The Relation among Physical Activity, Physical Fitness and Time of Useful Consciousness

Shuo-Wen Liang

Background

- Pilots have to face the challenge of **hypoxia** during a flight mission.
- Hypoxia result a **decrease of cognitive function**, thus deteriorate **judgment**.
- Exercise might improve hypoxia tolerance.

Hypoxia

Hypoxia: Abnormal oxygenation

- Histotoxic hypoxia
- Hypemic hypoxia
- Stagnant hypoxia
- **Hypoxic hypoxia**
  - Deficiency in alveolar oxygenation.
  - Reduced oxygen partial pressure in inspired air.

Comparison of Hyperventilation and Hypoxic Hypoxia Syndromes

Signs and Symptoms	*Hyperventilation*	*Hypoxia*
Onset of symptoms	Gradual	Rapid (altitude dependent)
Muscle activity	Spasm	Flaccid
Appearance	Pale, clammy	Cyanosis
Tetany	Present	Absent
Breathlessness	X	X
Dizziness	X	X
Dullness and drowsiness	X	X
Euphoria	X	X
Fatigue	X	X
Headache	X	X
Poor judgment	X	X
Lightheadedness	X	X
Faulty memory	X	X
Muscle incoordination	X	X
Numbness	X	X
Performance deterioration	X	X
Increased respiratory rate	X	X
Delayed reaction time	X	X
Tingling	X	X
Unconsciousness	X	X
Blurred vision	X	X

Reference: Fundamentals of Aerospace Medicine 4th ed.

How Does Hypoxia Affect Pilot?

- Reduce Visual Function
- Cardiovascular and Respiratory Effect
- Cognitive Impairment
  - Brain processing slow down
  - Intelligence↓
  - Memory ↓
  - Attention ↓
  - Judgement ↓

Time of Useful Consciousness (TUC)

- What is TUC/EPT?
- How to determine TUC?
- What are the common factors of TUC?

TABLE 2-5
Effective Performance Time at Altitude

Altitude		Effective Performance Time
m	ft	
5,500	18,000	20–30 min
6,700	22,000	10 min
7,600	25,000	3–5 min
8,500	28,000	2.5–3 min
9,100	30,000	1–2 min
10,700	35,000	0.5–1 min
12,200	40,000	15–20 s
13,100	43,000	9–12 s
15,200	50,000	9–12 s

Reference: Fundamentals of Aerospace Medicine 4th ed.

Physical Activity(PA)

- Body movement produced by muscle action that increases energy expenditure.
- **Exercise**: repetitive and purposeful physical activity.

Physical Fitness

- How well one performs **Physical Activity**.
- Physical fitness has proved associated with cardiovascular function.
- Beneficial effect of physical fitness might result in better cardiovascular health and thus a **better hypoxia tolerance** and a longer TUC.

ure 31.3 Health-related physical fitness components.

Reference: McArdle Exercise physiology 6th ed.

How Physical Activity Effect Your Body

- Cardiovascular System Regulation
  - Cardiac Output(CO)=Heart Rate(HR)×Stroke Volume(SV)
  - a-vO2 difference
- Brain Metabolism of Energy
- Gas Exchange and Transport Efficiency

Purpose

- Determine the Relationship of **Physical Activity** and **Time of useful consciousness (TUC)**:
  - Does TUC differ regards to different physical fitness level?
  - Does regular physical activity effect TUC?
- Help military and civil aeronautics pilot preventive of hypoxia event.

Method

Subject

- 81 air force healthy and active aircrew (72 men, 9 women, mean age 29.6) recruited in the Aerospace Physiology Research Laboratory.
- History of cardiovascular diseases or respiratory diseases was excluded.
- File up **physical activity questionnaire** and collect **physical fitness test** results before the research.

Physical Activity Questionnaire

FIGURE 1
Habitual physical activity questionnaire

Please, make a circle around the appropriate answer for each question, considering the past 12 months: 1. Do you or did you practice sports or physical exercise within the past 12 months: yes/no Which sport or physical exercise do you or did you practice more often? – how many hours a week? – how many months a year? If you practice or practiced a second modality of sport or physical activity, what is it?: – how many hours a week? – how many months a year?					
2. When compared to others of my age, I think my physical activity during leisure hours is: much more/more/the same/less/much less	5	4	3	2	1
3. During leisure hours, I sweat: very often/often/sometimes/seldom/never	5	4	3	2	1
4. During leisure hours, I practice sports or physical exercises: never/seldom/sometimes/often/very often	1	2	3	4	5
5. During leisure time, I watch TV: never/seldom/sometimes/often/very often	1	2	3	4	5
6. During leisure hours, I walk: never/seldom/sometimes/often/very often	1	2	3	4	5
7. During leisure hours I ride a bike:	1	2	3	4	5

