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# INFLUENCE OF ANTI-G RESPIRATORY MANEUVER TRAINING IN „CHAIR" POSITION ON +GZ-TOLERANCE

# WPŁYW TRENINGU PRZECIWPRZECIĄŻENIOWEGO W POZYCJI „KRZESEŁKO" NA TOLERANCJĘ PRZYSPIESZEŃ +GZ

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***ABSTRACT:*** *The anti-G straining maneuver (AGSM) is still an important part of pilot protection for G-induced loss of consciousness. Significant improvement in G-tolerance can be achieved and sustained by systematical physical training. The aim of the study was to evaluate effect of the new model of AGSM training in „chair" position on +Gz acceleration tolerance.* ***Materials and methods:*** *Nine healthy pilots were examined. The level of +Gz acceleration tolerance (before and after a period of two months of training) as well as +Gz value, at which the subject commenced performing ANTI-G respiratory maneuvers (AGRM), during centrifuge examinations were evaluated.* ***Results:*** *Seven subjects improved acceleration tolerance in GOR program and eight in ROR program. Beneficial effect of the training was also observed with*

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*regard to the levels of acceleration at which the subject commenced performing ANTI-G respiratory maneuvers. After training program completion, six subjects started performing AGRM at higher than initial +Gz acceleration levels.* ***Conclusion:*** *The anti-G respiratory maneuver training in „chair" position can improve +Gz gravity load tolerance, is easy to perform under any conditions, does not take much time and is safe to carry out from medical standpoint*
***KEY WORDS:*** *AGSM, physical training, accelerations*

***STRESZCZENIE:*** *Przeciwprzeciążeniowy natężony manewr oddechowy (anti-G straining maneuver AGSM) jest nadal istotną składową ochrony pilota przed utratą przytomności spowodowaną przeciążeniem (G-induced loss of consciousness GLOC). Istotną poprawę tolerancji przyspieszeń +Gz można uzyskać i utrzymywać poprzez systematyczny trening fizyczny. Celem pracy była ocena wpływu nowego modelu treningu AGSM w pozycji „krzesełko" na tolerancję przyspieszeń +Gz.* ***Materiał i metody:*** *Zbadano dziewięciu zdrowych pilotów. Zmierzono poziom tolerancji przyspieszeń +Gz (przed i po dwóch miesiącach treningu) oraz wartość +Gz przy, której badany rozpoczynał wykonywanie manewrów AGSM podczas badań na wirówce przeciwprzeciążeniowej.* ***Wyniki:*** *Siedmiu pilotów poprawiło tolerancję przyspieszeń w programie GOR oraz ośmiu – w programie ROR. Obserwowano również korzystny wpływ treningu na poziom tolerancji przy którym badani rozpoczynali wykonywanie AGSM. Po zakończeniu programu treningów sześciu badanych rozpoczynało wykonywanie AGSM przy wyższych wartościach przyspieszeń od wyjściowych.* ***Wnioski:*** *Trening przeciw-przeciążeniowych manewrów oddechowych w pozycji „krzesełko" poprawia tolerancję przyspieszeń +Gz, jest łatwy do wykonania, nie zabiera dużo czasu i jest bezpieczny z medycznego punktu widzenia*
***SŁOWA KLUCZOWE:*** *AGSM, trening fizyczny, przyspieszenia*

## Background

The human's ability to tolerate high +Gz acceleration depends on the maintenance of enough cerebral blood flow what prevent the occurrence of G-induced loss of consciousness (G-LOC). Therefore, arterial blood pressure must be increased so high as to compensate the G-induced hydrostatic column declining [4,6]. Anti-gravity straining maneuver was widely recognized as one of the important factors in blood pressure rising and preventing G-LOC. It is known that AGSM enable to increase acceleration tolerance by about +2 to +4 Gz [5,9]. The protective benefits of them are only as great as the effectiveness of its performance .

