

## Does Psychological Stress Improve Physical Performance ?

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TAKEMURA, Y., KIKUCHI, S. and INABA, Y. *Does Psychological Stress Improve Physical Performance ?* Tohoku J. Exp. Med., 1999, 187 (2), 111-120 — The purpose of this study is to determine whether psychological stress enhances physical performance and how personality traits affect it. The annual physical test was chosen as the psychological stressor. Ninety three students ran 50 meters as part of the test and one week after that as a control. The pulse rate and time were measured and pulse rate was used as an indicator of psychological stress. All students took the anxiety-trait scale test of the State-Trait Anxiety Inventory. The pulse rate was higher and the time record was better in the annual physical test compared with that of control. When we categorized the subjects by the anxiety-trait scale test, only the high anxiety-trait students could run faster when faced with higher stress. In conclusion, psychological stress can enhance the physical performance of certain students. It is possible that psychological stress and personality traits interact and both of them affect physical performance. ————— psychological stress; physical exercise; personality © 1999 Tohoku University Medical Press

Athletes seem to have much mental arousal, or psychological stress, in important athletic games like the Olympics. Some people think that such psychological stress has an adverse effect to physical performance. Indeed, visual or mental imagery, autogenic training, desensitization, and yoga, etc., are used to decrease psychological stress. However, it increasingly become clear that a certain type of stress does not necessarily impair performance and can even enhance it in some circumstances (Aper 1982; Jones and Hardy 1989; Kerr 1990; Sanders 1993). There are few studies that confirm these stress-performance relationships.

The effect of personality in sports is another interesting issue. Not only environmental stressors but also personality seems to affect physical performance. Several studies show that there is an interaction between environmental factors and trait (Martens 1975; Magnusson and Endler 1977). Several tests such as the Sport Competition Anxiety Test (Martens 1977) and the Sport Anxiety Scale

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(Smith et al. 1990) have been created to measure these traits.

The purpose of this study is to confirm that there is relation between psychological stress and physical performance. We attempted to determine whether a certain type of personality traits improved performance with increased psychological stress.

#### SUBJECTS AND METHODS

The subjects were 115 young Japanese male medical students aged 18 to 35 (mean age of  $24.1 \pm 3.1$  years) lived in the school dormitory. All of them were in excellent health with signed informed consent to participate in this study. Students with score C or below in the annual physical examination which included a psychiatric evaluation were excluded from the study. Approximately 96% of the students living in the dormitory participated in this study (115 students among 120 students).

The Anxiety-trait scale of Japanese State-Trait Anxiety Inventory (STAI) was administered to the students to determine their personality traits. The Japanese STAI is a translated questionnaire from the State-Trait Anxiety Inventory by Spielberger (Spielberger 1972) and has been proven to be compatible to the original STAI (Nakazato and Shimonaka 1989). We used the Anxiety-trait scale of the STAI in this study. The anxiety-trait refers to an anxiety-prone personality and the high anxiety-trait persons experience a more intense psychological stress from the same stressor than the low anxiety-trait persons (Spielberger 1975). The high anxiety-trait is defined by a score of 44 or more on the Anxiety-trait scale of the Japanese STAI and the low anxiety-trait was defined by a score of 43 or less. We divided the subjects into two groups, the high anxiety-trait students (high Ax students) and the low anxiety-trait students (low Ax students).

A preliminary study was done to determine the best method to measure psychological stress. Pulse rate, systolic blood pressure, diastolic blood pressure, and mean blood pressure were measured; and the Japanese-version Self-rating Depression Scale test was done five minutes before the semester written examination. The semester written examination was chosen as the stressor for this preliminary study because of its significance for the students and reputation for difficulty. The pulse rate was measured by a watch-sized heart rate monitor (TK-11859k, TAKEI Co., Tokyo). The blood pressure was measured by an automatic blood pressure measuring equipment (TK-11431e, TAKEI Co.). Two readings of the pulse rate and blood pressure were averaged. The Japanese-version Self-rating Depression Scale test is a translated version of the Self-rating Depression Scale by Zung (1965) and was used to evaluate the short term depressive status of the participants. For the control group, the test was administered with all students in the same classroom and no looming examination. We used %pulse rate and %blood pressure instead of pulse rate and blood pressure to standardize measurements.

$$\% \text{pulse rate} = \frac{\text{crude pulse rate} - \text{minimum pulse rate}}{\text{maximum pulse rate} - \text{minimum pulse rate}}$$

$$\% \text{blood pressure} = \frac{\text{crude blood pressure} - \text{minimum blood pressure}}{\text{maximum blood pressure} - \text{minimum blood pressure}}$$

The maximum pulse rate and blood pressure were obtained immediately after the 1500 meter run. After the exercise, the students immediately sat quietly, while pulse rate and blood pressure were recorded. The minimum pulse rate and blood pressure were obtained with the subjects in a sitting position after 15-minutes of rest in a quiet and dimly lit laboratory room.