Physical Fitness Test

Sit Up, Push Up and 3000m run

表 5　男子 3000 公尺徒手跑步成績換算

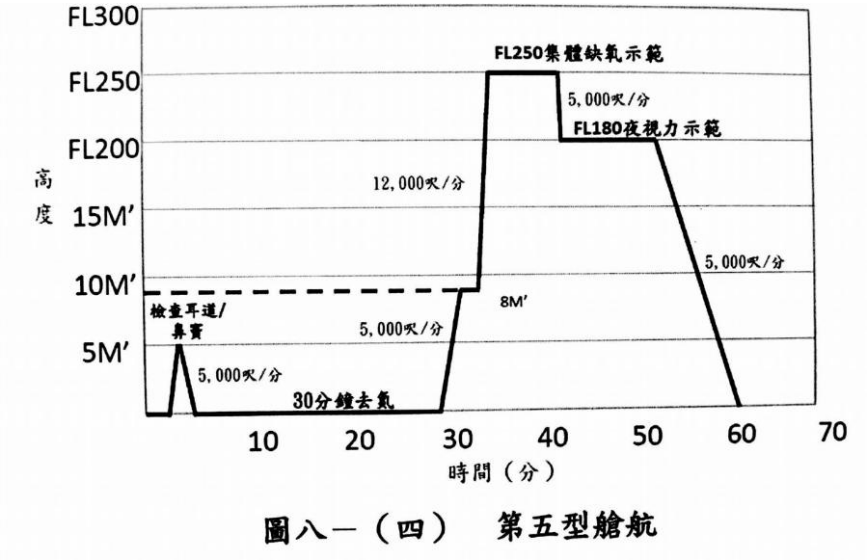
配分	19—22 歲	23—26 歲	27—30 歲	31—34 歲	35—38 歲	39—42 歲	43—46 歲	47—50 歲	51—54 歲	55—58 歲	59 歲
100	11' 10	11' 25	11' 40	11' 54	12' 17	12' 25	13' 01	13' 10	13' 50	14' 30	15' 15
99	11' 14	11' 30	11' 45	12' 00	12' 21	12' 31	13' 05	13' 14	13' 54	14' 34	15' 18
98	11' 18	11' 35	11' 50	12' 05	12' 25	12' 37	13' 09	13' 18	13' 58	14' 38	15' 21
97	11' 22	11' 40	11' 55	12' 10	12' 30	12' 43	13' 13	13' 22	14' 02	14' 42	15' 24
96	11' 26	11' 45	12' 00	12' 15	12' 35	12' 49	13' 17	13' 26	14' 06	14' 46	15' 27
95	11' 30	11' 50	12' 05	12' 20	12' 40	12' 55	13' 21	13' 30	14' 10	14' 50	15' 30
94	11' 34	11' 55	12' 10	12' 25	12' 45	13' 01	13' 25	13' 35	14' 14	14' 54	15' 33
93	11' 38	12' 00	12' 15	12' 30	12' 50	13' 07	13' 30	13' 40	14' 18	14' 58	15' 36
92	11' 42	12' 05	12' 20	12' 35	12' 55	13' 13	13' 35	13' 45	14' 22	15' 02	15' 39
91	11' 47	12' 09	12' 25	12' 40	13' 00	13' 19	13' 40	13' 50	14' 26	15' 06	15' 42
90	11' 51	12' 13	12' 30	12' 45	13' 05	13' 25	13' 45	13' 55	14' 30	15' 10	15' 45
89	11' 56	12' 17	12' 35	12' 50	13' 10	13' 31	13' 50	14' 00	14' 34	15' 14	15' 48
88	12' 00	12' 21	12' 40	12' 55	13' 15	13' 37	13' 55	14' 05	14' 38	15' 18	15' 51
87	12' 05	12' 26	12' 45	13' 00	13' 20	13' 43	14' 00	14' 10	14' 42	15' 22	15' 54
86	12' 09	12' 30	12' 50	13' 05	13' 25	13' 49	14' 05	14' 15	14' 46	15' 26	15' 57
85	12' 13	12' 34	12' 55	13' 10	13' 30	13' 55	14' 10	14' 20	14' 50	15' 30	16' 00
84	12' 17	12' 39	13' 00	13' 15	13' 35	14' 00	14' 15	14' 25	14' 54	15' 34	16' 04
83	12' 21	12' 43	13' 04	13' 20	13' 40	14' 05	14' 20	14' 30	14' 58	15' 38	16' 08
82	12' 26	12' 48	13' 08	13' 25	13' 45	14' 10	14' 25	14' 35	15' 02	15' 42	16' 12
81	12' 30	12' 52	13' 12	13' 30	13' 50	14' 15	14' 30	14' 40	15' 06	15' 46	16' 16
80	12' 34	12' 56	13' 16	13' 35	13' 55	14' 20	14' 35	14' 45	15' 10	15' 50	16' 20

