THE RELATIONSHIPS BETWEEN SPEED-STRENGTH ABILITIES OF LOWER EXTREMITIES OF YOUNG MILITARY PILOTS AND +Gz TOLERANCE

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INTRODUCTION: The level of muscle strength affects an aircraft pilot's tolerance to physical stress caused by the frequent exposure to high +Gz forces. Many recent reports (Tesch et al., 1983; Balldin et al., 1985; Epperson et al. 1985; Oksa et al., 1996) have suggested that whole body strength training, especially one that incorporates isometric exercises, can increase +Gz tolerance. On the other hand, isometric abdominal muscle strength training alone was not sufficient to enhance G tolerance (Balldin et al., 1985). Therefore, a muscle strength and muscle endurance training program for pilots should contain exercises involving various muscle groups. Wiegman et al. (1995) have found a strong correlation between Wingate lower body mean power and anti-G straining maneuvers duration. It suggests that apart from a high level of isometric strength, anaerobic power also seems to be an important physiological component in tolerance to acceleration stress. Thus, the strength-training program should lead to an increase in anaerobic power, as well by improvement of the speed-strength abilities.
The purpose of the study was to find the relationships between selected parameters of speed-strength abilities of lower extremities in young males and +Gz tolerance parameters. That relationship could then lead to the development of a specific strength-training program for pilots.

METHODS: Fifteen young males took part in the experiment. All were first year cadets at the Polish Air Force Academy. The average values of the basic parameters of physical characteristics of the subjects were: 74.7¦8.4 kg body mass, 1.80¦0.06 m body height and 20.5¦0.9 years of age. In order to estimate the basic speed-strength parameters of the lower extremities, young pilots performed squats. The exercises were done on a computerized stand (locally made) under isokinetic (w = 0.2 rad/s) and isotonic (M = 20 N¦m) conditions. The subjects performed three trials with maximal effort to estimate the maximal and average velocity (w), mechanical power (P) and moment of force (M) developed during the exercise (Skibniewski et al., 1996, Eliasz et al., 1997). The pilots were exposed to excessive +Gz acceleration forces on the human centrifuge. The length of its arm is 9.2 m. A pilot's cabin, weighing 600 kg, is suspended at the end of the arm. The maximum acceleration value is 16 G, with onset up to 6 G/s. The centrifuge is controlled by the computer and allows for precise reproduction of any programmed acceleration characteristics. A linear program (GOR-gradual onset rate) with acceleration rate 0.1 G/s was used (Kowalski & Wojtkowiak, 1997). An acceleration tolerance level value of 5.7 G was accepted as a minimum for qualifying for air service. The following physiological signals were recorded: heart rate, EKG, ear pulse signal and respiratory activity signal. During the experiment the pilot's face was monitored using the local TV system. Result distributions were tested using the Shapiro-Wilk test of normality. Descriptive statistics for each parameter, as well as the Pearson's correlation matrix, were used ($p<0.05$).

RESULTS: The results obtain by subjects during squats and centrifuge exposure are shown in Table 1. Maximal and average values of the velocity of the movement (measured as an angular velocity of the bar) developed by young pilots (1.37 and 1. 25 rad/s, respectively) were clearly lower than those obtained by young runners (1.89 and 1.45 rad/s), although the values of mechanical power were similar (Eliasz et al., 1997). The strong relationships (r=0.81) were found between the relative value (to body mass) of average power (Pave/m) and the average moment of force (Mave/m). The maximal and average moments of force (Mmax, Mave) developed by young pilots were closely related to body mass (r=0.75 and r=0.68, respectively).

Table 1: Mean values (¦SD) of the basic mechanical parameters of squats, maximal heart rate and centrifuge exposure duration of young pilots

Parameter	Units	Mean	S. D.	Minimum	Maximum
G-tolerance	s	68.3	7.1	59.1	80.2
HR	bpm	162	6	154	178
Pmax	W	796	119	597	996
Pmax/m	W/kg	10.7	1.3	8.1	13.1
Pave	W	526	84	374	672
Pave/m	W/kg	7.1	1.1	5.3	9.6
Mmax	Nm	3447	465	2571	4322
Mmax/m	Nm/kg	46.2	4.2	38.8	53.5
Mave	Nm	2567	350	1856	3026
Mave/m	Nm/kg	34.4	3.6	26.6	39.9
ωmax	rad/s	1.37	0.12	1.19	1.50
ωave	rad/s	1.25	0.12	1.04	1.43

Centrifuge exposure duration (59©80 s or 5.9©8.0 G) was similar to results obtained by Bulbulian et al. (1994), who tested highly experienced naval aviators.
We have not found any significant correlation between the speed-strength parameters of the lower extremities of young cadet-pilots and the centrifuge exposure duration.

DISCUSSION: High levels of headward accelerations (+Gz) during flight decrease the hydrostatic pressure of the column of blood above the heart, thereby decreasing brain perfusion pressure, which can lead to loss of peripheral vision and loss of consciousness (Bain et al., 1997). Pilots reduce these effects with an anti-G straining maneuver (AGSM) - a special respiratory/muscular effort, consisting of repetitive isometric contractions during expiration against a closed, or partially closed, glottis (Wiegman et a.,1995). Straining maneuvers activate leg, arm and abdominal muscles (Balldin et al.,1985, Oksa et al.,1996). Burton et al. (1987) suggests that one of the limiting factors for sustaining high +Gz is muscular strength. However, to respond to the rapid onset rates of high G forces, typical for

modern high performance aircraft, forceful and rapid muscle activation seems to be desirable. The pilot could achieve this effect by dynamic leg exercises. In this case acceleration tolerance is increased by skeletal muscles pumping venous blood from the legs (Watenpaugh et al., 1994). This helps maintain cardiac filling pressure by opposing centrifugation-induced accumulation of blood and extravascular fluid in the legs. The high correlation between Wingeate lower-body mean power and SACM duration, obtained by Wiegman et al., (1995), suggests that anaerobic ability could be an important factor in +Gz tolerance. The present study showed a lack of correlation between the speed-strength abilities (maximal strength, mechanical power) of the lower extremities of young military pilots and G-tolerance. In light of this data, our hypothesis, i.e., that higher values of the legs' strength and power accompany increased G-tolerance, does not seem to be applicable to sustained or slow onset rates of high G-forces, although it may be valid for fast rates of acceleration. The results are consistent with Tesch and Balldin's (1984) findings, who have found no relationships between G-tolerance and muscle fiber composition. This suggests that both strength and muscle endurance are desirable factors. Thus special strength training for pilots should contain high load exercises rather than dynamic one. According to suggestions of Wiegman et al. (1995) current recommendations for physical conditioning to enhance +Gz tolerance include a program of total body weight training to increase muscular strength and anaerobic capacity.
However, Bulbulian et al. (1994) have suggested that, apart from muscle strength, one of the most important factors enhancing acceleration tolerance is subject motivation during centrifuge exposure. This refers especially to sustained or slow onset rates of acceleration. One should take this into account when the centrifuge exposure duration is one of the basic parameters of +Gz tolerance.

CONCLUSIONS: The results suggest that there is no simple relationship between the strength and power of the legs' muscles and the acceleration tolerance of young men. Increased G-tolerance possibly requires the involvement of multiple muscle groups. The protocol for further investigation should include exercises that involve large muscle groups and are not limited to the lower extremities alone. Apart from the GOR linear program, the rapid onset rate program should also be used during the centrifuge exposure of military pilots.

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