AGSM consists of two basic parts [12] muscular – straining skeletal muscles (mainly lower body parts) – and respiratory – forceful, blocked exhalation (modified

Valsalva Maneuver). Improvement in G-tolerance can also be achieved by using ANTI-G suits, positive pressure breathing or via training flights and centrifuge training [3]. It should be noted that the latter two methods are expensive and their effect is not permanent. A significant improvement of +G-tolerance can be achieved and sustained by systematical physical training [1]. The current high performance aircraft training program of Polish cadets and pilots does not include an individual physical training scheme that could be performed off-duty. On the other hand, it is widely known that too excessive long-distance running can lead to excessive parasympathetic dominance and a disqualification from aircraft training [11].

An individual physical training scheme of high maneuverability aircraft cadets and pilots should meet the following theoretical criteria :

- It should develop all muscles taking part in AGSM, especially in the lower body parts. To be precise, not only should it enhance the muscle tension, but also the capability of sustaining the tension for a longer time period – corresponding to acceleration duration,
- It should be easy to perform in any conditions, and require no special equipment,
- It should not be time consuming,
- The physical effort level should be adequate to an individual physiological capacity of the subject and should not rise a risk of health complications,
- It should lead to an increase in +Gz acceleration tolerance.

The aim of the study was to evaluate an effect of AGSM training in „chair" position on +Gz acceleration tolerance.

## Materials and methods

The study group comprised of 9 males, aged 20-39 (average: 28,1 years), 170-188 cm tall (average 174,8 cm), of 62,5-92 kg weight (average 75,8 kg). The group included 4 experienced F-16 pilots and 5 second year students from the Polish Air Force Academy in Dęblin. All subjects were clinically healthy, took no pharmaceuticals and did not smoke cigarettes. Each signed informed consent to participate in study. Ethics Committee of the Polish Military Institute of Aviation Medicine cleared the protocol for execution of the study.

For each of the subjects, the succeeding parameters were defined:

1. Pre-training +G-tolerance in gradual onset rate (GOR) and rapid onset rate (ROR) programs.
2. Ability (measured as endurance time) to sustain the „chair" body position (Figure 1), while performing 10 series of ANTI-G respiratory maneuvers at 15-second intervals, up to the point the subject was not able to continue the exercise as a result of general exhaustion and/or leg shaking.
3. G-tolerance in GOR and ROR programs, as well as endurance ability tested in accordance to the point 2 above, after a period of two months of training 2-3 times a day.
4. The level of +Gz acceleration during GOR and ROR programs, at which the subject commenced performing ANTI-G respiratory maneuvers, before and after the „chair" body position training.

The position named for the purpose of this study as „chair" position (resembling a situation of sitting on a chair with a backrest, but without a seat) was presented on Figure 1.

Fig. 1. The „chair" position.
Ryc. 1. Pozycja „krzesełko".

The subject leans against the wall with his back. Knees bent to 90 degrees (thighs parallel to floor), left hand rests on left knee and the right arm is suspended in a sling at heart level (requirements of hemodynamic measurements).

Tests in „chair" position were carried out in morning hours, always in the same room, in silence, and in identical temperature conditions (air-conditioning). The following parameters were registered during the tests:

- heart rate (HR),
- systolic (SBP) / diastolic (DBP) / mean (MBP) blood pressure (BP), and
- systemic vascular resistance (SVR/TPR – total peripheral resistance)

measurement of the abovementioned parameters was carried out with CNSystem's TASK FORCE MONITOR equipment. The subjects performed AGRM in accordance to the learned method.

The decision to perform exactly 10 ANTI-G respiratory maneuvers while sustaining the „chair" position was based on the fact that during initial ROR tests, the experienced pilots performed 10-12 such maneuvers the on average, during a 7.0 G acceleration interval (more precisely, 2-3 maneuvers until reaching 7.0 G acceleration, 5-6 maneuvers during 15 seconds while the 7.0 G level acceleration sustained, and 2-3 maneuvers during deceleration from + 7 Gz to +4Gz level). Because of this fact, the subjects were told that the individual anti-G respiratory maneuver training (AGRM) in „chair" position should be performed in line with the scheme outlined in point 2. Over training period the subjects were supposed to continue the physical training (gym workout, running, swimming, cycling, etc.) at the same scale as they did before the program started. By the end of the training, the subjects provided a written opinion about this issue.

