.1 | 2.3 | 2.5 | 2.8 | 3.0 | 3.3 | 3.5 | 3.8 | 4.0 | 4.2 | 4.5 |
| 125 | 2.0 | 2.2 | 2.5 | 2.7 | 3.0 | 3.2 | 3.5 | 3.7 | 3.9 | 4.2 | 4.4 |
| 126 | 2.0 | 2.2 | 2.5 | 2.7 | 2.9 | 3.2 | 3.4 | 3.6 | 3.9 | 4.1 | 4.4 |
| 127 | 2.0 | 2.2 | 2.4 | 2.7 | 2.9 | 3.1 | 3.3 | 3.6 | 3.8 | 4.0 | 4.3 |
| 128 | 2.0 | 2.1 | 2.4 | 2.6 | 2.8 | 3.1 | 3.3 | 3.5 | 3.8 | 4.0 | 4.2 |
| 129 | 1.9 | 2.1 | 2.4 | 2.6 | 2.8 | 3.0 | 3.2 | 3.5 | 3.7 | 3.9 | 4.2 |
| 130 | 1.9 | 2.1 | 2.3 | 2.6 | 2.8 | 3.0 | 3.2 | 3.4 | 3.6 | 3.9 | 4.1 |
| 131 | 1.9 | 2.0 | 2.3 | 2.5 | 2.7 | 2.9 | 3.1 | 3.4 | 3.6 | 3.8 | 4.0 |
| 132 | 1.8 | 2.0 | 2.3 | 2.5 | 2.7 | 2.9 | 3.1 | 3.3 | 3.5 | 3.8 | 4.0 |
| 133 | 1.8 | 2.0 | 2.2 | 2.4 | 2.6 | 2.8 | 3.1 | 3.3 | 3.5 | 3.7 | 3.9 |
| 134 | 1.8 | 2.0 | 2.2 | 2.4 | 2.6 | 2.8 | 3.0 | 3.2 | 3.4 | 3.6 | 3.9 |
| 135 | 1.7 | 1.9 | 2.2 | 2.4 | 2.6 | 2.8 | 3.0 | 3.2 | 3.4 | 3.6 | 3.8 |
| 136 | 1.7 | 1.9 | 2.1 | 2.3 | 2.5 | 2.7 | 2.9 | 3.1 | 3.3 | 3.5 | 3.8 |
| 137 | 1.7 | 1.9 | 2.1 | 2.3 | 2.5 | 2.7 | 2.9 | 3.1 | 3.3 | 3.5 | 3.7 |
| 138 | 1.6 | 1.8 | 2.1 | 2.3 | 2.5 | 2.7 | 2.8 | 3.0 | 3.2 | 3.4 | 3.7 |
| 139 | 1.6 | 1.8 | 2.0 | 2.2 | 2.4 | 2.6 | 2.8 | 3.0 | 3.2 | 3.4 | 3.6 |
| 140 | 1.6 | 1.8 | 2.0 | 2.2 | 2.4 | 2.6 | 2.7 | 3.0 | 3.2 | 3.3 | 3.6 |
| 141 | | 1.8 | 2.0 | 2.2 | 2.4 | 2.6 | 2.7 | 2.9 | 3.1 | 3.3 | 3.5 |
| 142 | | 1.7 | 2.0 | 2.1 | 2.3 | 2.5 | 2.7 | 2.9 | 3.1 | 3.3 | 3.5 |
| 143 | | 1.7 | 1.9 | 2.1 | 2.3 | 2.5 | 2.6 | 2.8 | 3.0 | 3.2 | 3.4 |
| 144 | | 1.7 | 1.9 | 2.1 | 2.3 | 2.5 | 2.6 | 2.8 | 3.0 | 3.2 | 3.4 |
| 145 | | 1.7 | 1.9 | 2.1 | 2.2 | 2.4 | 2.6 | 2.7 | 3.0 | 3.1 | 3.4 |
