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REVIEW ARTICLE

THE IMPORTANCE OF TRAINING ON SPECIAL AVIATION GYMNASTIC INSTRUMENTS IN THE PROFESSIONAL DEVELOPMENT OF A YOUNG MILITARY PILOT

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Abstract: The purpose of this article is to present the mechanisms of occurrence and the effects of angular and centripetal accelerations, as well as the possibilities of coping with motion sickness. Based on his own research and observations, as well as a review of studies from national research centers, the author attempted to answer the following question: What is the significance of training on Special Aviation Gymnastic Instruments in the professional development of a young military pilot? He determined that training on Special Aviation Gymnastic Instruments , through vestibular habituation, may be useful in the prevention of motion sickness. The use of training on Special Aviation Gymnastic Instruments during the initial flight training period for young cadet pilots has the greatest and well-justified importance, increasing the effectiveness of flight training and flight safety.

Keywords: Special Aviation Gymnastic Instruments , motion sickness, angular accelerations, military pilot

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INTRODUCTION

The technical development of aviation has caused the aircraft to become a tool that significantly exceeds the physiological limits of the human body. While operating the latest generation of aircraft (F-16, M-346 Master, FA-50, F-35), the complexity of tasks and the rapid dynamics of changing flight parameters have increased the demands placed on pilots. The presence of adverse flight factors (accelerations, altitude hypoxia, cognitive function disturbances) poses an ever-growing threat not only to the pilot's health but also to life [18,37]. A pilot, as an information-processing and decision-making operator, requires a high level of psychomotor and intellectual performance, as well as appropriate and comprehensive psychophysical preparation for flight operations [7,20]. Currently, the forms and methods used in professional preparation continue to evolve. There is ongoing research for effective training measures (physical exercises using gymnastic equipment, free physical exercises) that can induce desirable adaptive responses in the body, reduce the influence of unfavorable flight environment factors, and increase the professional performance of pilots. In individual air forces, the complex objectives related to optimal psychophysical preparation of pilots are achieved in various ways [18,21]. In the Polish military aviation system, one of the methods of influencing the pilot's body is training on Special Aviation Gymnastic Instruments (SAGI). This training has undergone multiple modifications in recent years and is still conducted with young cadet pilots at the Polish Air Force University (PAFU) in Dęblin [3,6,11,12,14,27].

The purpose of this article is to present the mechanisms of occurrence and the effects of angular and centripetal accelerations on the pilot's body, as well as the possibilities of coping with motion sickness. Based on his own research and observations, and on a review of specialist literature from national research centers, the author attempted to answer the following question: What is the significance of training on SAGI in the professional development of a young military pilot?

The significance of special training in the professional development of a young pilot

The need for special psychophysical training for pilots was recognized even before the Second World War. From that period date the first studies concerning mainly the possibility of influencing pilot sensitivity to angular and centripetal (linear) accelerations through special ground training [12].

In the 1960s and 1970s, the first diverse studies were conducted, aimed at evaluating the behavior of hemodynamic indicators, electrocardiography, and presenting the radiological image of the heart [1,9,10]. Research was also conducted on the possibility of increasing the tolerance threshold to +Gz accelerations through training on SAGI [27]. These works contributed valuable knowledge at the time regarding the potential use of SAGI in training young pilots. However, due to the selective nature of the topics, these studies did not provide a complete picture of the issue, and further research was necessary.

At the beginning of the 1980s, considering the significant importance of special physical preparation for young pilots in view of the upcoming modernization of Polish aviation with a new generation of aircraft, the Military Institute of Aviation Medicine (WIML) undertook comprehensive studies on the usefulness of SAGI training in improving pilot professional performance. Studies were carried out on the effects of looping exercises on the circulatory system, vestibular organ habituation, and the physical performance and endurance of young pilots. Unfortunately, for non-substantive reasons, the research work was suspended for several years due to the cessation of recruitment and training of young military pilots at the Higher Officers Aviation School (pol. Wyższa Oficerska Szkoła Lotnicza – WOSL) in Dęblin [15].