國軍基本體能訓測合格標準表

區分 \ 年齡(歲)		19-22歲	23-26歲	27-30歲	31-34歲	35-38歲	39-42歲	43-46歲	47-50歲	51-54歲	55-58歲	59歲
仰臥起坐	男	43	42	41	40	38	36	34	31	28	24	20
	女	33	32	31	29	27	24	21	19	17	14	12
俯地挺身	男	51	50	48	46	43	40	37	33	28	24	20
	女	36	35	33	30	27	24	21	19	18	17	16
3000公尺跑步	男	14'00"	14'25"	14'50"	15'15"	15'35"	16'00"	16'15"	16'25"	16'50"	17'20"	17'40
	女	16'50"	16'55"	17'20"	18'20"	18'45"	19'00"	19'20"	19'30"	19'50"	20'25"	20'45

Hypobaric Chamber

- Type V cabin flight simulate **25,000 ft** altitude.
- After entering the cabin, they will inhale 100% oxygen for **denitrogenation** to prevent decompression sickness.
- Cabin pressure reaches 25,000 ft. Subjects will be removed from the oxygen mask and start experience hypoxia.



圖八—（四） 第五型艙航

TUC Determination

- Subject will be asked to perform logical, arithmetic tasks from the beginning of hypoxia exposure.
- Subject **SpO2** monitored.
- Termination
  - Subject SpO2 falls below **65**.
  - Subject can no longer perform easy logical tasks. (**cognitive function decrease**)
  - TUC is recorded.

Statistical Analysis

- Subject means and standard deviations were calculated for demographics and physical fitness test results.
- **Linear regression** is used to evaluate TUC and physical fitness test association.
- Divide population into subgroups by age 21-30 and above 30.