| 146 | | 1.6 | 1.8 | 2.0 | 2.2 | 2.4 | 2.6 | 2.7 | 2.9 | 3.1 | 3.3 |
| 147 | | 1.6 | 1.8 | 2.0 | 2.2 | 2.4 | 2.5 | 2.7 | 2.9 | 3.1 | 3.3 |
| 148 | | 1.6 | 1.8 | 2.0 | 2.2 | 2.4 | 2.5 | 2.7 | 2.8 | 3.0 | 3.2 |
| 149 | | 1.6 | 1.8 | 2.0 | 2.1 | 2.3 | 2.5 | 2.6 | 2.8 | 3.0 | 3.2 |
| 150 | | 1.6 | 1.8 | 1.9 | 2.1 | 2.3 | 2.5 | 2.6 | 2.8 | 3.0 | 3.2 |
| 151 | | | 1.7 | 1.9 | 2.1 | 2.3 | 2.4 | 2.6 | 2.7 | 2.9 | 3.1 |
| 152 | | | 1.7 | 1.9 | 2.1 | 2.3 | 2.4 | 2.6 | 2.7 | 2.9 | 3.1 |
| 153 | | | 1.7 | 1.9 | 2.0 | 2.2 | 2.4 | 2.5 | 2.7 | 2.8 | 3.0 |
| 154 | | | 1.7 | 1.8 | 2.0 | 2.2 | 2.4 | 2.5 | 2.7 | 2.8 | 3.0 |
| 155 | | | 1.6 | 1.8 | 2.0 | 2.2 | 2.3 | 2.5 | 2.6 | 2.8 | 3.0 |
| 156 | | | 1.6 | 1.8 | 2.0 | 2.2 | 2.3 | 2.4 | 2.6 | 2.7 | 2.9 |
| 157 | | | 1.6 | 1.8 | 1.9 | 2.1 | 2.3 | 2.4 | 2.6 | 2.7 | 2.9 |
| 158 | | | 1.6 | 1.8 | 1.9 | 2.1 | 2.2 | 2.4 | 2.6 | 2.7 | 2.9 |
| 159 | | | 1.6 | 1.7 | 1.9 | 2.1 | 2.2 | 2.4 | 2.5 | 2.7 | 2.8 |
| 160 | | | | 1.7 | 1.9 | 2.1 | 2.2 | 2.3 | 2.5 | 2.6 | 2.8 |
| 161 | | | | 1.7 | 1.8 | 2.0 | 2.2 | 2.3 | 2.5 | 2.6 | 2.8 |
| 162 | | | | 1.7 | 1.8 | 2.0 | 2.1 | 2.3 | 2.5 | 2.6 | 2.8 |
| 163 | | | | 1.7 | 1.8 | 2.0 | 2.1 | 2.3 | 2.4 | 2.6 | 2.8 |
| 164 | | | | 1.6 | 1.8 | 2.0 | 2.1 | 2.2 | 2.4 | 2.5 | 2.7 |
| 165 | | | | 1.6 | 1.8 | 2.0 | 2.1 | 2.2 | 2.4 | 2.5 | 2.7 |
| 166 | | | | 1.6 | 1.8 | 1.9 | 2.1 | 2.2 | 2.4 | 2.5 | 2.7 |
| 167 | | | | 1.6 | 1.7 | 1.9 | 2.0 | 2.2 | 2.3 | 2.5 | 2.6 |
| 168 | | | | 1.6 | 1.7 | 1.9 | 2.0 | 2.2 | 2.3 | 2.5 | 2.6 |
| 169 | | | | 1.6 | 1.7 | 1.9 | 2.0 | 2.1 | 2.3 | 2.4 | 2.6 |
| 170 | | | | | 1.7 | 1.8 | 2.0 | 2.1 | 2.3 | 2.4 | 2.6 |