## Centrifuge tests methods

The tests were performed in morning hours, after breakfast and well-slept night. The studied subjects were clinically healthy (normal results of standard ECG, echocardiogram, chest X-ray, ionogram, routine blood biochemical tests), without any complaints, and were not taking any pharmaceutical agents. Centrifuge tests was interrupted after appearing minimum one from below mentioned indications:

- Serious abnormalities in ECG registration,
- Lack of reaction on light stimuli (3 successive wrong answers),
- Loss of consciousness (G-LOC),
- At the studied subject request,
- Achievement of maximum +Gz level.

During GOR program +Gz acceleration increased by 0,1 G/s, up to a maximum 9,0 G. Deceleration was at 0,5 G/s. The ROR program commenced at a resting level of +1.4Gz, then, the acceleration increased at a rate of 1G/s, up to the following +Gz levels reached at the peaks of the consequent intervals: +4,0- 5,0 - 5,5 – 6,0 – 6,5 – 7,0 – 7,0 – 7,0 – 7,0 – 7,0 – 7,0 sustained for 15 seconds. Deceleration was at 0,5G/s. Pauses between consecutive intervals lasted for 15 seconds. Shall we assume that the subject had to strain skeletal muscles during an acceleration exceeding 4.0 G , then the total muscle straining time over a single GOR program (up to +9Gz) amounted to about 60 seconds. Whereas, in case of the ROR program (encompassing 6 intervals with the maximal acceleration of +7Gz), it amounted to about 240 seconds. It should be noted that the ROR program was carried out after a 2-hour brake following the GOR program. Statistical evaluation of the results was carried out by means of one-side t-Student test for related variables, at $p<0.05$, utilizing STATISTICA software from Stat-Soft (USA).

## Results

„Chair" position endurance time and maximum +Gz acceleration tolerance in GOR and ROR programs – before and after the training – was shown in table 1.

Tab. 1. „Chair" position endurance time and maximal +Gz acceleration tolerance in GOR and ROR programs – before and after the training

Tab. 1. Czas utrzymywania pozycji "krzesełko" oraz maksymalne wartości tolerancji przyspieszeń +Gz w programach GOR I ROR – przed i po treningu.

| | **Before the two-month training program** | | | **After the two-month training program** | | |
|---|---|---|---|---|---|---|
| | **TIME [s]** | **GOR [+Gz]** | **ROR [+Gz]** | **TIME [s]** | **GOR [+Gz]** | **ROR [+Gz]** |
| **B.A.** | 170 | 7.5 | 6.5 | 389 | 9 | 7 (3)* |
| **Ś.G.** | 44.7 | 7.1 | 7 (2)* | 327 | 8.5 | 7 (4)* |
| **K.A.** | 143.2 | 7.6 | 7 (4)* | 222 | 9 | 7 (6)* |
| **S.A** | 121 | 8.7 | 7 (1)* | 220 | 7.4 | 7(1)* |
| **Z.K.** | 156.8 | 7.9 | 7 (1)* | 217 | 7.8 | 7 (1)* |
| **L.K.** | 71 | 6.7 | 6.5 | 209 | 6.9 | 7 (1)* |
| **Sz.W.** | 81.8 | 6.7 | 7 (1)* | 206.2 | 8.6 | 7 (6)* |
| **G.B.** | 56 | 7.2 | 6 | 201 | 7.3 | 6.5 |
| **J.A.** | 41.4 | 7.4 | 7 (3)* | 185 | 8.8 | 7 (5)* |
| **Mean±SD** | 98.43±50.01 | 7.42±0.69 | | 241.8±68.59 | 8.14±0.8 | |

Time (s) – time period over which the subject sustained the "chair" position GOR+Gz, ROR+Gz – the level of +Gz tolerance in GOR and ROR tests

