Background: The goal of this study was to evaluate energy expenditure and dietary intake of nutrients during Taekwondo practice in elite Korean male Taekwondo players.

Methods: Elite Korean male high school (high school player: HP; n = 59) and college players (college player: CP; n = 58) wore an accelerometer to measure energy expenditure and recorded their daily dietary intake for nutritional analysis over the course of five days.

Results: Nutritional adequacy ratios for total energy (0.82), vitamin C (0.97), calcium (0.78), and folate (0.75) were below recommended levels for all players. When comparing daily nutrient intake and energy expenditure between HP and CP, the HP group had significantly higher total calorie intake (402.7 kcal, p < 0.001), calcium (126.3 mg, p = 0.018), phosphorus (198.0 mg, p = 0.002), iron (1.3 mg, p = 0.002), and vitamin B2 (0.4 mg, p < 0.001) than the CP group. Although there was no significant difference in the estimated energy requirement during Taekwondo practice, the total energy expenditure (151.2 kcal, p = 0.001), total activity counts (130,674 counts, p = 0.038) and energy expenditure during Taekwondo practice (257.7 kcal, p < 0.001) were significantly higher in the HP than in the CP.

Conclusion: The results indicate that a sports nutrition program based on energy balance is necessary to achieve optimal health and performance in elite male Taekwondo players.

Key Words: Taekwondo practice, Energy balance, Nutrient intake, Energy expenditure

INTRODUCTION

Taekwondo is a Korean martial art and sport with origins dating back at least 1,000 years. Taekwondo is increasingly popular, and the World Taekwondo Federation (WTF) reports that Taekwondo is practiced in at least 189 countries [1]. The increased participation in Taekwondo has fostered the development of scientifically-based practice and objective match methods, and advancement of various techniques employed in the practice of Taekwondo [1]. Taekwondo is an athletic event lasting for only three rounds of two minutes each, and the major factors that determine player’s performance include power and speed to attack an opponent quickly, agility to smoothly convert from attacking to blocking, muscular endurance to achieve repeated movement, and the anaerobic capacity to move rapidly and explosively. Comprehensive practice is required to improve an athlete’s fitness and performance in Taekwondo [2]. Previous studies [1-3] have shown that Taekwondo exercise improves physical fitness including cardiorespiratory fitness, balance, muscular endurance and power, flexibility, agility, centripetal
force, and striking force. Because of the substantial effects on fitness, it is likely Taekwondo improves overall health as well.

Athletic performance can be affected by a number of factors such as physical fitness, practice, nutrition, and the recovery process. Among these, diet plays a crucial role in practice and performance. The dietary requirements for Taekwondo and other combat sports can vary depending on the sex and age of the athlete [1]. Ubeda et al. [4] reported that optimal nutritional status, body weight, and body composition were the key factors affecting combat sport performance. Adequate dietary intake by athletes, particularly with respect to adequate energy intake, should meet the energy demands of the sport and can reduce fatigue and injury, whereas inadequate nutrition can impair performance. Therefore, both good physical conditioning and dietary habits are necessary to excel in Taekwondo and other combat sports [5,6].

The energy demands of Taekwondo have not been well quantified in conjunction with dietary factors, especially in young elite Taekwondo players. This study aimed to evaluate energy expenditure and dietary intake of nutrients during Taekwondo practice in elite Korean male Taekwondo players.

**MATERIALS AND METHODS**

1. **Participants**

Elite Korean male Taekwondo players (high school group, HP: n = 59, range 17.2-19.7 years, college group, CP: n = 58, range 20.1-24.2 years) were recruited through invitations disseminated via the coaching staff over a 6-month period. Informed consent was obtained from all participants before the start of the study in accordance with the policies and procedures of the institutional review board of the Sports Science Institute in Seoul National University. All participants were instructed to maintain their typical diet and physical activity patterns during Taekwondo practice over the experimental period. All players maintained a daily dietary record and responded to physical activity questionnaires.

2. **Program of Taekwondo practice**

All subjects were engaged in the same Taekwondo practice during the five-day experimental period of this study. All Taekwondo players trained for five hours per day, with two hours devoted to the technical aspects of Taekwondo and three hours devoted to improving their basic fitness. The training sessions on Monday, Tuesday and Thursday were moderate intensity, and the sessions on Wednesday and Friday were vigorous.

3. **Measurement of physical characteristics**

Anthropometric parameters and body composition were measured in a fasting state, while wearing light indoor clothing without shoes. Body mass index (BMI) was calculated from measured weight and height as the ratio of weight (kg) / height (m²). All participants were instructed to weigh themselves with an empty bladder immediately after waking and before breakfast [7]. Body composition was determined via bioelectrical impedance (Inbody 3.0, Biospace, Korea) by a trained technician. The bioelectrical impedance device was calibrated before testing according to manufacturer’s instructions, and the test was conducted in a fasted state between 7:00 and 9:00 a.m. while standing on an upright scale. Blood pressure was measured on the right arm using a standard mercury sphygmomanometer (Baumanometer, USA).