The absolute values obtained after presenting the study results for table 3 should be corrected because of the subjects'age (tab.4).

Tab. 4 : Corrected predicted and maximal oxygen intake values, after considering subject's age.

# CONVERTION TABLE

(18 - 39 YEARS, 2.0 - 4.0 L/MIN)

| AGE | MAXIMAL OXYGEN INTAKE FROM ASTRAND-RYHMING NOMOGRAM | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2.0 | 2.1 | 2.2 | 2.3 | 2.4 | 2.5 | 2.6 | 2.7 | 2.8 | 2.9 | 3.0 | 3.1 | 3.2 | 3.3 | 3.4 | 3.5 | 3.6 | 3.7 | 3.8 | 3.9 | 4.0 |
| 18 | 2.1 | 2.2 | 2.3 | 2.4 | 2.6 | 2.7 | 2.8 | 2.9 | 3.0 | 3.1 | 3.2 | 3.3 | 3.4 | 3.5 | 3.6 | 3.7 | 3.8 | 4.0 | 4.1 | 4.2 | 4.3 |
| 19 | 2.1 | 2.2 | 2.3 | 2.4 | 2.5 | 2.6 | 2.7 | 2.9 | 3.0 | 3.1 | 3.2 | 3.3 | 3.4 | 3.5 | 3.6 | 3.7 | 3.8 | 3.9 | 4.0 | 4.1 | 4.2 |
| 20 | 2.1 | 2.2 | 2.3 | 2.4 | 2.5 | 2.6 | 2.7 | 2.8 | 2.9 | 3.0 | 3.1 | 3.2 | 3.4 | 3.5 | 3.6 | 3.7 | 3.8 | 3.9 | 4.0 | 4.1 | 4.2 |
| 21 | 2.1 | 2.2 | 2.3 | 2.4 | 2.5 | 2.6 | 2.7 | 2.8 | 2.9 | 3.0 | 3.1 | 3.2 | 3.3 | 3.4 | 3.5 | 3.6 | 3.7 | 3.8 | 3.9 | 4.0 | 4.2 |
| 22 | 2.1 | 2.2 | 2.3 | 2.4 | 2.5 | 2.6 | 2.7 | 2.8 | 2.9 | 3.0 | 3.1 | 3.2 | 3.3 | 3.4 | 3.5 | 3.6 | 3.7 | 3.8 | 3.9 | 4.0 | 4.1 |
| 23 | 2.0 | 2.1 | 2.2 | 2.3 | 2.4 | 2.5 | 2.6 | 2.7 | 2.8 | 2.9 | 3.1 | 3.2 | 3.3 | 3.4 | 3.5 | 3.6 | 3.7 | 3.8 | 3.9 | 4.0 | 4.1 |
| 24 | 2.0 | 2.1 | 2.2 | 2.3 | 2.4 | 2.5 | 2.6 | 2.7 | 2.8 | 2.9 | 3.0 | 3.1 | 3.2 | 3.3 | 3.4 | 3.5 | 3.6 | 3.7 | 3.8 | 3.9 | 4.0 |
| 25 | 2.0 | 2.1 | 2.2 | 2.3 | 2.4 | 2.5 | 2.6 | 2.7 | 2.8 | 2.9 | 3.0 | 3.1 | 3.2 | 3.3 | 3.4 | 3.5 | 3.6 | 3.7 | 3.8 | 3.9 | 4.0 |
| 26 | 2.0 | 2.1 | 2.2 | 2.3 | 2.4 | 2.5 | 2.6 | 2.7 | 2.8 | 2.9 | 3.0 | 3.1 | 3.2 | 3.3 | 3.4 | 3.5 | 3.6 | 3.7 | 3.8 | 3.8 | 3.9 |
