

The Distribution Range of Total Thiamin Concentration in Whole Blood of University Student Athletes

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Summary

A considerable problem of insufficient vitamin intake exists among athletes. The objective of this study is to reveal the total thiamin concentration in whole blood of university student athletes and general students of the same age group, and to investigate the possibility of a lack of thiamin due to a difference in the amount of exercise. The results showed that the distribution of thiamin concentration for both male and female general students was within the standard value, and that there was an almost normal distribution. In contrast, for the distribution of thiamin concentration in athletes, there was a lower frequency marking higher values compared with that in general students. In addition, as the average thiamin concentration in both male and female student athletes was significantly lower than that in general students, we hypothesized the possibility of a latent thiamin deficiency among student athletes. To clarify this issue, other blood examination items should be further reviewed.

Keywords: thiamin (vitamin B₁); blood examination; nutritional state; athlete; university student

Introduction

In recent years, the interest in avitaminosis has been low, owing to the current belief that the national nutritional status has improved and that vitamin deficiency is now a problem of the past. However, studies have shown that nutritional imbalances and latent avitaminosis do exist^{1,2)}.

In a previous study with university students, we investigated the total thiamin concentration in whole blood, and reported that the thiamin concentration of the participants was mostly within the standard value. Furthermore, although the results indicated the possibility of a latent deficiency¹⁾, no marked deficiency conditions were observed among the participants^{3,4)}.

However, in the young population, a lack of thiamin exists because of special factors such as diet habit and transition to independent living⁵⁾. Therefore, the possibility of an avitaminosis condition, which is dependent on certain circumstances, cannot be denied. Above all, a notable issue concerning vitamin intake exists among exercising persons.

In a previous report, increased energy consumption was found to enhance the metabolism of thiamin, which leads

to an increase in the body's thiamin requirement⁶⁾. Also, in a study on rats, a decrease in thiamin content in the body due to increased energy consumption was observed⁷⁾. Currently, the standard thiamin requirement is set per 1000 kcal of energy^{8,9)}. Exercising persons are often required to take thiamin in accordance with the recommended increased amount of energy intake⁷⁾; however, there are few actual data demonstrating this need. Also, there is no report showing that athletes who perform highly intensive exercise develop thiamin deficiency.

In this study, we focused on university students who are members of clubs composed of top athletes. We can assume that these athletes engage in strict training activities daily. We compared their total thiamin concentration in whole blood with that of general students from the same age group. Through this, we examined the influence of exercise and the possibility of nutritional deficiency conditions.

Materials and Methods

Participants

We asked for the cooperation of student athletes (here-

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after, “athletes”) belonging to sports clubs in three universities (known here as A, C, and M universities). A total of 172 participants (68 men and 104 women) aged 18–22 years agreed to take part in our research after 2009. Concerning the club affiliations, 68 male students, 24 female students, and 80 female students were members of the Rugby Club, Ekiden Relay Race Club, and other sports clubs, respectively. As these participants are considered top athletes, they are expected to engage in strict training on a daily basis. Moreover, the participating universities are prominently known as athletic universities that produce international standard competitors such as Olympic athletes.

Another group, which we have labeled general students, was also studied; these participants were from N University and aged between 18 and 20 years. The number of participants was 472 (54 men, 418 women), all of whom agreed to take part in our research after 2008.

Biochemical examination of blood

Blood was collected from the median cubital vein in the morning after fasting. To test for the total thiamin concentration in whole blood (hereafter known as thiamin concentration), we outsourced the blood analysis to BML Inc. The postcolumn fluorometric detection high-performance liquid chromatography method by Kimura et al. was used (standard value, 21.3–81.9 ng/mL) for the analysis^{10,12)}.

Statistics

We used the software IBM SPSS Statistics 21 for statistical analysis. To examine the difference in average values, we used the nonparametric Mann-Whitney U test and assigned $p < 0.05$ as the significant difference.

Agreement

We explained the research content in written form, and the participants signed certificates of informed consent. This investigation was approved by the Nagoya University of Arts and Sciences Ethics Committees and meets the standards of the Declaration of Helsinki.

Results

Fig. 1 shows the distribution of thiamin concentration in both athletes and general male students. Fig. 2 shows the same data for the female participants.