4. **Measurement of energy expenditure**

Energy expenditure was estimated using an accelerometer as a surrogate for direct measurements. The accelerometer (Actical, Minimiter, USA) was secured on the right hip (anterior to the iliac crest) with an elastic belt and worn for five days, from Monday to Friday. Activity counts were converted to energy expenditure using Actical software. Total energy expenditure (TEE), total counts (TAC), energy expenditure during light activity (EEL), moderate activity (EEM), and vigorous activity (EEV) were determined. In this study, 60-second sampling epochs were used, and average values of TEE, TAC, EEL, EEM, and EEV per day over five days were calculated [8,9].

5. **Analysis of estimated energy requirement**

The Estimated Energy Requirement (EER) for each Taekwondo player was calculated using the formula for the physical activity level of a very active adolescent (≤19 yrs)
and adult male (≥20 yrs), as described in the Dietary Reference Intakes for Koreans (KDRIs). For adolescent male players, EER was calculated using the equation: EER = 88.5 – 61.9 × age (yrs) + 1.42 × (26.7 × weight (kg) + 903 × height (m)) + 25 kcal/day. For adult male players, EER = 662 – 9.53 × age (yrs) + 1.48 × (15.91 × weight (kg) + 539.6 × height (m)) [10].

6. Measurement of dietary intake

To measure dietary nutrient intake, all participants maintained a daily dietary record during the same five days when the accelerometer was worn. Subjects were asked to record intake of all foods, and to quantify the portion of foods consumed by referring to the weight or volume information provided on the food package or by using standardized household measures (e.g., standard teaspoons, table spoons, cups). Foods that did not fit into a standard measuring cup or spoon were described by dimensions using a grid measured in centimeters. In addition, experienced dietitians were available to discuss specific methods for recording foods that players were likely to consume but might have difficulty describing or quantifying [11]. Data from the food diaries were analyzed using the Can-pro program (Version 3.0, Korean Nutrition Society, Korea), which is a nutrient intake assessment software developed by the Korean Nutrition Society. Based on the dietary intake data provided by the subjects, the average daily intake of energy, protein, fat, carbohydrate, calcium, phosphorus, iron, vitamin A, vitamin B1, vitamin B2, vitamin B6, niacin, vitamin C, and folate were determined. To assess nutritional adequacy without energy intake, the nutritional adequacy ratio (NAR) and mean adequacy ratio (MAR) were calculated using the KDRIs as standards, with a level of 1.0 considered adequate. NAR was calculated as follows: NAR = (amount of nutrient intake / recommended amount of nutrient). MAR was calculated as follows: MAR = (sum of N NAR / N). All NAR values were truncated at 1.0 to prevent nutrient intake in excess of the recommended daily allowance (RDAs), by mathematically compensating for low intake of other nutrients that could not be substituted nutritionally [2,13].

7. Statistical methods

Data analyses were conducted using SPSS Version 18.0 (Chicago, USA). Descriptive statistics are presented as mean ± standard deviation and frequencies. Mean comparisons between the two subject groups were analyzed using independent samples and t-tests. An alpha level (α) of p < 0.05 was considered statistically significant in all analyses.

RESULTS

Physical characteristics of the participants are presented in Table 1. The subjects ranged in age from 17.2 to 24.2 years. On average, players had 6.7 years of experience. Age (p < 0.001), weight (p < 0.001), BMI (p < 0.001), SBP (p = 0.001), DBP (p = 0.004), muscle mass (p < 0.001), fat mass (p < 0.001), and years of experience as a player (p < 0.001) were all significantly higher in the CP than in the HP, although height was similar between the two

| Table 1. Physical characteristics of subjects |
|-----------------------------------------------|
| **College player group (n=58)** | **High school player group (n=59)** | **p** |
| Age, years | 22.0 ± 2.3 | 18.8 ± 1.4 | <0.001 |
| Height, cm | 175.4 ± 5.7 | 173.9 ± 5.5 | 0.145 |
| Weight, kg | 73.3 ± 9.8 | 63.3 ± 8.0 | <0.001 |
| BMI, kg/m² | 23.8 ± 2.8 | 20.9 ± 2.4 | <0.001 |
| Muscle mass, kg | 57.1 ± 6.4 | 51.4 ± 5.6 | <0.001 |
| Fat mass, kg | 13.3 ± 2.5 | 9.1 ± 1.5 | <0.001 |
| SBP, mmHg | 129.9 ± 14.4 | 121.9 ± 12.0 | 0.001 |
| DBP, mmHg | 76.7 ± 8.3 | 70.5 ± 9.7 | 0.004 |
| Experience as player, years | 8.7 ± 3.1 | 5.6 ± 2.4 | <0.001 |

Values are mean ± SD. p-values are the difference between the college and high school Taekwondo player groups. BMI: body mass index, SBP: systolic blood pressure, DBP: diastolic blood pressure.
groups.