| 27 | 1.9 | 2.0 | 2.1 | 2.2 | 2.3 | 2.4 | 2.5 | 2.6 | 2.7 | 2.8 | 2.9 | 3.0 | 3.1 | 3.2 | 3.3 | 3.4 | 3.5 | 3.6 | 3.7 | 3.8 | 3.9 |
| 28 | 1.9 | 2.0 | 2.1 | 2.2 | 2.3 | 2.4 | 2.5 | 2.6 | 2.7 | 2.8 | 2.9 | 3.0 | 3.1 | 3.2 | 3.3 | 3.4 | 3.5 | 3.6 | 3.7 | 3.7 | 3.8 |
| 29 | 1.9 | 2.0 | 2.1 | 2.2 | 2.3 | 2.4 | 2.5 | 2.6 | 2.7 | 2.7 | 2.8 | 2.9 | 3.0 | 3.1 | 3.2 | 3.3 | 3.4 | 3.5 | 3.6 | 3.7 | 3.8 |
| 30 | 1.9 | 2.0 | 2.1 | 2.2 | 2.2 | 2.3 | 2.4 | 2.5 | 2.6 | 2.7 | 2.8 | 2.9 | 3.0 | 3.1 | 3.2 | 3.3 | 3.4 | 3.5 | 3.6 | 3.6 | 3.7 |
| 31 | 1.8 | 1.9 | 2.0 | 2.1 | 2.2 | 2.3 | 2.4 | 2.5 | 2.6 | 2.7 | 2.8 | 2.9 | 3.0 | 3.0 | 3.1 | 3.2 | 3.3 | 3.4 | 3.5 | 3.6 | 3.7 |
| 32 | 1.8 | 1.9 | 2.0 | 2.1 | 2.2 | 2.3 | 2.4 | 2.5 | 2.5 | 2.6 | 2.7 | 2.8 | 2.9 | 3.0 | 3.1 | 3.2 | 3.3 | 3.4 | 3.5 | 3.5 | 3.6 |
| 33 | 1.8 | 1.9 | 2.0 | 2.1 | 2.2 | 2.2 | 2.3 | 2.4 | 2.5 | 2.6 | 2.7 | 2.8 | 2.9 | 3.0 | 3.0 | 3.1 | 3.2 | 3.3 | 3.4 | 3.5 | 3.6 |
| 34 | 1.8 | 1.9 | 2.0 | 2.0 | 2.1 | 2.2 | 2.3 | 2.4 | 2.5 | 2.6 | 2.6 | 2.7 | 2.8 | 2.9 | 3.0 | 3.1 | 3.2 | 3.3 | 3.4 | 3.4 | 3.5 |
| 35 | 1.7 | 1.8 | 1.9 | 2.0 | 2.1 | 2.2 | 2.3 | 2.3 | 2.4 | 2.5 | 2.6 | 2.7 | 2.8 | 2.9 | 3.0 | 3.1 | 3.1 | 3.2 | 3.3 | 3.4 | 3.5 |
| 36 | 1.7 | 1.8 | 1.9 | 2.0 | 2.1 | 2.2 | 2.3 | 2.3 | 2.4 | 2.5 | 2.6 | 2.7 | 2.8 | 2.9 | 3.0 | 3.0 | 3.1 | 3.2 | 3.3 | 3.4 | 3.5 |
| 37 | 1.7 | 1.8 | 1.9 | 2.0 | 2.1 | 2.2 | 2.3 | 2.3 | 2.4 | 2.5 | 2.6 | 2.7 | 2.8 | 2.9 | 3.0 | 3.0 | 3.1 | 3.2 | 3.3 | 3.4 | 3.5 |
| 38 | 1.7 | 1.8 | 1.9 | 2.0 | 2.1 | 2.2 | 2.3 | 2.3 | 2.4 | 2.5 | 2.6 | 2.7 | 2.8 | 2.9 | 3.0 | 3.0 | 3.1 | 3.2 | 3.3 | 3.4 | 3.5 |
| 39 | 1.7 | 1.8 | 1.8 | 1.9 | 2.0 | 2.1 | 2.2 | 2.3 | 2.4 | 2.4 | 2.5 | 2.6 | 2.7 | 2.8 | 2.9 | 2.9 | 3.0 | 3.1 | 3.2 | 3.3 | 3.4 |