Results

Linear Regression Result -1

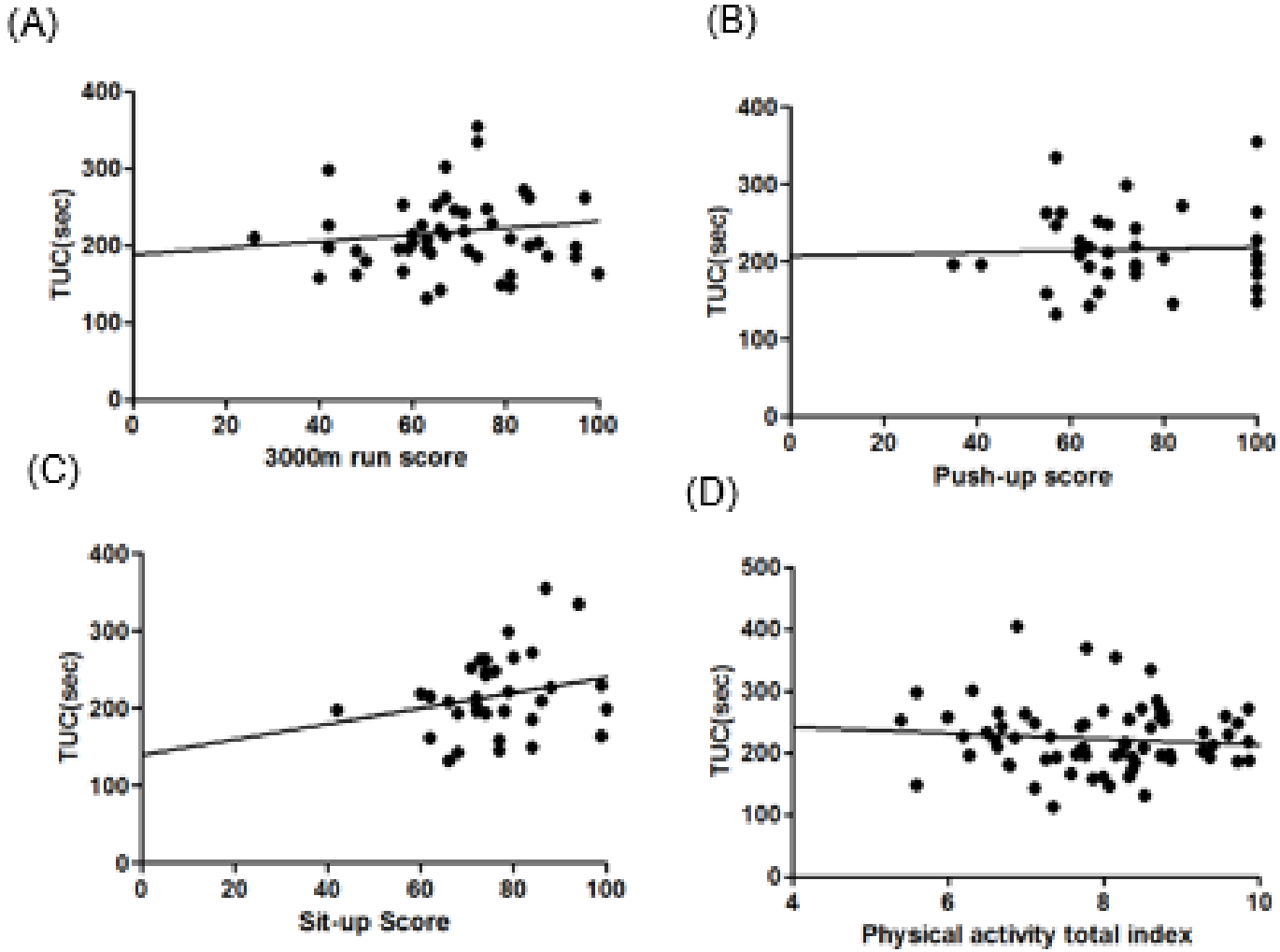


Figure 1. Relationship between TUC and physical parameters. Correlation between TUC and the scores of 3000m run ($r^2 = 0.016$, $p = 0.38$) (A), push-up ($r^2 = 0.001$, $p = 0.82$) (B), sit-up ($r^2 = 0.005$, $p = 0.18$) (C), and Baecke questionnaire score total index ($r^2 = 0.012$, $p = 0.34$) (D).