* the figures in parenthesis present the number of accomplished intervals with +7.0 Gz acceleration

There were statistically significant differences of time period over which the subject sustained the „chair" position (p=0.0001) and of +Gz maximum level during GOR and ROR programs (respectively p=0.03; p=0.008) before and after the training. In the majority of cases there was a distinct relation between extension of „chair" position endurance time and improvement in +Gz acceleration tolerance in GOR as well as ROR program. Seven subjects improved acceleration tolerance in GOR program and eight in ROR program. Beneficial effect of training was also observed with regard to the levels of acceleration at which the subject commenced performing AGRM (see Fig. 2 and 3). After completion of the training program, six subjects started performing AGRM at higher than initial +Gz acceleration levels (+5Gz vs +4Gz).

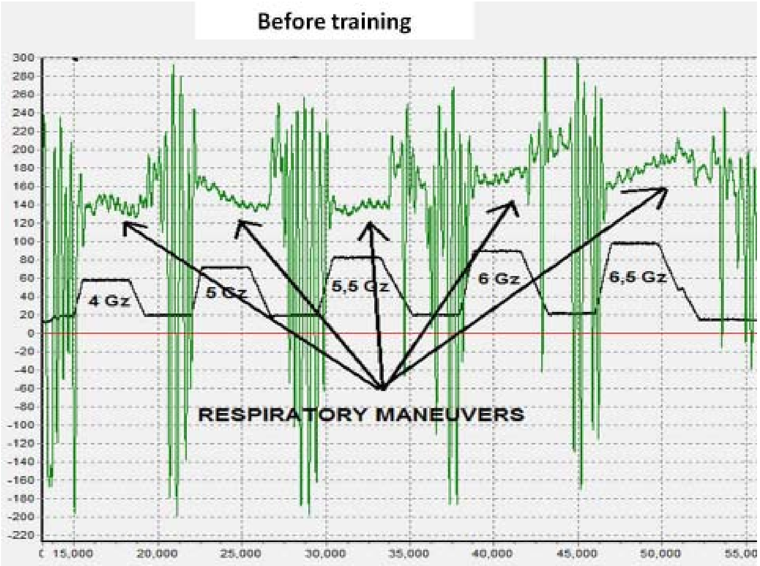


Fig. 2. The intervals of ROR test (before training), during which the subject performed ANTI-G respiratory maneuvers.
Ryc. 2. Interwały w programie ROR (przed treningiem), przy których badany wykonywał manewry przeciwprzeciążeniowe.

As presented in Figure 2, the subject performed anti-G respiratory maneuvers during all intervals of ROR program, starting from the +4 Gz.

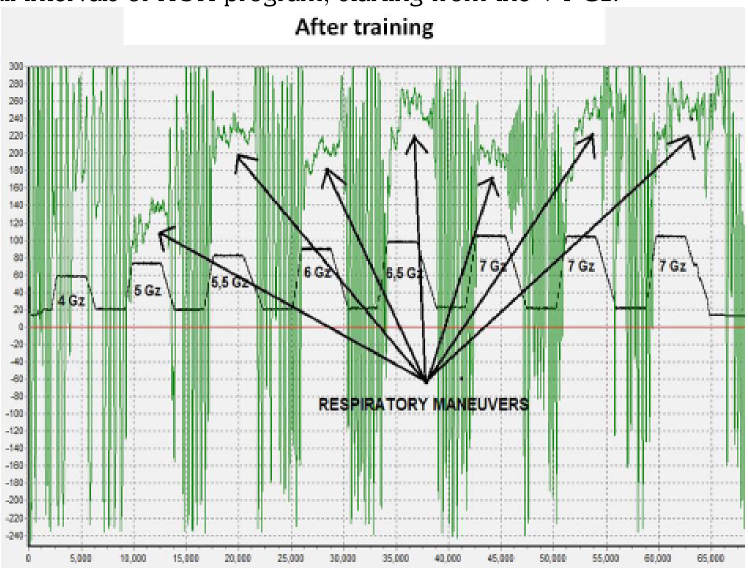


Fig. 3. Respiratory maneuvers of the same subject, registered during post-training ROR test.
Ryc. 3. Manewry oddechowe u tego samego badanego, zarejestrowane podczas badania ROR po treningu.