In the preliminary study, only %pulse rate was increased during the semester written examination with statistical significance (+14.4%;  $t=5.33$ ,  $p<0.01$ ). We decided to use the pulse rate to measure psychological stress.

The students ran a 50 meter dash in the annual physical test. The annual physical test is done once a year by the medical school to evaluate students' physical fitness and is very important to students because the fitness is weighted heavily in their evaluation. The 50 meter run was done in pairs and repeated one week after the annual physical test (in the non-test time) as control. A can of soda was given to the winner in the non-test time runs to enhance their competitive spirit.

The pulse rate was measured two minutes before start time of the 50 meter runs both in the annual physical test and in the non-test time. The pulse rate was measured by a watch-size heart rate monitor (TK-11859k, TAKEI Co.) and two readings of the pulse rate were averaged. No warm up exercises were permitted, and the students were required to sit in their chairs for at least 15 minutes until pulse rate was measured. The %pulse rate was defined as above. We defined the high stress group as the students whose %pulse rate two minutes before the start of the 50 meter run were more than or equal to the median and the low stress group as all others.

The time of the 50 meter run (time record) was recorded by a stop watch (SVAY 005, SEIKO Co., Tokyo). The minimum measurable unit of time was 0.01 second. We defined "improver" as those students whose record time in the annual physical test was better than that in the non-test time and "non-improver" as all others.

Paired  $t$ -test was used to compare the mean %pulse rate and the mean time record between the annual physical test and the non-test time. The Student's  $t$ -test was used to find the differences of age, weight, height, and other factors, between the high Ax students and the low Ax students. We used the Student's  $t$ -test and/or the chi-square test to compare the decrease (the annual physical test vs. the non-test time) in time between each stress group of each Ax student. All  $p$ -values here are two-tailed. All data were stored and analyzed using the SAS software Version 6 on an IBM computer (SAS Institute Inc. 1988).

## RESULTS

Mean % pulse rate, as an indicator of psychological stress, two minutes before the 50 meter run in the annual physical test was significantly higher than that in the non-test time (15.1% and 5.1% respectively;  $t=5.29$ ,  $p<0.01$ ).

Mean time record in the annual physical test was significantly shorter than that in the non-test time (7.13 seconds and 7.20 seconds respectively;  $t=2.23$ ,  $p<0.05$ ).

Table 1 shows the difference between the high Ax students and the low Ax students. The higher pulse rate in the annual physical test in the high Ax students was observed, but no significant difference was observed otherwise. There was no difference of the time records in the non-test time between the high Ax students and the low Ax students (Table 1).

The subjects were divided into three groups using the categories defined before, 1) the high stress group of the high Ax students (high stress high Ax students), 2) the low stress group of the high Ax students (low stress high Ax students), and 3) the low Ax students.

We found a significant difference in the record time between the annual physical test and the non-test time only in the high stress high Ax students (0.20 seconds better;  $t=3.35$ ,  $p<0.05$ ). There was no significant difference in the time records between the annual physical test and the non-test time in the other two kinds of students, the low stress high Ax students and the low Ax students.

The high stress high Ax students have better time records in the annual physical test than the low stress high Ax students (Table 2 and Fig. 1). There was no significant difference in the time records in the non-test time between the high stress high Ax students and the low stress high Ax students. The chi-square

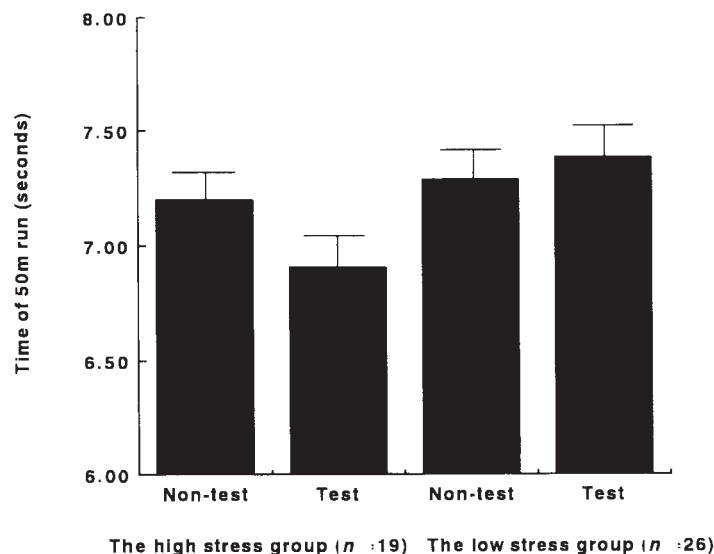


Fig. 1. Comparison of time of 50 m run between the high stress group and the low stress group of the high anxiety-traits students.