The obtained relative values of predicted $VO_2$ max (in l/min) are divided by the amount of the subject's body weight and we gain relative values of $VO_2$ max in ml/kg/min. Both values of $VO_2$ max given in l and ml serve to define the level of physical capacity according to Polish norms worked out for military pilots. When the level of capacity is examined the greater diagnostic meaning of a relative value is accepted, converted to 1 kg of body weight, considering it, in case of any discrepancy, as final. Current physical capacity norms (predicted maximum oxygen intake) of military pilots are presented in tables 5 & 6.

Tab. 5 : $VO_2$ max norms of Polish military pilots (Klukowski, Klossowski - 1987) in l/min. For minimal values, presented in column 2, extended cardiological examinations are suggested.

## AEROBIC CAPACITY ($VO_2max$) OF POLISH AIR FORCE PILOTS

| AGE | MIN | POOR | FAIR | AVERAGE | GOOD | HIGH |
|---|---|---|---|---|---|---|
| 18 - 19 | 2.0 | 2.49 | 2.5 - 2.69 | 2.7 - 3.29 | 3.3 - 3.49 | 3.5 |
| 20 - 24 | 2.1 | 2.59 | 2.6 - 2.79 | 2.8 - 3.39 | 3.4 - 3.59 | 3.6 |
| 25 - 29 | 1.9 | 2.39 | 2.4 - 2.59 | 2.6 - 3.19 | 3.2 - 3.49 | 3.5 |
| 30 - 34 | 1.8 | 2.19 | 2.2 - 2.39 | 2.4 - 2.89 | 2.9 - 3.19 | 3.2 |
| 35 - 39 | 1.7 | 2.09 | 2.1 - 2.29 | 2.3 - 2.79 | 2.8 - 3.09 | 3.1 |
| 40 - 44 | 1.6 | 1.99 | 2.0 - 2.19 | 2.2 - 2.59 | 2.6 - 2.89 | 2.9 |
| 45 - 49 | 1.5 | 1.89 | 1.9 - 2.09 | 2.1 - 2.49 | 2.5 - 2.79 | 2.8 |
| 50 - 54 | 1.4 | 1.79 | 1.8 - 1.99 | 2.0 - 2.39 | 2.4 - 2.69 | 2.7 |

Tab. 6 : The same norms in ml/kg/min.

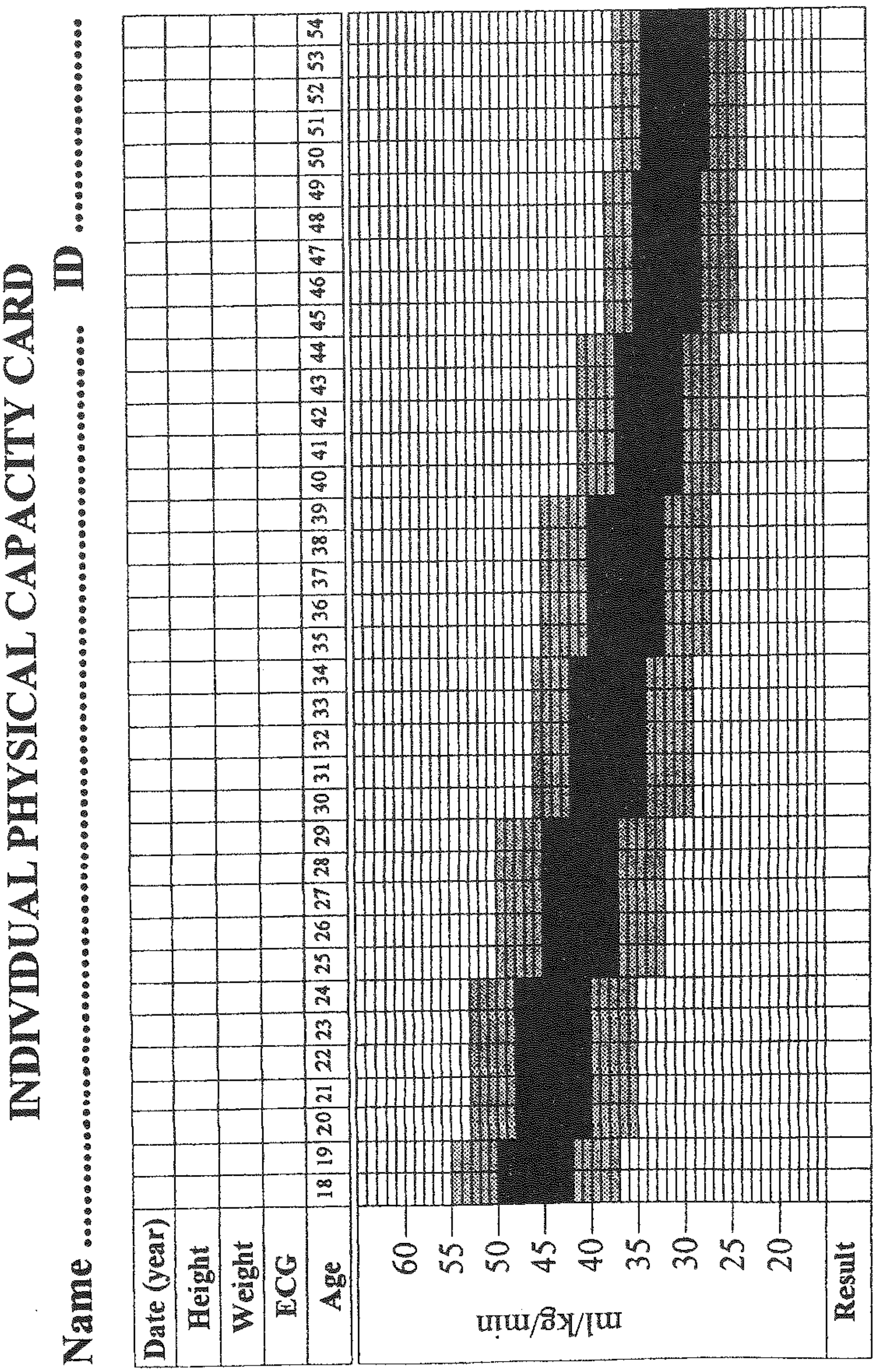
## AEROBIC CAPACITY ($VO_2max/kg$) OF POLISH AIR FORCE PILOTS