The results in Fig. 1 show that the range of thiamin concentration in 68 male athletes was from a minimum deviation of 24 ng/mL to a maximum deviation of 50 ng/mL, and that the concentration value fell in the range of 31–40 ng/mL in approximately 71% (48 students) of all male athlete participants. In contrast, the range of thiamin concentration in the 54 male general students was from a minimum deviation of 22 ng/mL to a maximum deviation of 84 ng/mL; approximately 39% (21 students) of the general student participants showed a concentration in the range of 41–50 ng/mL. In addition, the average \pm standard deviation for male athletes was 34.5 ± 5.3 ng/

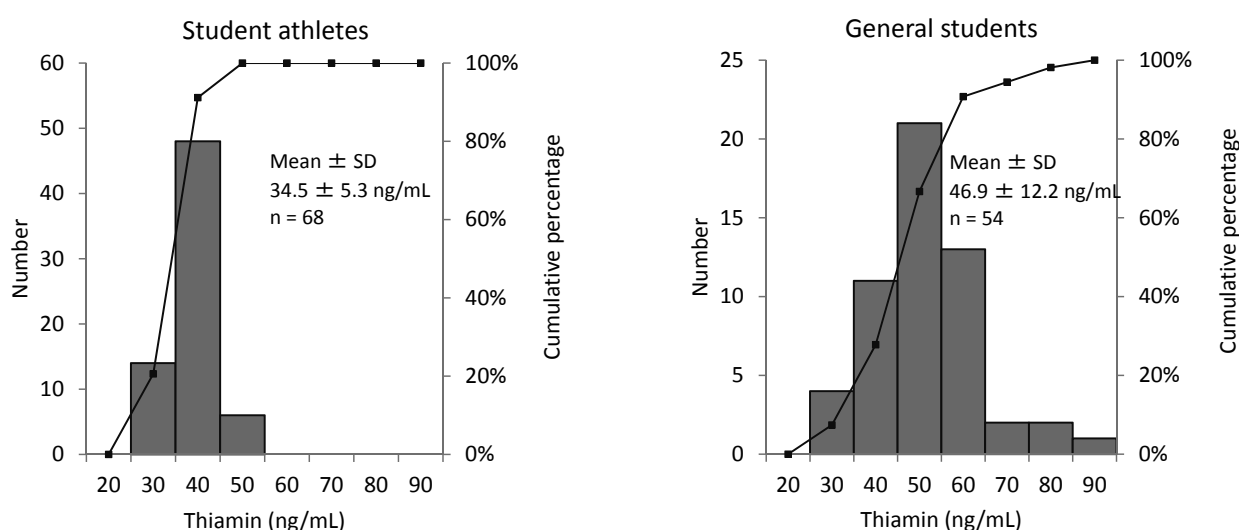


Fig. 1 Comparison of the distribution of total thiamin concentration in whole blood between student athletes and general students (males).

The average values of thiamin concentration were significantly lower in athletes than in general students. ($p < 0.001$ The nonparametric Mann-Whitney U test.)

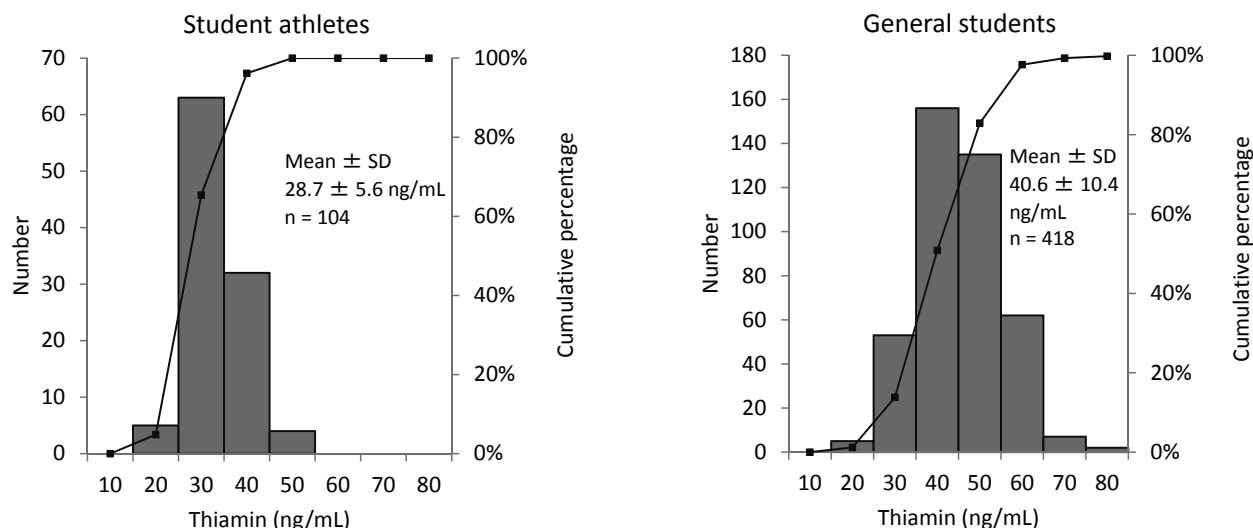


Fig. 2 Comparison of the distribution of total thiamin concentration in whole blood between student athletes and general students (females).
The average values of thiamin concentration were significantly lower in athletes than in general students.
($p < 0.001$ The nonparametric Mann-Whitney U test.)

mL, whereas that for male general students was 46.9 ± 12.2 ng/mL.