TABLE 1. *Difference between the high anxiety-trait students (high Ax students) and the low anxiety-trait students (low Ax students)*

Variables	Total students ( <i>n</i> = 115)		High Ax students ( <i>n</i> = 47)		Low Ax students ( <i>n</i> = 68)		Difference between high & low Ax students
	Mean	S.D.	Mean	S.D.	Mean	S.D.	
Age (year-old)	24.1	3.1	23.6	0.5	24.5	0.4	0.12
Weight (kg)	65.3	9.5	65.1	1.4	65.6	1.4	0.82
Height (cm)	169.7	6.6	168.9	1.0	170.5	1.0	0.24
Body Mass Index (BMI) (kg/m <sup>2</sup> )	22.6	2.7	22.8	0.40	22.5	0.40	0.56
Anxiety-trait scale score	44.8	8.9	51.9	0.8	37.9	0.8	<0.001
PR, rest (/min)	65.6	7.5	66.5	1.1	64.7	1.1	0.23
PR post 1500 m run (/min)	137.8	22.9	138.5	3.6	137.0	3.4	0.77
PR pre 50 m run, Test (/min)	76.3	10.5	79.3	1.5	73.4	1.5	<0.01
PR pre 50 m run, non-Test (/min)	69.9	8.7	70.1	1.3	69.7	1.3	0.82
Systolic BP, rest (mmHg)	118.4	11.1	117.5	1.6	119.3	1.6	0.43
Systolic BP, post 1500 m run (mmHg)	166.1	22.3	167.0	3.5	165.3	3.5	0.74
Diastolic BP, rest (mmHg)	70.0	9.3	70.0	1.4	70.0	1.3	0.99
Diastolic BP post 1500 m run (mmHg)	72.7	14.6	72.7	2.4	72.8	2.3	0.97
Time record, 50 m run, non-Test (second)	7.20	0.58	7.25	0.09	7.15	0.09	0.41
Time record, 1500 m run (minute)	5.902	0.671	5.944	0.105	5.863	0.102	0.30

S.D., standard deviation; PR, pulse rate; Test, the annual physical test; BP, blood pressure.

TABLE 2. *Difference between the high stress group and the low stress group of the high anxiety-trait students*

	High stress group ( <i>n</i> = 19)		Low stress group ( <i>n</i> = 26)		Difference between high& low stress group
	Mean	s.d.	Mean	s.d.	<i>p</i> -value
%PR pre 50 m run, non Test (%)	1.1	3.6	5.7	3.4	0.36
%PR pre 50 m run, Test (%)	27.9	3.8	8.8	3.7	<0.001
Time record, 50 m run, non Test (seconds)	7.20	0.12	7.29	0.11	0.30
Time record, 50 m run, Test (seconds)	6.90	0.15	7.38	0.14	<0.01

s.d., standard deviation; PR, pulse rate; Test, the annual physical test.

test analysis also showed a significantly higher percentage of “improvers” in the high stress high Ax students compared with the low stress high Ax students (60% vs. 33%;  $\chi^2=4.32$ ,  $p<0.05$ ). There was no significant difference in time record in the annual physical test and in the non-test time between in the low stress high Ax students and in the low Ax students.

#### DISCUSSION

The measurement of psychological stress is a controversial issue. There are many measurement methods which are not perfect and questionnaire validity can be problematic. Given these issues, we performed a preliminary study to find an appropriate way to measure stress status. There are three methods to measure stress status: physiological, biochemical, and psychological. Examples of physiological measurements are pulse rate, systolic, diastolic or mean blood pressure, forearm blood flow, respiratory rate, electrodermal activity, thermograph, EEG, EKG, and EMG (Frankenhaeuser 1987). Examples of biochemical measurements are serum cortisol, epinephrine, nor-epinephrine, vasopressin, and thyroid hormones (Konzett 1975). There are several types of questionnaires to measure psychological stress including the Beck Depression Inventory (Beck et al. 1961), the Self-rating Depression Scale (Zung 1965), and the State-Trait Anxiety Inventory (Spielberger 1972). To fit our purpose to measure short term psychological stress in the field with minimal side effects to the students, we selected pulse rate, systolic blood pressure, diastolic blood pressure, mean blood pressure and the Japanese-version Self-rating Depression Scale test as items to be measured in the preliminary study. The Japanese-version Self-rating Depression Scale was chosen because it was known to be compatible to the original Self-rating Depression Scale by Zung (1965).