The continuation of the research was carried out in the early 1990s [15]. These were the last studies of that period involving exercises onSAGI . Subsequent research was conducted in the first decade of the 2000s at the Polish Air Force Officers College in Dęblin (renamed the Polish Air Force University - PAFU in 2018). The aim of the studies was to develop special goggles for virtual spatial visualization of the aviation environment, with emphasis on assessing the ability of students to perform additional tasks during exercises on SAGI (solving arithmetic problems, recognizing aircraft silhouettes, and counting geometric figures). An additional extension of this research was the development of a test (the Jędrys test), which could make it possible to assess pre- and post-training effects of SAGI exercises in relation to susceptibility to vestibulo-autonomic disturbances in young cadet pilots [11,35]. The test (Jędrys test) was subsequently implemented into training. It is currently considered one of the most important elements of a pilot's professional training, because the level (quality) of further specialized training depends on good psychophysical preparation and habituation of the vestibulo-autonomic system. Therefore, before beginning this part of training, pilots are required to complete general conditioning training (general-development exercises) and targeted training (isometric-breathing exercises, slow-rotation exercises, strength exercises using body weight), which constitutes the introductory stage of training [3,4]. Conducting special training (training onSAGI) for pilots, in comparison with training for elite athletes, is more complex due to the specific nature of the pilot's working environment (accelerations, altitude hypoxia, cognitive function disturbances) and belongs to the category of demanding training tasks.

The SAGI currently used at the Polish Air Force University (PAFU – Dęblin, Poland) include the following devices: looping, gyroscope, and the single aero wheel (Fig. 1). The mechanism of how SAGI exercises affect the pilot's body, as well as the methodology of training on theseinstruments , is well understood and comprehensively described in the extensive national literature [12,14,35].

SAGI is a solution that forces the trainee to move in all axes (vertical, transverse, and sagittal) and planes (frontal, transverse, and sagittal) of the body, causing the activation of specific muscle groups together with loading of the circulatory system, the respiratory system, and the central nervous system (Fig. 2).

Practice and experience have shown that through exercises on SAGI a young pilot can develop the skills and habits necessary to perform the most complex aerobatic maneuvers (rolls, barrel

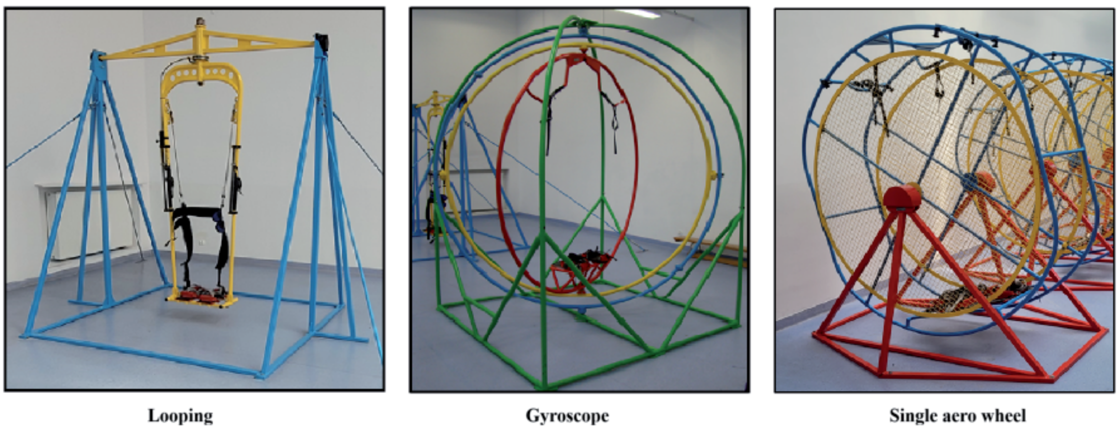

Fig. 1. Special Aviation Gymnastic Instruments [12].