Meanwhile, Fig. 2 shows the data for 104 female athletes. The range of thiamin concentration was from a minimum deviation of 19 ng/mL to a maximum of 50 ng/mL, and approximately 61% (63 students) of all female athlete participants showed a concentration value in the range of 21–30 ng/mL. In contrast, the range of thiamin concentration in 418 female general students was from a minimum of 11 ng/mL to a maximum of 77 ng/mL, with approximately 37% (155 students) of them showing a concentration value in the range of 31–40 ng/mL. In addition, the average \pm standard deviation for female athletes was 28.7 ± 5.6 ng/mL, whereas that for female general students was 40.6 ± 10.4 ng/mL.

For both male and female general student participants, the distribution of thiamin concentration was mostly within the standard value, and the distribution was almost normal. For the distribution of thiamin concentration in female athletes, there was a lower frequency marking higher values compared with those in female general students.

From the above results, there was a similar trend for both male and females, and compared with general students, the average values of thiamin concentration were significantly lower in athletes ($p < 0.001$).

Discussion

Thiamin mainly functions as a co-enzyme of carbohydrate metabolic enzymes, and thiamin deficiency causes subjective symptoms such as feelings of malaise in the whole body, fatigue, palpitations, and shortness of breath. Thiamin is an important nutrient for maintaining normal bodily functions^{1, 13, 14}. It has been reported that with exercise, the energetic metabolism increases, which, in turn, increases the required quantity of thiamin. If the thiamin level is inadequate for the consumption of glucose, the metabolism from pyruvic acid to acetyl-CoA is hindered^{15, 16}. The increased production of lactic acid from pyruvic acid leads to an accumulation of lactic acid, which causes fatigue¹⁷. Currently, the standard thiamin requirement is set per 1000 kcal of energy. In exercising persons, it is often recommended to increase the amount of energy intake by consuming well-balanced meals^{9, 18}.

In this investigation, we compared the distribution and average values of thiamin concentration between athletes and general students. The results showed that for both male and female athletes, the distribution of thiamin concentration showed a lower frequency marked high values than that in general students. In addition, for both male and females, because the average value of thiamin concentration was significantly low, the possibility of a latent thiamin deficiency in student athletes was considered.

In a previous study, it was reported that thiamin deficiency rarely occurs as a result of exercise if the standard quantity of daily thiamin intake is satisfied¹⁹. We can

Table 1 Dietary reference intakes for athletes and general students

	Athletes (example of A University) ¹⁾	Dietary reference intakes for Japanese ²⁾
Energy (kcal)	4500	2650
Protein (g)	170 ³⁾	60
Fat (%energy)	25	20 ≤ , < 30
Carbohydrate (%energy)	60	50 ≤ , < 70
Calcium (mg)	1000–1500	800
Iron (mg)	15–20	7.0
Vitamin A (μg)	900–1500	850
Vitamin B ₁ (mg)	2.7–3.6	1.4
Vitamin B ₂ (mg)	2.2–2.7	1.6
Vitamin C (mg)	200	100
Dietary fibers (g)	36–45	19 ≤

1) Determined from the Nutrition and Meal Guide for Athletes, 2006.

2) Recommended amount for Physical activity level II and 18–29-year-old males from the Dietary Reference Intakes for Japanese, 2010.

