AGSM Proficiency and Depression Are Associated With Success of High-G Training in Trainee Pilots

Chul Yun; Sohyun Oh; Young Ho Shin

INTRODUCTION: High-gravity (G) training is used to educate trainee pilots about anti-G straining maneuvers (AGSM) in an environment similar to that of a real fighter aircraft, and to enhance their G tolerance. The success or failure of high-G training could be multifactorial, but most previous studies have only focused on the effect of pilots' physical condition.

METHODS: A total of 138 male trainee pilots participated in this study. All trainee pilots had received AGSM training from experienced instructors and then underwent centrifuge high-G training. Participants completed questionnaire surveys about body size, lifestyle, self-reported AGSM proficiency, resilience (Connor-Davidson Resilience Scale, CD-RISC), and depression level (Center for Epidemiologic Studies Depression Scale, CES-D).

RESULTS: Of the 138 subjects, 100 (72.5%) successfully completed high-G training without experiencing G-induced loss of consciousness (G-LOC) within two trials; these were allocated to the success group. The remaining 38 (27.5%) subjects who completed the training after three or more attempts, or who failed to complete the training at all, were allocated to the failure group. Multivariate analyses revealed that the success of centrifuge training was positively associated with age and self-reported AGSM proficiency, and negatively associated with depression level.

DISCUSSION: The success of high-G training was significantly associated with self-reported AGSM proficiency and depression level. Instructors should emphasize the importance of AGSM proficiency and offer practice-based learning to trainee pilots. In addition, they should pay attention to not only trainee pilots' physical condition, but also their psychological status.

KEYWORDS: pilot training, centrifuge, anti-G straining maneuvers, depression.

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Pilots of military high-performance aircraft are frequently exposed to high gravity (G) forces that result from quick turns or movements. High G force can cause cerebral hypoxia and even loss of consciousness, which is referred to as 'G-LOC'.[5,19] Several pieces of apparatus have been designed to prevent G-LOC, including anti-G suits, positive pressure breathing systems, and reclined seats,[4,18] but using anti-G straining maneuvers (AGSM) is the most effective method.[8,20] Therefore, all trainee pilots should be familiar with AGSM and need to successfully complete the high-G training course without experiencing G-LOC to qualify for the basic fighter pilot training course.

AGSM comprises two steps: whole body muscle tensing and the L-1 maneuver, which consists of the Valsalva maneuver with a totally closed glottis while breathing. Previous studies have focused on the relationship between the success of high-G training without G-LOC and physical conditions, such as muscle mass, weight training, and respiration capability, which have also been directly associated with the effectiveness of AGSM.[1,3,16] However, the influence of self-reported AGSM proficiency on the success of high-G training has not yet been evaluated.

Psychological distress is closely correlated with the severity of disease symptoms and functional disabilities. More specifically, several studies have reported that psychological distress determines symptom severity and functional disabilities of the musculoskeletal system.[12,13,17] High-G situations are sudden, require urgent action, and the associated dangers must be

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managed by pilots themselves; thus, individual psychological status can be expected to influence the ability to cope with these situations. However, the influence of psychological status on the success of high-G training has not yet been evaluated. The purpose of this study was to evaluate the associations between self-reported AGSM proficiency, resilience, depression levels, and the success of high-G training. We hypothesized that high levels of self-reported AGSM proficiency, high resilience, and low depression levels would be associated with the success of high-G training.

METHODS

Subjects

Between January 2017 and September 2017, 140 trainee pilots had centrifuge training before starting the official pilot training course in our institution. Among them, two female pilots were excluded from the analysis due to their small population size. A total of 138 male trainee pilots were enrolled in the final analysis. Before the centrifuge training, all trainee pilots received AGSM training from experienced instructors. They learned the theoretical background and method of AGSM for 2 h and then performed an L-1 maneuver by themselves for 1 h. After AGSM training, participants completed questionnaire surveys about body size, lifestyle, AGSM proficiency, resilience, and depression level. This study was approved by the institutional review board of the Aerospace Medical Center of the Republic of Korea Air Force (ROKAF) (ASMC-17-IRB-001).

Equipment and Materials

The studied variables were in one of the four following categories: 1) physical characteristics, including body size; 2) lifestyle information; 3) self-reported AGSM proficiency; and 4) resilience and depression level. The physical characteristics of age, height, weight, and body mass index (BMI) were included. BMI was calculated by using the provided height and weight. The mean age of the trainee pilots was 23.3 $\pm$ 1.5 yr (range, 21–30 yr); mean height, 175.5 $\pm$ 4.8 cm (range, 164–189 cm); mean weight, 70.7 $\pm$ 7.4 kg (range, 55–93 kg); and mean BMI, 22.9 $\pm$ 1.8 $kg \cdot m^{-2}$ (range, 19.0–27.1 $kg \cdot m^{-2}$).