Linear Regression Result -2

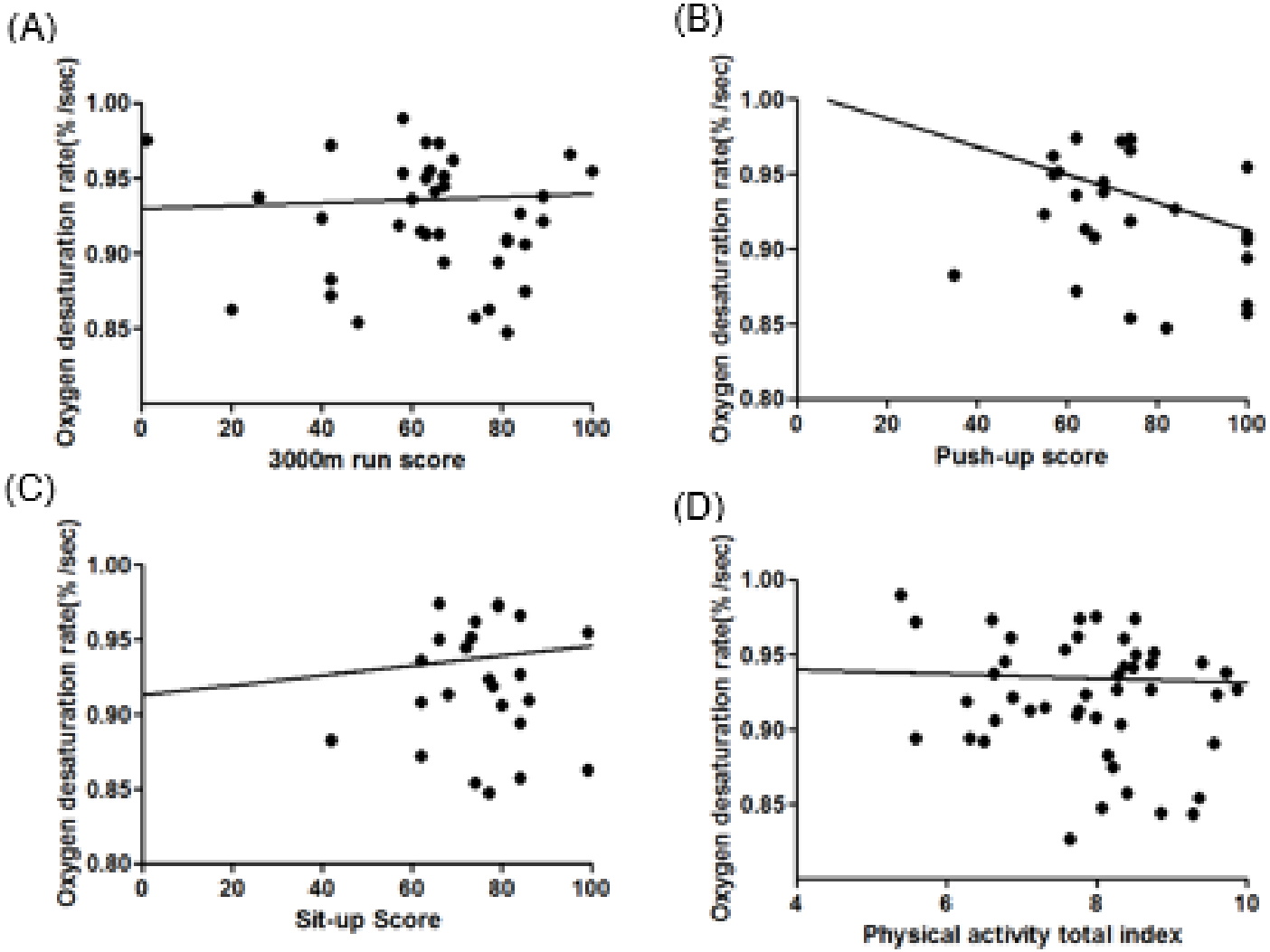


Figure 2. Relationship between oxygen desaturation rate and physical parameters. Correlation between oxygen desaturation rate and the scores of 3000m run ($r^2 = 0.001$, $p = 0.85$) (A), push-up score ($r^2 = 0.085$, $p = 0.12$) (B), sit-up ($r^2 = 0.005$, $p = 0.73$) (C), and Baecke questionnaire score total index ($r^2 = 0.001$, $p = 0.82$) (D).