As Figure 3 shows, the subject commenced ANTI-G respiratory maneuvers during the second interval (later than initially), at acceleration level of +5Gz. The result of a two-month ANTI-G „chair" position training was that the majority of the subjects (6 out of 9) commenced performing ANTI-G respiratory maneuvers at higher +Gz acceleration levels than during pre-training tests. The „chair" position caused increase in subjects' SBP, DBP, MBP and TPR. Values of these parameters increased during consecutive series of respiratory maneuvers, and gradually decreased to normal after the exercise. Response of the cardiovascular system to the 9th series of ANTI-G respiratory maneuvers in „chair" position performed by a subject with B.A. initials was presented in Figure 4. The subject was a F-16 pilot, who trained most systematically of all the subjects and achieved the best training results.

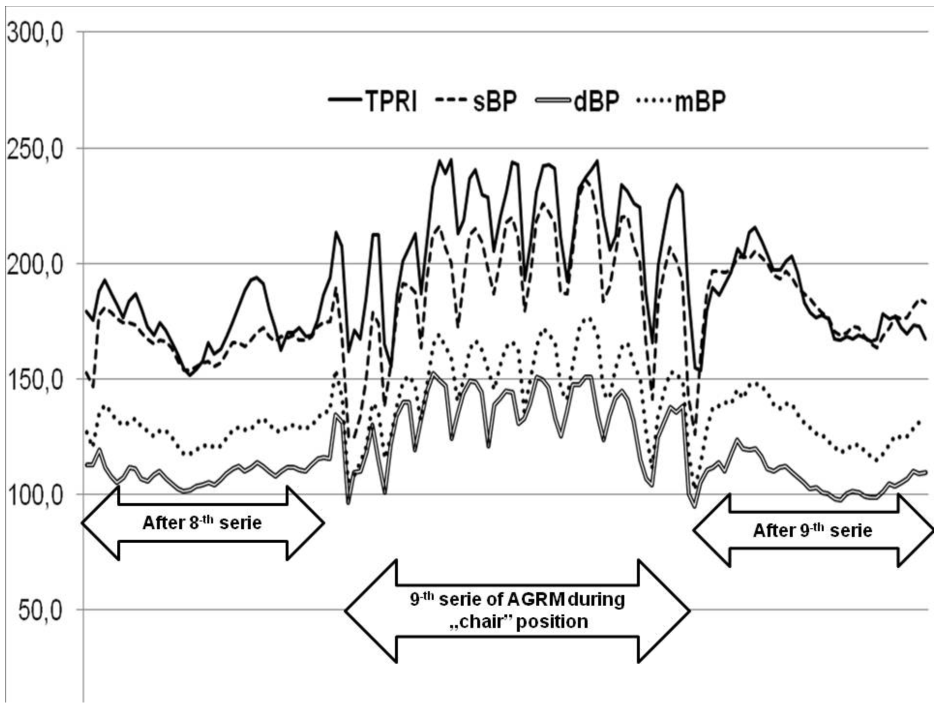


Fig. 4. Changes in SBP, DBP, MBP, and TPR during consecutive series of ANTI-G respiratory maneuvers performed in "chair" position.

Ryc. 4. Zmiany SBP, DBP, MBP i TPR podczas kolejnych serii manewrów przeciwprzeciążeniowych wykonywanych w pozycji "krzesełko".

In their written opinions, all subjects stated that the training program was easy to perform under any conditions and that it did not take much time. In an initial stage they experienced lasting leg muscle fatigue, which disappeared after several days of regular exercise. The training program strengthened leg muscles and improved +Gz acceleration tolerance. The subjects felt less tired after the post-training tests (especially after ROR program). They also emphasized that the training allowed them to improve the technique of anti-G respiratory maneuvers performance.