| AGE | POOR | FAIR | AVERAGE | GOOD | HIGH |
|---|---|---|---|---|---|
| 18 - 19 | 36 | 37 - 41 | 42 - 49 | 50 - 54 | 55 |
| 20 - 24 | 34 | 35 - 39 | 40 - 47 | 48 - 52 | 53 |
| 25 - 29 | 31 | 32 - 36 | 37 - 44 | 45 - 49 | 50 |
| 30 - 34 | 28 | 29 - 33 | 34 - 41 | 42 - 45 | 46 |
| 35 - 39 | 26 | 27 - 31 | 32 - 39 | 40 - 44 | 45 |
| 40 - 44 | 25 | 26 - 29 | 30 - 36 | 37 - 40 | 41 |
| 45 - 49 | 23 | 24 - 27 | 28 - 34 | 35 - 37 | 38 |
| 50 - 54 | 22 | 23 - 26 | 27 - 33 | 34 - 36 | 37 |

CISM INTERNATIONAL SYMPOSIUM
WARSAW - POLAND
1995

To make comparisons, the individual card of physical capacity changes due to age has been worked out (fig. 1). The curve with marked 50 centile corresponds with the arithmetic average of $VO_2$ max decrease. Such a card enables steady, long-time observation of changes in physical capacity level against a background of average population values.

Fig. 1 : Individual physical capacity card ($VO_2$ max) of a pilot (Klossowski, Slysz - 1987) against the background of norms.



During examining effort, using a bicycle ergometer, it is possible to measure arterial blood pressure what enables additional estimation of the character of circulatory system adaptation response, which is described below.

## 2. The estimation of circulatory system adaptation response to submaximal effort

You can define the character of circulatory system adaptation to effort by recording the heart rate and measuring arterial blood pressure (at the end of each examination) during the effort test. To obtain this estimation, it is necessary to compare the values of the load with maximal values of hemodynamic parameters obtained during the trial. In healthy subjects, or in person who are believed to be healthy, hyperkinetic or hypertonic reactions are most often abnormal (2,5,6).

### 2.1. Hypertonic response to physical effort

The results of our studies are based on the measurements of systolic arterial blood pressure ($BP_s$), during physical effort, performed using Korotkov's auscultatory method. To estimate a response to effort, we use $BP_s$ values obtained during the last minute of work and 30 seconds after finishing the trial. This estimation method demands relating $BP_s$ measurements to relative load, in terms of kg of body weight.