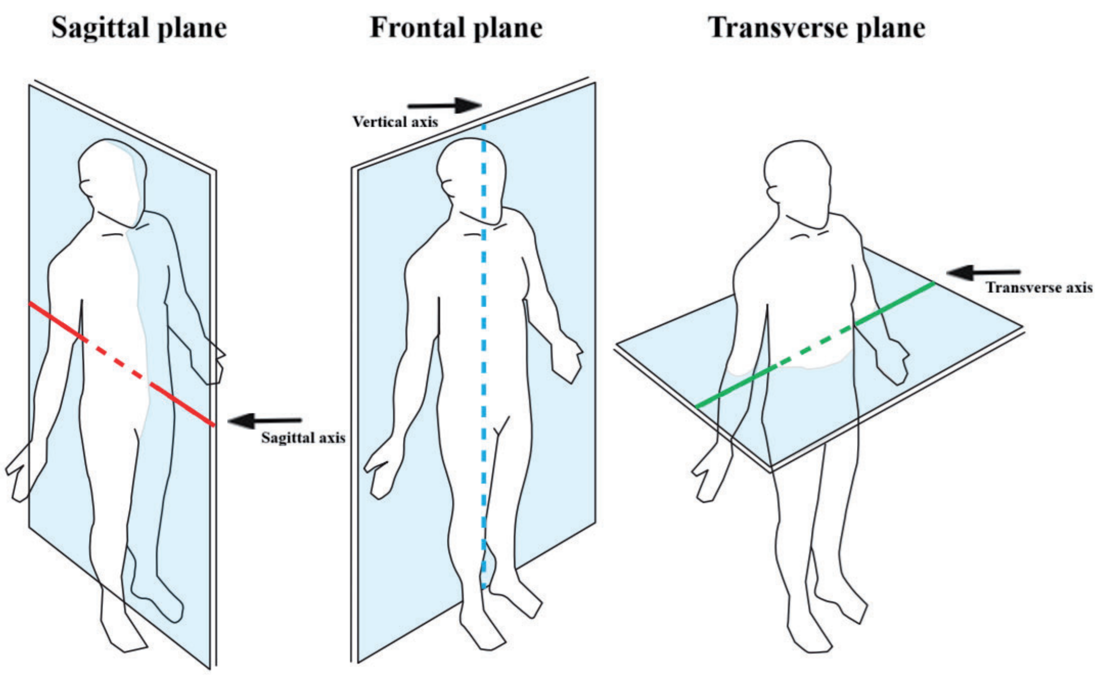

Fig. 2. Body axes and planes [12].

rolls, loops, and spins) [5]. Changes introduced during training in the external environment cause changes in the internal environment of the young cadet pilot's body. They cause the pilot (similarly to real flight) to be exposed to negative factors such as angular and centripetal accelerations, or the effect of blood shifting between the lower and upper parts of the body, which leads to variable physiological loads on the body [4]. Taking into account the dynamic aspect of exercises on SAGI (movement in various axes and planes of the body), it is necessary to emphasize their influence on the semicircular canals and otolith organs of the vestibular system. The greatest impact of angular accelerations on the pilot's body is produced by exercises on the looping, the gyroscope, and thesingle aero wheel , in that order. Such accelerations also occur during rotational exercises (slow-rotation exercises) or during the execution of aerobatic maneuvers in actual flight (rolls, barrel rolls, loops, and spins).

Systematic training on SAGI leads to the phenomenon of habituation, that is, a reduction in the response of the semicircular canals – the receptors of the vestibular system – to repeated kinetic stimuli. These receptors respond to head rotations in various directions and are responsible for detecting angular accelerations. In contrast, the receptors of the otolith organs – the utricle and saccule – are responsible for detecting linear accelerations (Fig. 3) [24]. The sensory information generated by the vestibular system contributes to maintaining postural stability and balance, as well as stabilizing the retinal image through the vestibulo-ocular reflex.

The main advantage supporting the use of SAGI in flight training is above all the emphasis on ensuring the safety of flying personnel. In addition, habituation of the vestibulo-autonomic system to angular and centripetal accelerations leads in a measurable way to a reduction in the effects of increasing fatigue, loss of health, and the growing costs of flight training [34]. Performing rotations on SAGI constitutes a typical form of loading (training) for the circulatory and respiratory systems, as well as for low- and high-pressure baroreceptors stimulated by positive (+Gz) accelerations (direction of acceleration: head-to-feet) and negative (–Gz) accelerations (direction of acceleration: feet-to-head) [13]. Changes in vestibulo-ocular reflex parameters depending on pilot experience are repeatable and reduce not only nystagmus but also otolithic modulation [2]. During vertical-axis rotation (OVAR) with a sinusoidal profile, eye movement responses are the result of a combination of semicircular canal reactions with otolithic components [33]. Studies have shown that in inexperienced young pilots, head movements in various directions (rotation, turning, tilting) increase susceptibility to motion sickness, which in most cases is of vestibular origin [23]. It must also be emphasized that the receptors of the vestibular system (semicircular canals and otolith organs) are not perfect sensors of motion stimuli. Individuals with impaired vestibular function (the peripheral portion of the vestibular system) will perceive a moving, slightly blurred image of a stable visual world with every head movement, a phenomenon known as oscillopsia [29]. In such cases, the central nervous system, when processing