In the preliminary study, only pulse rate was found to be a reasonable way to measure stress. This result is in agreement with other studies that found pulse

rate to be the most appropriate method to measure short term stress (Imhof 1969; Ulrych 1969; Steptoe et al. 1991). Although several studies support that blood pressure, especially diastolic blood pressure, is also a good indicator of short term psychological stress (Brod et al. 1959; Steptoe et al. 1991), the preliminary study did not support this perhaps due to the young age of the subjects. The failure of the Self-rating Depression Scale to detect psychological stress in our study may have been caused by the fact that not all students expressed their depression.

The %pulse rate was used in this study instead of the crude pulse rate because there was much variability in the difference between the maximum pulse rate and the minimum pulse rate. In order to use standardized increments of the pulse rate, %pulse rate was calculated and used.

The increase in pulse rate may have been caused by other factors besides psychological stress although we attempted to minimize confounding factors. The variables that were controlled were age, sex, warm-up exercise intensity, temperature, humidity, wind speed, altitude, ingestion including alcohol intake, smoking, and stage of the sleep-wakefulness cycle (Dill 1942; Steptoe et al. 1991). However, in spite of the systematic warm-up exercises, the differences of the warm-up among the students could contribute to the difference of %pulse rate to some extent.

The students ran faster in the annual physical test than in the non-test time. If the increased %pulse rate is mainly due to psychological stress, we might conclude that psychological stress seems to enhance the physical ability in a short distance run. Many people believe that the mental arousal has a negative effect on physical performance, especially in big athletic games. Visual or mental imagery, autogenic training, desensitization, and yoga, etc. are now used in sports to decrease psychological stress. Many coaches employ a variety of techniques like "pep talks", punishment, and threats in an attempt to increase tension or "psych-up" their athletes. While coaches frequently employ "pep talks" as a means of energizing their teams, there is little to suggest that such practices are of any value in the competitive situation. Martens and Morgan (1973) has reviewed research studies of psychological stress states in relation to motor behavior, and it seems that the evidence is equivocal; that is, there is evidence which suggests that psychological stress plays a role in performance of motor skills, but an equal amount of evidence suggests that it does not. The present study supports the benefit of psychological stress on running ability.

Still, we need to consider the other factors that affect physical performance. The students' lack of motivation in the non-test time, for example, can reduce the time record. In order to decrease this effect, we provided the winner of the 50 meter race with a can of soda. Although this reward seemed to enhance the students' competitive spirit effectively, their attitude may have affected their physical performance to some extent.

Two theories have been proposed for the relationship between psychological

stress and physical performance (Morgan 1974). First is the Drive Theory which holds that increases in drive level are thought to be associated with increments in performance in a linear fashion (Aper 1982; Kerr 1990; Sanders 1993). Here the drive level can be translated to mean psychological stress. Hence, as psychological stress increases this theory would predict that there are increases in performance. The second theory is the inverted-U hypothesis (Neiss 1988; Jones and Hardy 1989). This position holds that increase in psychological stress will be followed by increments in performance up to a given point. Additional stress will result in performance decrement. In other words, the hypothesis says that appropriate anxiety or psychological stress has a positive correlation with physical performance, however there is a threshold after which psychological stress causes a negative effect. Even though we found a significant relationship between the % pulse rate and time record in the high Ax students by simple regression analysis, we question the results because of the relative circular shape of the scatterplots of the data.

Personality and performance in sports has been a subject of considerable interest. Research on personality and performance have focused on whether personality or environmental factors are the primary determinants of behavior. Many early studies used the personality approach, in which personality was viewed as being stable under any situation (Cattell 1946). Several current studies also supported this approach, e.g. the relationship between physical performance and type A personality (Bass and Akhras 1987) or health locus of control (Brandon and Loftin 1991). There are, indeed, several tests developed to determine the best personality traits for athletes, for example, the Sport Competition Anxiety Test (Martens 1977), the Sport Anxiety Scale (Smith et al. 1990), Trait Sport Confidence Inventory (Vealy 1986), and Sport Orientation Questionnaire (Gill and Deeter 1988). Later studies, however, argued that environmental factors were better indicators of behavior (Mischel 1968). Current theory favors an approach in which personality and environmental factors interact (Magnusson 1977). In this study, there was no significant difference in the time records of the annual test between the high anxiety-trait students (high Ax students) and the low anxiety-trait students (low Ax students) (7.20 seconds and 7.06 seconds respectively;  $t=1.05$ ,  $p=0.30$ ). However we found that the high Ax students improved their performance when faced with higher psychological stress. Also, the low Ax students could not always perform better even if they responded to the high psychological stressor. Our results agree with the previous study mentioned earlier that found an interaction between personality traits and physical performance.

In conclusion, psychological stress can enhance the physical performance of certain students. It is possible that psychological stress and personality traits interact and both of them affect physical performance.

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