3) Computed from a Rugby player's protein/fat/carbohydrate ratio (15:25:60).

therefore hypothesize that the athletes could not maintain sufficient thiamin intake through their diet. However, among the athlete participants of this study, a tendency to provide proper attention to nutritional intake was observed. Especially in A University, there is a club called Nutrition Support Team for Athletes that offers sufficient meals to members to ensure a fair nutrition supply²⁰⁾. For instance, Table 1 shows that the energy intake for the athletes was 4500 kcal/day and protein intake was 170 g, which is two to three times higher than that recommended for males from the same age group. Especially, thiamin intake was provided at 2.7–3.6 mg, a level far higher than the recommended value (1.4 mg) to match the energy consumption in food intake standards^{20, 21)}. Nevertheless, in this study, some influence of thiamin concentration was observed, and we can consider that increased energetic metabolism might have other special effects besides increasing the thiamin requirement. For instance, the decreased vitamin absorption due to exercise and the increased excretion of vitamin in the urine and sweat can be considered as factors; however, there are extremely few data to demonstrate these assumptions at present²²⁾. Therefore, in the future, a review of causation should be undertaken through a longitudinal examination of the appropriate amount of nutritional intake, from meals or supplements, for both athletes and general students.

Also, as there is a report stating that there was no extensive lack of thiamin in participants who performed exercise at a level with low maximum oxygen intake^{23–25)}, we can assume that the athletes we targeted in this study have a high exercise strength and a high maximum oxygen intake.

As this study is a cross-sectional investigation, it was difficult to examine the causality between exercise and

the blood examination values. Therefore, for all of the parameters we considered, further longitudinal investigations should be performed. The sex, type of sports, practice duration, and body characteristics varied among the athletes in this study. Therefore, a detailed research needs to be carried out in consideration of the above-mentioned characteristics. Also, we cannot deny the possibility that the students we targeted in this study were receiving a specific nutrition supply from vitamin preparations and other sources. In recent years in Japan, the frequency of using vitamin premix formulations, which are likely to be combined with processed foods, has increased and there is a wide variety of thiamin-rich processed foods, beverages, and pharmaceuticals available²⁶⁾. It is also necessary to examine the effects of those formulations.

University students are at an age when they transition from being reliant on their families to living an independent life. It is anticipated that their lifestyle (especially diet), which is closely related to health, changes during this time^{27–29)}. Therefore, this population needs appropriate nutritional intake; however, athletes who exercise heavily every day generally have a low interest on nutrition and diet, and they especially tend to miss the importance of trace elements such as vitamins and minerals. On the other hand, it is difficult to generally set the requirement for the intake of energy and each nutritional item among athletes because of the variety of sports events, activity duration, as well as the athlete's sex and body type. Therefore, the type of exercise should be considered and, at the same time, the appropriate amount of nutritional intake should be set, to be able to offer a recommendation for this population.