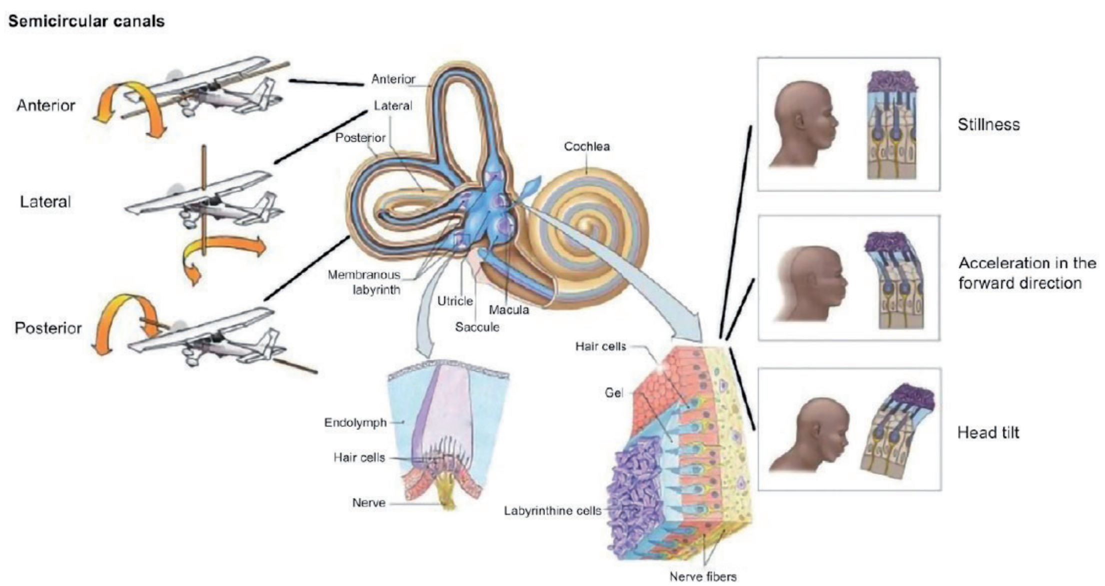

Fig. 3. The functions of individual receptors of the vestibular system [24].

this receptor input, will not account for the relevant laws of physics (Newton's second law) or the differential relationship between position, velocity, and acceleration. This characteristic of vestibular system receptors promotes perceptual errors and vestibular illusions that may lead to spatial disorientation [16,19]. This results primarily from the fact that the receptors of the vestibular system are not capable of reflecting the true nature of the physical (motion) stimuli that occur during flight. The perception thresholds of these receptors prevent an accurate description of the character of changes in the spatial configuration of the aircraft [31]. Pilots may unwittingly succumb to spatial disorientation, which manifests as a distorted perception of reality and leads to incorrect decision making (an error in determining one's position and movement relative to the reference frame, that is the Earth). Such errors often result in events and aviation accidents with tragic consequences [17]. The diagnosis of these changes has attracted the interest of many specialists in physiology, neurology, aviation medicine, and physical education [18,22,26]. According to the author's own observations and a review of domestic literature on the subject, exercises performed on SAGI have a beneficial effect on resistance to motion sickness and improve vestibular habituation [5,11,15,36]. They are also of significant importance at the initial stages of flight training for young pilots, contributing to an improvement in the level of specialised psychophysical preparation that is essential for later professional advancement [3]. However, it must be noted that improperly conducted training on SAGI may trigger undesirable symptoms (nausea, apathy, headaches, cold sweating on the forehead and hands), which are typical of motion sickness.