The lifestyle characteristics evaluated were smoking, alcohol consumption, and regular exercise. Smoking measurements included whether the respondent smoked cigarettes or not and the amount smoked. The alcohol consumption item measured whether the respondent drank alcohol or not, the frequency of alcohol consumption, the amount of alcohol consumed per occasion, and the amount of alcohol consumed per week. The amount of alcohol consumed per week was measured in bottles, whereby 1 bottle was equal to one bottle of Soju (Korean gin, about 360 ml, and 20–25% alcohol by volume). Nondrinkers were considered to drink 0 bottles of alcohol. Finally, the exercise item measured whether the respondent engaged in regular aerobic or anaerobic exercise and the total aerobic or anaerobic hours per a week. The amount of cigarettes smoked was quantified in pack years (py). Nonsmokers were considered to smoke 0 py. Smokers accounted for 26.1% (36 of 138) of the cohort. The mean amount of cigarettes smoked was 0.6 $\pm$ 1.3 py (range, 0–10 py). Trainee pilots who drank regularly accounted for 76.1% (105 of 138) of the cohort. The mean amount of alcohol consumed per week was 1.4 $\pm$ 2.1 bottles (range, 0–18 bottles). Regular aerobic or anaerobic exercises were performed by 89.9% (124 of 138) of the subjects. The mean exercise hours per week were 2.8 $\pm$ 2.4 h (range, 0–12.7 h).

Self-reported AGSM proficiency was evaluated using the following three questions about performing the maneuvers: "Are you able to perform the proper body posture during the maneuvers?", "To brace yourself against gravity, can you strain your limbs properly?", and "Are you able to perform the respiration protocol during maneuvers?". Each question was rated by the subject on a 4-point Likert scale (with 1 indicating a strong no; 2 indicating no; 3, yes; and 4, a strong yes). Scores ranged from 3 to 12 and the higher score was indicative of a higher self-reported AGSM proficiency.

Resilience was evaluated using the Connor-Davidson Resilience Scale (CD-RISC).[7] The CD-RISC is a brief self-rated questionnaire with solid psychometric properties which can be applied to healthy subjects. The scale compromises 25 items, each of which is rated on a 5-point scale (0–4). Subjects determine their responses according to their feelings during the month prior to assessment. The total score ranges from 0 to 100, with a higher score reflecting greater resilience.[6]

Depression level was evaluated using the Center for Epidemiologic Studies Depression Scale (CES-D). The CES-D compromises 20 items rated on a scale of 0 to 3. Thus, the possible total scores range from 0 to 60, and the average score for the general population has been reported as 9.1 $\pm$ 9.6.[2] The CES-D screens symptoms related to depression or psychological distress and is a valuable tool for quantifying the symptoms of depression. A score of 16 is widely used as a predictive cutoff for estimating the presence of a major depressive disorder.[2]

Procedures

All subjects wore a standard five-bladder G-suit and did not wear a helmet. They leaned back on the seat of the centrifuge, but were not allowed to rest their head against the seat. They were required to maintain a face-front position and could check the level of induced G force on a monitor in front of them. In addition, they were required to perform AGSM during training. The detailed high-G training protocol of all subjects was as follows: a peak G level of 6 G, an acceleration rate to a peak of 1 $G \cdot s^{-1}$, a deceleration rate to a base of 1 $G \cdot s^{-1}$, a sustained peak G level of 30 s, and a total high-G exposure time of 39.6 s.

Basically, each individual was assigned a single episode in the centrifuge. However, trainees who experienced G-LOC during their first trial were required to repeat the high-G training until success. A total of 58 (42.0%) of the 138 subjects completed the training protocol in a single attempt. A total of 42 subjects (30.4%) completed the training on the second attempt, and 32 subjects (23.2%) completed the training after three attempts or more. Six subjects did not pass the centrifuge training. We divided the subjects into a success group ($N = 100$),

who completed training within two attempts, and a failure group ($N = 38$), who completed training after three attempts or more, or who failed to complete the training.

The criterion for qualifying for the success or failure group was set at the second trial. There were several reasons for this. First, failure in the first trial could be due to unfamiliarity with the centrifuge environment and poor individual physical conditioning prior to AGSM, whereas failure at the second trial would more clearly indicate an intrinsic problem. Second, subjects who experienced G-LOC during the first trial underwent the second trial immediately after all other members of their group finished their first trial in our institute. From the third trial, the training was performed at a distance of time. All subjects were aware that the second trial was a kind of Maginot line for high-G training.