Linear Regression Result-3

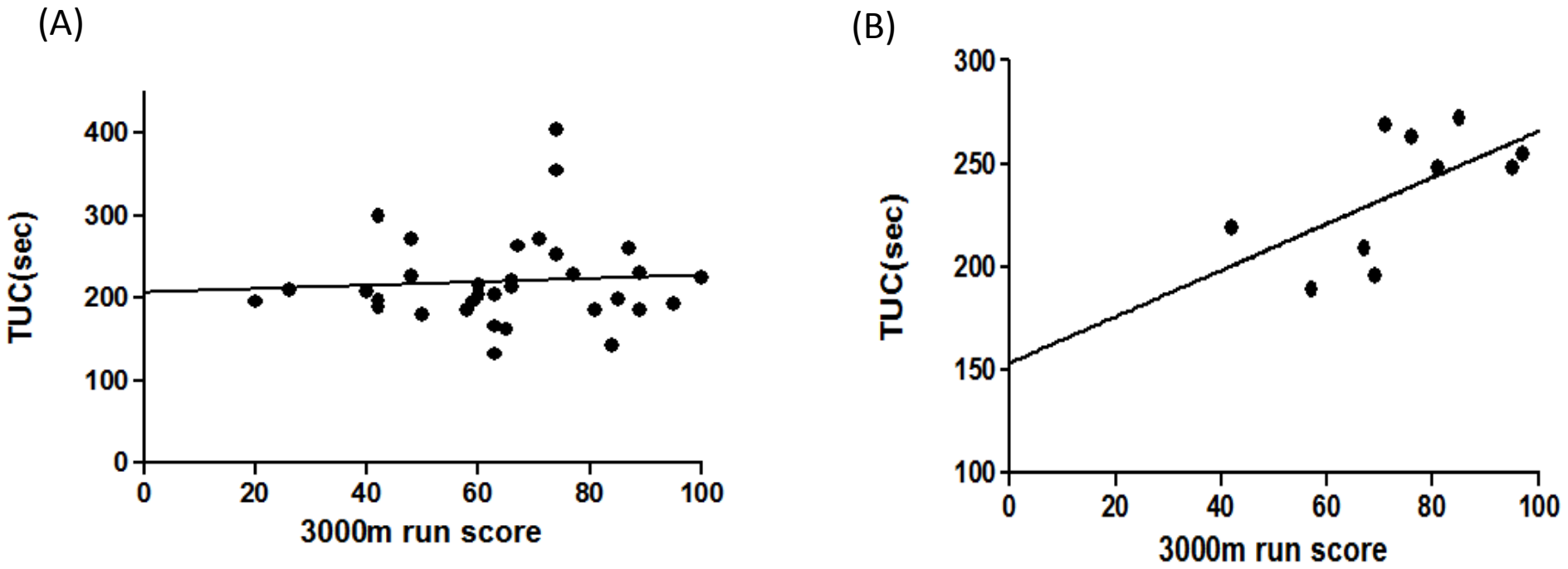


Figure 3. Relationship between TUC and physical parameters in different ages. Correlation between TUC and 3000m run score under (r^2 = 0.005, p = 0.69) (A) or **over** (r^2 = 0.37, p = 0.06**) (B)** 30 years old.

Linear Regression Result-4

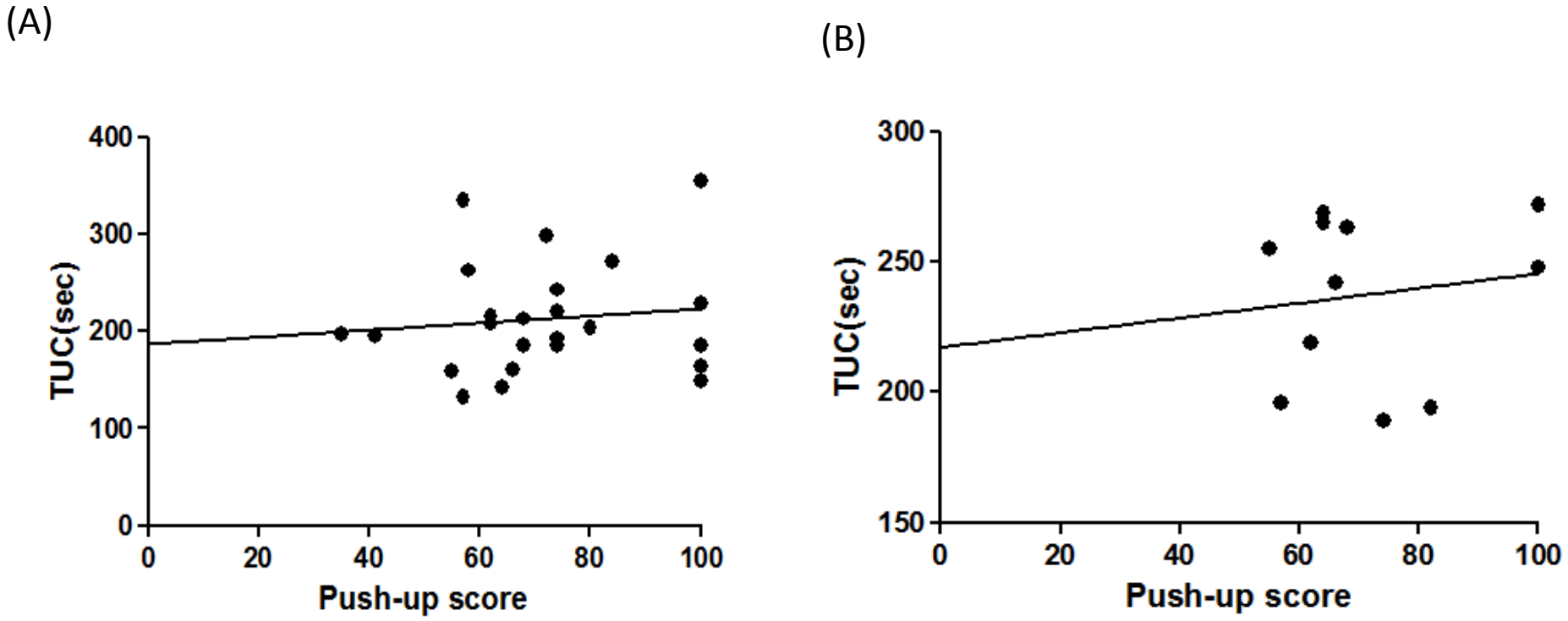


Figure 3. Relationship between TUC and physical parameters in different ages. Correlation between TUC and push-up score under (r^2 = 0.013, *p*=0.59) (A) or over 30 (r^2 = 0.024, *p* = 0.62) (B).