As a permitted limiting value we accepted $BP_s$ population average plus two standard deviations. If during any variant (1, 1.5 or 2 W kg) of an effort trial or half an hour after finishing it, the measured values are equal or exceed the extreme values given in table 7, we recognize it as a hypertonic reaction. Such a reaction proves the decrease of tolerance to effort because of the growth of arterial blood pressure values, which are disproportionate to the load.

Tab. 7 : The estimation of systolic arterial blood pressure response (in mm of Hg) in pilots in different decades (Klukowski, 1984) of their life.

## HYPERTONIC REACTION DURING AEROBIC TESTING

| AGE | 18 - 29 | | | 30 - 39 | | | 40 - 49 | | | 50 - 59 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WORKLOAD (W/kg) | 2.0 | 1.5 | 1.0 | 2.0 | 1.5 | 1.0 | 2.0 | 1.5 | 1.0 | 2.0 | 1.5 | 1.0 |
| BPS => (mm Hg) | 215 | 205 | 200 | 220 | 210 | 205 | 225 | 215 | 210 | 225 | 215 | 210 |
| BPS 30" after => (mm Hg) | 190 | 185 | 180 | 195 | 190 | 185 | 200 | 195 | 190 | 200 | 195 | 190 |

## 2.2. Hyperkinetic response to physical effort

We talk about circulatory system hypertonic reaction in case of too big heart rate (HR), in response to a given effort load during a submaximal trial. In table 8 the permitted extremal HR values are presented with various load variants. Similarly, as limiting values, we have accepted population averages increased by two standard deviations.

Tab. 8 : The estimation of heart rate response to effort in pilots in different decades of their life.

# HYPERKINETIC REACTION DURING AEROBIC TESTING

| AGE | 18 - 29 | | | 30 - 39 | | | 40 - 49 | | | 50 - 59 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LOAD (WATT) | 140 | 130 | 120 | 130 | 120 | 110 | 120 | 110 | 100 | 110 | 100 | 90 |
| HR LIMIT | 168 | 164 | 160 | 160 | 156 | 152 | 152 | 148 | 144 | 144 | 140 | 136 |
| $VO_2$MAX | 2.1 | | | 1.9 | | | 1.8 | | | 1.7 | | |
| LOAD (W/kg) | 2.0 | 1.5 | 1.0 | 2.0 | 1.5 | 1.0 | 2.0 | 1.5 | 1.0 | 2.0 | 1.5 | 1.0 |

In table 8 three variants of the estimation of heart rate reaction to effort are presented. Variant A presents the basic way of estimating. There are given the load values in Watts and corresponding limiting values. If, at the given or lower load level, we obtain the value that is equal or lower then the presented permitted value of maximal heart rate - we estimate that the circulatory system response is hyperkinetic. E.p. if a heart rate of 35 years old pilot (age group 30 - 39) reaches 150/min during the trial with 100 W load, it is hyperkinetic response.

Variant B is used at low $VO_2$ max values and treated as additional estimation. If the subject reaches minimal values presented in the table (usually during a 6 minutes' trial with load of approximately 1 W/kg), the probability of circulatory system hyperkinetic response is high.

Variant C has been worked out especially for men whose body weight is relatively low and doesn't exceed 60 kg. The rule of estimating is the same as in variant A, but instead of implicit load values in Watts, explicit load is given.

The presented methods of pilot's physical capacity estimation ($VO_2$ max, the character of circulatory system adaptation response) are used during mass examinations of healthy people aging 18-54. They cannot, however, replace detailed clinical tests.

# FREQUENCY OF PHYSICAL CAPACITY EXAMINATIONS

| PILOT | AGE | TESTS |
|---|---|---|
| JET | 25 - 34 | every 3 years |
| | 35 - 50 | every 2 years |
| | above 50 | annually |
| TRANSPORT, HELICOPTER | 40 - 50 | every 3 years |
| | above 50 | annually |
| ANOTHER FLYING PERSONNEL | 40 - 50 | every 5 years |
| | above 50 | every 2 years or as recommended |
| CIVIL | 40 - 50 | every 5 years |
| | above 50 | every 2 years or as recommended |