Statistical Analysis

Descriptive statistics of participants are described as means and 95% confidence intervals. Correlations between continuous variables were evaluated using the Pearson correlation test. The correlation coefficient was interpreted using the scale proposed by Evans: 0.00–0.19, very weak; 0.20–0.39, weak; 0.40–0.59, moderate; 0.60–0.79, strong; and 0.80–1.00, very strong.[9] Differences between the success group and failure group were assessed using a Student's *t*-test or Mann-Whitney *U*-test for continuous variables, and Fisher's exact test for categorical variables. Multivariate logistic regression analyses were conducted to analyze the odds ratio (OR) for the success of high-G training with variables that had a *P*-value less than 0.5 in the univariate analysis (binary logistic regression, forward conditional method). All statistical analyses were performed using IBM-SPSS version 22.0 (IBM Corp., Armonk, NY, USA), and a *P*-value of 0.05 was considered significant.

RESULTS

The correlations among parameters of the study population are shown in **Table I**. There was a weak positive correlation between the amount of regular exercise and self-reported AGSM proficiency, and a very weak correlation between resilience level and CES-D. Self-reported AGSM proficiency was not significantly correlated with resilience level and CES-D.

For all subjects, the mean self-reported AGSM proficiency was 9.0 (range, 4–12), the mean CD-RISC score was 73.3 (range, 44–100), and the mean CES-D score was 10.0 (range, 2–31). In 8 subjects (5.8% of 138 subjects), there was a strong possibility of a major depressive disorder.

A comparison of subject variables between the success and failure groups is shown in **Table II**. Age and BMI were significantly higher in the success group. In addition, self-reported AGSM proficiency and resilience level were significantly higher in the success group than the failure group. The CES-D score was not significantly different between the two groups, but the proportion of subjects for whom there was a strong possibility of a major depressive disorder was significantly higher in the failure group than in the success group. Multivariate logistic regression analyses revealed that the success of centrifuge training was significantly positively associated with age (OR, 1.862; 95% CI, 1.139–3.042; $P = 0.013$) and self-reported AGSM proficiency (OR, 1.562; 95% CI, 1.190–2.052; $P = 0.001$), and negatively associated with CES-D score (OR, 1.129; 95% CI, 1.015–1.256; $P = 0.026$) (**Table III**).

DISCUSSION

The success or failure of high-G training is multifactorial, but the influence of psychological status on high-G training has not yet been analyzed. The influence of psychological status could have a huge impact on high-G training because of trainee pilots' unfamiliarity with the centrifuge environment and fear of failing this test, which is an essential step toward becoming a fighter pilot. In a previous study, many subjects who volunteered to experience their first high-G training experienced anxiety that interfered with completion of their training.[14]

AGSM is the most effective method for improving G tolerance,[8,20] but there is no objective tool to evaluate individual

Table I. Correlation Coefficient (*r*) Between Parameters in the Study Population.

	AGE (yr)	BMI (kg · m^{-2})	AMOUNT SMOKED (PY)	ALCOHOL CONSUMPTION AMOUNT (BOTTLES/wk)	REGULAR EXERCISE AMOUNT (h/wk)	PROFICIENCY OF ANTI-G STRAINING MANEUVERS	RESILIENCE LEVEL	CES-D
BMI (kg · m^{-2})	0.058	1						
Amount smoked (PY)	0.253**	0.114	1					
Alcohol consumption amount (bottles/wk)	−0.035	0.024	0.379**	1				
Regular exercise amount (h/wk)	−0.064	0.081	−0.038	0.009	1			
Proficiency of anti-G straining maneuvers	0.014	0.116	0.139	0.196*	0.446**	1		
Resilience level	0.181*	0.029	0.082	0.095	0.083	0.046	1	
CES-D	0.008	−0.196*	0.113	−0.092	−0.068	0.062	−0.211*	1

PY: pack-years; CES-D: Center for Epidemiologic Studies Depression Scale.
*Statistically significant ($P < 0.05$), **$P < 0.001$.

Table II. Subject Variables of Trainee Pilots.

SUBJECT VARIABLES	SUCCESS GROUP ($N = 100$)	FAILURE GROUP ($N = 38$)	*P*-VALUE
Age (yr)	23.5 (1.6)	22.7 (0.7)	0.003*
BMI (kg · m^{-2})	23.1 (1.9)	22.4 (1.7)	0.039*
Amount smoked (PY)	0.6 (1.4)	0.5 (0.9)	0.907
Alcohol consumption amount (bottles/wk)	1.4 (1.5)	1.4 (3.1)	0.056
Regular exercise (yes:no)	91: 9	33: 5	0.531
Regular exercise amount (h/wk)	2.9 (2.6)	2.7 (2.1)	0.949
Proficiency of anti-G straining maneuvers	9.4 (1.6)	8.0 (1.7)	<0.001*
Resilience level	74.7 (10.2)	69.6 (8.9)	0.009*
CES-D	9.4 (2.7)	11.6 (5.9)	0.116
CES-D < 16: CES-D ≥ 16	98: 2	32: 6	0.006*