Linear Regression Result-5

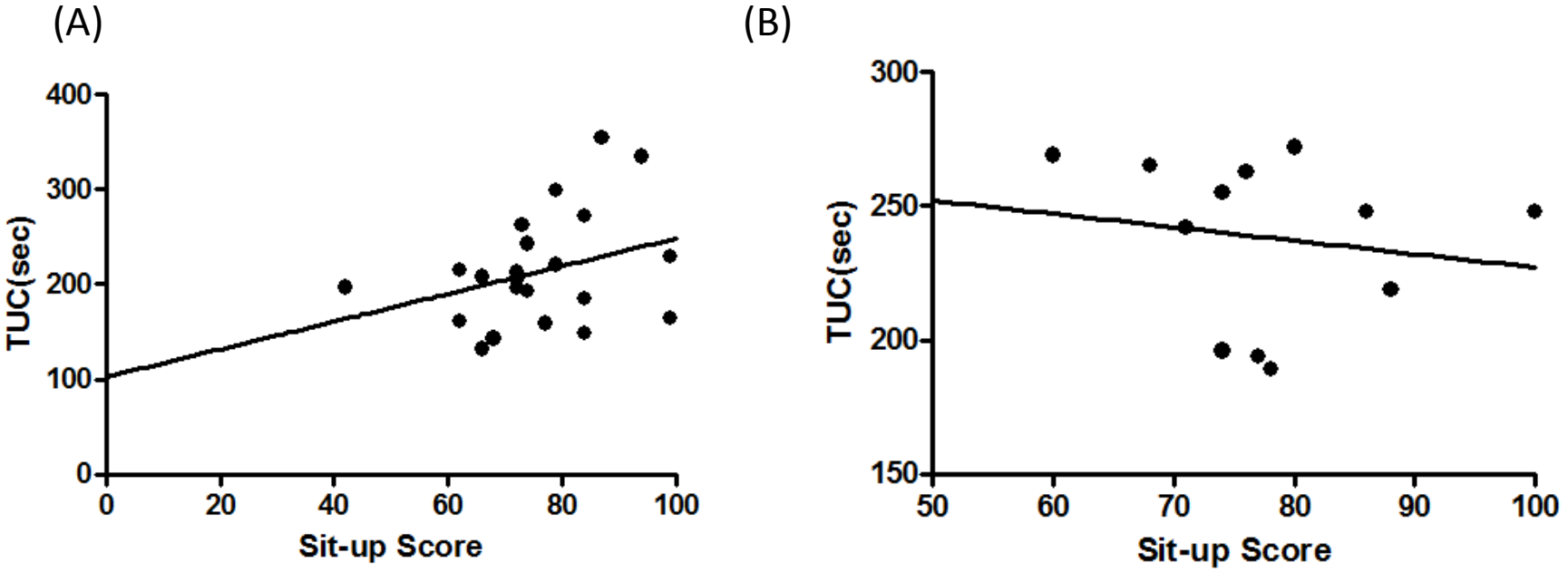


Figure 3. Relationship between TUC and physical parameters in different ages. Correlation between TUC and sit-up score under (r^2 = 0.10, p = 0.13) (A) or over 30 (r^2 = 0.028, p = 0.60)(B) .

Discussion

Effect of Physical Training at Moderate Altitude (1850 m) on Hypoxic Tolerance

- Aviat. Med Journal
- Indian Air Force
- Physical fitness training at the altitude of 1850m improve TUC

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SEN GUPTA, J., L. MATHEW, and P. M. GOPINATH. Effect of *physical training at moderate altitude (1850 m) on hypoxic tolerance.* Aviat. Space Environ. Med. 50(7):714-716, 1979.

Effect of systematic physical training at moderate altitude (1850 m) on hypoxic tolerance was estimated on a group of young soldiers, by determining the Time of Useful Consciousness (TUC) at a simulated altitude of 7620 m in a hypobaric chamber together with the Critical Flicker Frequency (CFF) test. The subjects, after initial testing at Delhi (near sea level) were taken to an altitude of 1850 m and divided into two groups. One group was given systematic endurance physical training for 8 weeks, while the other group served as control. The subjects were then taken to an altitude of 3500 m and kept at that altitude for 4 weeks, after which they were brought back to Delhi and TUC was estimated again within 2 d. The results indicate that endurance physical training at moderate altitude improved hypoxic tolerance and the central nervous system activity under hypoxia.