Assessment of Vestibulo-Vegetative Habituation

Taking into account the importance of specialised training used in Polish Air Force University (PAFU) and the role of rotational exercises performed onSAGI, the assessment of training effects, particularly those concerning habituation of the vestibulo-vegetative system, is carried out by means of a test on an unlocked swing – a looping device (an additional rotation function around the longitudinal axis of the trainee's body achieved after releasing the lock) (Fig. 4) [11.12]. The test has been verified over the past several years in practical use in PAFU and is known in aviation jargon as the "Jędrys test" (named after the author of this specific assessment). In contrast to the Coriolis test, it differs in that it is performed over a longer period of time and in a standing position [11,36]. With the assistance of a partner, the subject is rotated around the longitudinal axis of the body at a frequency of one rotation every two seconds. During the rotation, the subject performs head movements in the following sequence: head extension, forward flexion, head turn to the left (the chin touches the left clavicle), head turn to the right (the chin touches the right clavicle), head extension. In every chin position the subject is required to maintain the posture for two seconds. The assessment criteria are based on performing these actions within a specified time:

– 600 seconds – very good,
– 480 seconds – good,
– 360 seconds – sufficient.

The test is discontinued when symptoms of motion sickness occur (strong nausea, a sensation of "pulling" in the epigastric area, hypersalivation, dizziness) [11].

The test has significant diagnostic value (effective in detecting motion sickness) and can be easily performed both immediately before and after the completion of a training cycle. In this test, vestibular habituation occurs more rapidly and is retained for a longer time, even under the influence of weaker stimuli. It is believed that, in addition to peripheral receptors, subcortical centres of the brain (part of the extrapyramidal system), primarily the reticular formation, also participate in the process of vestibular habituation [32]. The performance of the test does not require additional equipment.

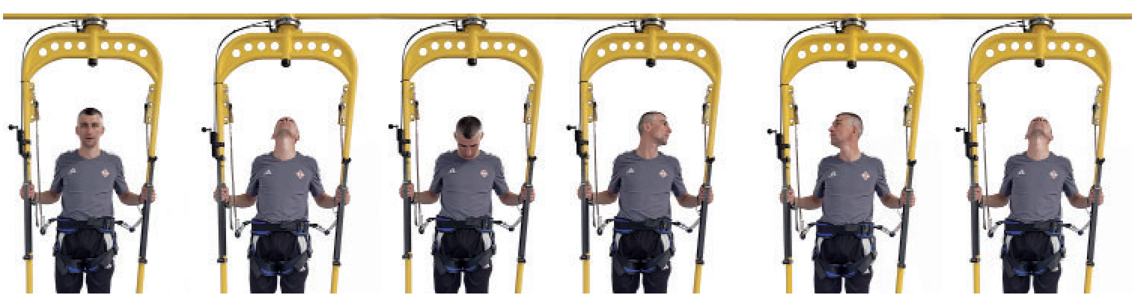

Fig. 4. Assessment of vestibular habituation in the unlocked looping [12].

Physical effort always accompanies the "Jędrys test", which does not occur in the Coriolis rotational test performed on the Barany chair. The standing position during this test provides information about orthostatic capacity, which undoubtedly plays an important role for every pilot's organism. It has been demonstrated that the parasympathetic component is most pronounced in young individuals and predominates over sympathetic system activation at rest. In contrast, the standing position produces physiological stimulation of the sympathetic system, which makes it possible to maintain blood pressure. The inhibitory effect of the parasympathetic system diminishes with age [38]. Under the influence of upright posture, venous return to the heart is reduced, while sympathetic activation in response to baroreceptor stimulation causes an increase in heart rate and vascular resistance. In healthy individuals, the baroreceptor reflex positively affects cerebral perfusion. Postural hypotension, on the other hand, is a symptom of impaired vasoconstrictive function of the sympathetic system, leading to cerebral hypoperfusion with symptoms such as loss of consciousness, dizziness, visual disturbances, and balance disorders associated with standing up [30].

SUMMARY

The specific nature of the work of pilots operating highly maneuverable aircraft, as well as literature data, clearly indicate that efforts should be made to optimize training methods for the special psychophysical preparation of pilots [8,21,25]. Over many years of using SAGI in various centers (Polish Air Force University in Dęblin, Military Institute of Aviation Medicine in Warsaw), a series of experiments of varying scope were conducted to determine the extent to which training on these instruments influences the professional development of a young pilot.

In summary, based on the chronologically presented results of research from national centers, it can be concluded that the issue of special psychophysical preparation of young pilots is both extensive and highly complex. Divergent opinions and varied positions still exist regarding the significance of SAGI training in the professional development of young military pilots. It is also difficult to speak of a unified, universally accepted concept of special training. Further progress in this field is possible only through the collaboration of many specialists addressing the issue of improving flight performance in young pilots [12].

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AUTHORS' DECLARATION

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