References

- 1) Takeda A, Sakano M, Mizoguchi Y, Suyama T, Takeda R, Takeda T, and Kimura M (2004) Vitamin B₁ Nutritional Status Assessed by Blood Vitamin B₁ Values of Middle-Aged Japanese Men and Women. *Trace Nutrients Research* 23: 124-127.
- 2) Bates CJ (2006) Thiamin. In: Bowman BA, Russell RM, eds. *Present knowledge in nutrition*. 9th ed. Volume 1. International Life Sciences Institute, Washington, D.C. pp. 242-249.
- 3) Ito Y, Yamanaka K, Susaki H, Kitagawa M, Tamura A, and Igata A (2010) A study of the distribution range of total thiamine concentration in the blood of university students. *Annual Report of Institute of Health and Nutrition Nagoya University of Arts and Sciences* 4: 11-18.
- 4) Ito Y, Yamanaka K, Susaki H, Kitagawa M, and Igata A (2011) A Study into the Distribution Range of Total Thiamin Concentration in the Blood of Female University Students and the Factors Involved. *School Health* 7: 55-61.
- 5) Hiraoka M and Yasuda K (1998) Study on Nutritional Status of Thiamin and Riboflavin in Female Students -Blood Thiamin and Riboflavin Levels in Female-. *Vitamins* 72: 679-684.
- 6) Sato A, Shimoyama Y, Ishikawa T, and Murayama N (2011) Dietary thiamin and riboflavin intake and blood thiamin and riboflavin concentrations in college swimmers undergoing intensive training. *Int J Sport Nutr Exerc Metab* 21: 195-204.
- 7) Shibata K, and Fukuwatari T (2013) The Body Vitamin B₁ Levels of Rats Fed a Diet Containing the Minimum Requirement of Vitamin B₁ Is Reduced by Exercise. *J Nutr Sci Vitaminol* 59: 87-92.
- 8) The Ministry of Health, Labour, and Welfare (2009) *Dietary Reference Intakes for Japanese*, Tokyo.
- 9) Shibata K, Fukuwatari T, Imai E, Hayakawa T, Watanabe F, Takimoto H, Watanabe T, and Umegaki K (2013) Dietary Reference Intake for Japanese 2010: Water-Soluble Vitamins. *J Nutr Sci Vitaminol* 59: S67-82.
- 10) Kimura M, Fujita T, and Itokawa Y (1981) High Sensitive Method for the Determination of Thiamine in Blood by High Performance Liquid Chromatography. *Vitamins* 55: 185-189.
- 11) Ihara H, Hirano A, Wang L, Okada M, and Hashizume N (2005) Reference values for whole blood thiamine and thiamine phosphate esters in Japanese adults. *J Anal Bio Sci* 28: 241-246.
- 12) Ishiwata Y and Oka H (2011) Current Situations and Issues of Vitamin B₁ Measurement. *Vitamins* 85: 338-345.
- 13) Tietz NW (1995) *Thiamine -Clinical Guide to Laboratory Tests-*, 3rd.ed. WB Saunders Company, Philadelphia PA. pp. 528-585.
- 14) Takeda A, Suyama T, Suzuki C, Imanishi M, Takeda T, Takeda R, Kitamura R, Tamai H, and Kimura M (2002) Vitamin B₁ Nutritional Status Assessed by Blood Vitamin B₁ Value of Middle Aged Japanese Men and Women. *Vitamins* 76: 349-353.
- 15) Strumilo S, Czerniecki J, and Dobrzyn P (1999) Regulatory effect of thiamin pyrophosphate on pig heart pyruvate dehydrogenase complex. *Biochem Biophys Res Commun* 256: 341-345.
- 16) Lonsdale D (2006) A review of the biochemistry, metabolism and clinical benefits of thiamin(e) and its derivatives. *eCAM* 3: 49-59.
- 17) Parolin ML, Chesley A, Matsos MP, Spriet LL, Jone NL, and Heigenhauser GJF (1999) Regulation of skeletal muscle phosphorylase and PDH during maximal intermittent exercise. *Am J Physiol Endocrinol Metab* 277: 890-900.
- 18) Sauberlich HE, Herman YF, and Stevens CO (1970) Thiamin requirement of the adult human. *Am J Clin Nutr Metabol* 23: 671-672.
- 19) Manore MM (2000) Effect of physical activity on thiamine, riboflavin, and vitamin B-6 requirements. *Am J Clin Nutr* 72: 598-606.
- 20) Ishiguro Y, Tamura A, Aoishi K, Koide T, Aoishi T, Kanno M, and Takada M (2009) Nutritional and health management for university rugby-football players. *Annual Report of Institute of Health and Nutrition Nagoya University of Arts and Sciences* 3: 31-37.
- 21) Japan Sports Association (2006) *Determined from Nutrition and Meal Guide for Athlete*. Daiichi Shuppan Publishing Co.,Ltd, Tokyo.
- 22) Van der Beek EJ (1991) Vitamin supplementation and physical exercise performance. *J Sports Sci* 9: 77-90.
- 23) Van der Beek EJ, Van Dokkum W, Wedel M, Schrijver J, and Van den Berg H (1994) Thiamin, riboflavin and vitamin B₆: impact of restricted intake on physical performance in man. *J Am Coll Nutr* 19: 629-640.
- 24) Yamada T, Takahashi T, and Muramatsu S (2004) Thiamine and Riboflavin Metabolism during Endurance Physical Training. *Kanto Gakuin University*

- ty Society of Human and Environmental Studies bulletin 2: 137-142.
- 25) Woolf K and Manore MM (2006) B-vitamins and exercise: does exercise alter requirements? *Int J Sport Nutr Exerc Metab* 16: 453-484.
 - 26) Yoshida M, Hishiyama T and Igarashi T (2008) A Novel Method for Determining Total Vitamin B₁ in Processed Food Enriched with Dibenzoyl Thiamine. *Journal of the Japanese Society for Food Science and Technology* 55: 421-427.
 - 27) Butler SM, Black DR, Blue CL, and Gretebeck RJ (2004) Change in diet, physical activity, and body weight in female college freshman. *Am J Health Behav* 28: 24-32.
 - 28) Franko DL, Cousineau TM, Trant M, Green TC, Rancourt D, Thompson D, Ainscough J, Mintz LB, and Ciccazzo M (2008) Motivation, self-efficacy, physical activity and nutrition in college students: randomized controlled trial of an internet-based education program. *Prev Med* 47: 369-377.
 - 29) Pullman AW, Masters RC, Zalot LC, Carde LE, Saraiva MM, Dam YY, Randall Simpson JA, and Duncan AM (2009) Effect of the transition from high school to university on anthropometric and lifestyle variables in males. *Appl Physiol Nutr Metab* 34: 162-171.