16); hence, these two tests have been employed in this study.

MATERIALS AND METHODS

Twenty healthy soldiers (20-26 years old) participated in the study. The initial TUC determinations were made at Delhi in a decompression chamber fitted with an oxygen demand regulator Mk 17 (normal air Ltd. Yovil; England). Three subjects were tested per day. The chamber was maintained at a thermoneutral temperature (26-28°C) throughout the experiment. The subjects breathed through the regulator which was set at the normal air position and thus delivered an air-oxygen mixture equivalent to normal air at sea level. When the simulated altitude was stabilised at 7620 m, the subjects were given paper and pencil and were asked to perform a simple numeric writing test by counting backward from

- 2013
- Plos One
- Soichi Ando et al.
- Exercise has a improvement effect on cognitive function.

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PLOS ONE

The Effects of Exercise Under Hypoxia on Cognitive Function

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Abstract

Increasing evidence suggests that cognitive function improves during a single bout of moderate exercise. In contrast, exercise under hypoxia may compromise the availability of oxygen. Given that brain function and tissue integrity are dependent on a continuous and sufficient oxygen supply, exercise under hypoxia may impair cognitive function. However, it remains unclear how exercise under hypoxia affects cognitive function. The purpose of this study was to examine the effects of exercise under different levels of hypoxia on cognitive function. Twelve participants performed a cognitive task at rest and during exercise at various fractions of inspired oxygen (FIO_2: 0.209, 0.18, and 0.15). Exercise intensity corresponded to 60% of peak oxygen uptake under normoxia. The participants performed a Go/No-Go task requiring executive control. Cognitive function was evaluated using the speed of response (reaction time) and response accuracy. We monitored pulse oximetric saturation (SpO_2) and cerebral oxygenation to assess oxygen availability. SpO_2 and cerebral oxygenation progressively decreased during exercise as the FIO_2 level decreased. Nevertheless, the reaction time in the Go-trial significantly decreased during moderate exercise. Hypoxia did not affect reaction time. Neither exercise nor difference in FIO_2 level affected response accuracy. An additional experiment indicated that cognitive function was not altered without exercise. These results suggest that the improvement in cognitive function is attributable to exercise, and that hypoxia has no effects on cognitive function at least under the present experimental condition. Exercise-cognition interaction should be further investigated under various environmental and exercise conditions.

Citation: Ando S, Hatamoto Y, Sudo M, Kiyonaga A, Tanaka H, et al. (2013) The Effects of Exercise Under Hypoxia on Cognitive Function. PLoS ONE 8(5): e63630. doi:10.1371/journal.pone.0063630

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- 1995
- Sports Medicine J Brandon LJ
- Middle distance running suggests a better VO_2 max and anaerobic threshold.

Physiological Factors Associated with Middle Distance Running Performance

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Contents

Summary

Middle distance running involves popular race distances with performance dependent on a number of physiological factors. The physiological characteristics of successful runners are different from those of sprinters and long distance runners. Maximal oxygen uptake ($\dot{V}O_{2max}$), running economy and the anaerobic threshold are variables that have been shown to limit performance during long distance running, and rapid velocity and anaerobic variables have been shown to limit performance during sprinting. Success with middle distance running is dependent on an integrative contribution from aerobic and anaerobic variables which allows a runner to maintain a rapid velocity during a race. The relative contributions of the 2 energy systems are functions of distance, intensity and the physiological abilities of the runner. Middle distance runners can be successful with physiological profiles that include a variety of aerobic and anaerobic capabilities, and this characteristic separates them from long distance runners.

Discussion

- Exercise improves hypoxia cognitive function, but the mechanism is yet to be determined.
- Physical fitness is measured by multiple methods. Most research suggests physical activity has a beneficial effect on hypoxia tolerance.
- These previous research provides alternative methods to measure PA and TUC association.

Limitation

- Different gender with a different physical fitness level criteria should be separated.
- Physical Fitness test result does not objectively represent subject physical fitness level.

Conclusion

- This research suggests a regular physical activity **might** enhance pilots hypoxia tolerance. A further evaluation to determine the mechanism is needed.

Thank You For Listening!

Acknowledgement

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