PY: pack-years; CES-D: Center for Epidemiologic Studies Depression Scale.
* Statistically significant ($P < 0.05$).

self-reported AGSM proficiency or performance level. Furthermore, the influence of self-reported AGSM proficiency on G tolerance has not been quantitatively analyzed. We designed three simple questions to assess self-reported AGSM proficiency in this study. We found a mean score of 9, which indicates that the proficiency level of subjects was 'good' rather than 'very good'. Considering that it is essential to master AGSM before becoming a fighter pilot and most of the trainees were theoretically familiar with the maneuver, we expected a higher level of proficiency. We thought that this discrepancy was due to lack of chances for trainee pilots to perform this maneuver in a simulation setting.

The importance of assessing the psychological status of pilots has been emphasized after recent unexplained air crash accidents. This is the first study to evaluate the influence of psychological status on the success of high-G training in trainee pilots. While most subjects were within the normal range for CES-D scores, depression level was significantly associated with the success of high-G training. Therefore, providing emotional support or reassurance for extremely nervous subjects would avoid missing talented subjects. More specifically, advance exposure to the centrifuge environment and a clear explanation of the training process or showing of a video that includes all high-G training procedures would help to reduce psychological discomfort or anxiety. Eight subjects (5.8%) were not in the normal range for CES-D scores, even though trainee pilots are selected after thorough medical exams and a self-reported psychological test. Because piloting is a complex and special professional vocation that comes with a high level of responsibility,[10] psychological problems could be aggravated as the number of flight hours accumulates. Therefore, a systematic approach that includes screening, diagnosis, and management of psychological problems in trainee pilots is essential.

Table III. Results of Multivariate Analysis Using Binary Logistic Regression for Variables Associated with the Success of the Centrifuge Training.

	B (SLOPE)	*P*-VALUE	ODDS RATIO (95% CI)
Age (yr)†	0.621	0.013	1.862 (1.139–3.042)
BMI (kg · m^{-2})†	0.119	0.359	1.126 (0.874–1.450)
Alcohol consumption amount (bottles/wk)‡	0.096	0.316	1.101 (0.912–1.330)
Proficiency of anti-G straining maneuvers†	0.446	0.001*	1.562 (1.190–2.052)
Resilience level†	0.029	0.235	1.030 (0.981–1.081)
CES-D‡	0.121	0.026*	1.129 (1.015–1.256)

CI = confidence interval; CES-D: Center for Epidemiologic Studies Depression Scale.
* Statistically significant ($P < 0.05$).
† Success possibility with 1 unit increase of the variable.
‡ Success possibility with 1 unit decrease of the variable.

We expected the resilience level to be associated with the success of high-G training, as CD-RISC scores reflect the ability to overcome troublesome situations.[7] As expected, resilience was significantly associated with the success of high-G training according to the bivariate analysis, but not according to the multivariate analysis. There are several potential explanations for this difference. First, because resilience is closely related to depression and could be a marker for depression,[11,15] CD-RISC scores would be influenced by the CES-D scores to some extent. Second, the performance time of high-G training is too short to reflect an individual's intrinsic level of resilience.

Our study has several limitations that should be considered. First, because this study was a retrospective case-control study conducted at a single time point, a causal relationship between psychological status and the success of high-G training could not be demonstrated. A longitudinal study with this cohort could better assess the causality of this relationship. Second, to simplify the lifestyle questionnaire, we only evaluated the amount of cigarettes smoked, alcohol consumption, and exercise habits. Third, our evaluation of psychological status was limited to the CES-D and resilience level. A more comprehensive assessment, including coping, cognitive processes, self-efficacy, and other aspects of psychological morbidity would have been more informative. Finally, because we evaluated AGSM proficiency using a self-reported form rather than by objective measurement by a third party, this evaluation may not reflect the actual proficiency level of each subject.

In conclusion, the success of high-G training was significantly associated with self-reported AGSM proficiency and depression level. Instructors should emphasize the importance of AGSM proficiency and provide trainee pilots with practice-based learning. In addition, instructors should pay attention not only to physical conditions, but also to the psychological status of trainee pilots. Some (5.8%) subjects exhibited CES-D scores that were in the depression range, although most trainees had depression levels that were within a normal range. Therefore, it is necessary to monitor closely, diagnose, and treat any identified psychological problems in trainee pilots to prevent a bad influence from the impaired psychological status of these trainee pilots to air power.

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