## Discussion

Knowledge on an effect of acceleration on hemodynamics became a basis for development of AGSM (Anti-G Straining Maneuver). AGSM involves simultaneous straining of all major muscle groups of abdomen , arms and legs, combined with forcible exhalation effort against partly (M1) or fully (L1) closed glottis. The aim of this maneuvers is to counteract the influence of gravity forces. Straining skeletal muscles increases the peripheral resistance of arterial network, impeding blood movement to the lower body parts and magnifying the effect of forceful exhalation and thorax pressure increase. As a result, both the pressure in the aorta, as well as cerebral blood flow increase. Pressure of strained muscles exerted venous tone has a beneficial effect on return of venous blood to the right heart [8,10]. A well-documented influence of ANTI-G suits and positive pressure breathing on hemodynamics during +Gz acceleration, is based on the theoretical premises described above [3,5]. It should be noted that these factors improve +Gz-tolerance regardless of anti-G straining maneuvers.

In spite of the evidence provided by several studies describing an effect of various kinds of physical training on +Gz acceleration tolerance in head-foot axis, no uniform training model was finally defined [1]. It's understood that such model should increase the mass, strength and endurance of skeletal muscles – particularly the muscles of the lower limbs. It is also understood that the contribution of muscular and respiratory components of AGSM in increasing the cerebral blood flow is not equal. Similarly, the level of physical exhaustion resulting from these activities is also very different. Respiratory maneuvers repeated with high frequency (when an end of one maneuver becomes, after a rapid exhalation, the beginning of another one) are much more tiring than muscle straining. During +Gz acceleration, the muscles taking part in inhalation phase are working against the gravity force vector, what requires (parallel to rising of acceleration) the use of grater force to stretch the increasingly heavier thorax. Our previous studies have shown that the frequency of ANTI-G respiratory maneuvers performed by pilots rises with the increase in gravity load, and is notably higher at levels of +7 Gz than at lower levels [7].

There is no way of precisely quantifying the contribution of each AGSM component in +Gz toleration improvement during the centrifuge test. Similarly, any attempt to clearly indicate advantages of one component over another in laboratory conditions (especially using noninvasive methods) seem to rise valid concerns. According to some authors [2], straining skeletal muscles translates into greater increase in blood pressure, in comparison to the Valsalva Maneuver (VM). The researchers studying this issue measured blood pressure with a transducer located in the brachial artery, accompanied by simultaneous pressure recording using another transmitter in the esophagus. They demonstrated that blood pressure increased during VM in relation to the value close to the one measured in the esophagus. Concluding their research, the authors stated that the muscular component play a greater role in AGSM and is more useful to sustain increased values of the average blood pressure at eye/brain level. Results of our study also seem to point to such conclusion. A two-month „chair" position AGRM training improved +Gz tolerance in most subjects. It also caused that most of them started performing anti-G respiratory maneuvers at higher (as compared to pre-training) levels of acceleration. Taking into account the fact that solely straining the muscles sufficed to compensate acceleration levels higher by 1.0 G, we may conclude that the muscular component of AGSM plaid a bigger role in improving +Gz tolerance than the respiratory component. Consequently, the research shows, that the physical training of cadets/pilots that are subject to high gravity loads should be focused to a greater extent on improving the efficiency of muscular component of AGSM. Nevertheless, further research is required to confirm the beneficial influence of „chair" position training itself – assuming no simultaneous performance of the respiratory ANTI-G maneuvers during the „chair" exercise. The appropriate training intensity level should also be defined – eventually, what is the maximal amount of time that the pilot should sustain in „chair" position and how many times per day should he repeat the exercise to keep +Gz tolerance at high level.

It should be emphasized, however, that the herby proposed leg muscle training is a static training that only allows to prolong the muscle straining period. In order to increase muscular mass and strength, pilots should additionally perform proper strength training.

## Conclusion

The anti-G respiratory maneuver training in „chair" position can improve +Gz gravity load tolerance, is easy to perform in any conditions, does not take much time and is safe to carry out from medical standpoint.

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