Energy expenditure and estimated energy requirements of the participants are shown in Table 2. Average EER and TEE for all players was 3,615.1 kcal and 1,573.5 kcal, respectively. There was no significant difference in absolute EER between the CP and HP. However, EER in kcal per kg body weight for the HP was 57.5 kcal per kg and 49.0 kcal per kg for the CP (p < 0.001). In addition, absolute TEE (151.2 kcal, p = 0.001), relative TEE (5.7 kcal/kg body weight, p < 0.001), TAC (103,673 counts, p = 0.038) and EEV (257.7 kcal, p < 0.001) were significantly higher in the HP than in the CP. However, EEM (154 kcal, p = 0.012) was significantly higher in the CP than in the HP.

Table 2. Energy expenditure and estimated energy requirements of elite Taekwondo players

|                       | College player group (n=58) | High school player group (n=59) | p      |
|-----------------------|----------------------------|--------------------------------|--------|
| **EER**               |                            |                                |        |
| EER, kcal             | 3,588.0 ± 249.5            | 3,642.2 ± 325.8                | 0.308  |
| kcal/kg body weight   | 49.0 ± 7.0                 | 57.5 ± 8.8                     | <0.001 |
| **TEE**               |                            |                                |        |
| TEE, kcal             | 1,497.9 ± 245.1            | 1,649.1 ± 246.1                | 0.001  |
| kcal/kg body weight   | 20.4 ± 2.7                 | 26.1 ± 3.3                     | <0.001 |
| **TAC, counts**       | 731,683 ± 229,419          | 862,357 ± 175,773              | 0.038  |
| **EEL, kcal**         | 194.6 ± 55.1               | 184.4 ± 94.3                   | 0.468  |
| **EEM, kcal**         | 1,039.7 ± 229.5            | 943.3 ± 87.2                   | 0.012  |
| **EEV, kcal**         | 263.7 ± 63.6               | 521.4 ± 36.4                   | <0.001 |

Values are mean ± SD. p-values are the difference between the college and high school Taekwondo player groups. EER: estimated energy requirement, TEE: total energy expenditure, TAC: total counts, EEL: energy expenditure of light intense activity, EEM: energy expenditure of moderate intense activity, EEV: energy expenditure of vigorous intense activity.

Comparisons of daily macronutrient intake showed that the HP consumed significantly more total energy (402.7 kcal, p < 0.001), protein (13.9 g, p = 0.002), fat (17.8 g, p = 0.002), and carbohydrate (46.3 g, p < 0.001) than the CP. In addition, the HP con-
Table 4. Micronutrient intake of elite Korean male Taekwondo players

|                     | College player group (n=58) | High school player group (n=59) | p    |
|---------------------|-----------------------------|---------------------------------|------|
| Calcium, mg         | 586.8 ± 230.2               | 713.1 ± 340.0                   | 0.018|
| Phosphorus, mg      | 1,242.0 ± 366.0             | 1,440.0 ± 326.3                 | 0.002|
| Iron, mg            | 18.5 ± 7.9                  | 19.8 ± 7.8                      | 0.002|
| Vitamin A, μgRE     | 1,145.2 ± 500.1             | 1,155.1 ± 585.4                 | 0.957|
| Vitamin B1, mg      | 2.0 ± 0.7                   | 2.4 ± 0.8                       | 0.083|
| Vitamin B2, mg      | 1.4 ± 0.4                   | 1.8 ± 0.5                       | <0.001|
| Vitamin B6, mg      | 2.4 ± 1.1                   | 2.6 ± 1.1                       | 0.362|
| Niacin, mg          | 22.2 ± 8.8                  | 25.3 ± 8.8                      | 0.052|
| Vitamin C, mg       | 97.6 ± 56.6                 | 104.8 ± 60.4                    | 0.500|
| Folate, μg          | 282.9 ± 98.7                | 315.6 ± 96.7                    | 0.067|

Values are mean ± SD. p-values are the difference between the college and high school Taekwondo player groups.

The results of the nutritional adequacy analysis in elite male Taekwondo players are shown in Table 5. Energy (NAR = 0.82), vitamin C (NAR = 0.97), calcium (NAR = 0.78) and folate (NAR = 0.75) were below the KDRI recommended daily levels in all HP and CP players. Moreover, NAR for energy intake in the CP (NAR = 0.77) and the HG (NAR = 0.88) were considerably lower than the recommended EER for their respective age groups. In addition, the NAR for vitamin C intake (CP: 0.98, HP: 0.95), calcium (CP: 0.84, HP: 0.71), and folate (CP: 0.71, HP: 0.79) in both the CP and HP were lower than recommended by the KDRI. There were significant differences between the two groups in NAR energy (p < 0.001) and NAR calcium (p = 0.041).

**DISCUSSION**

Appropriate energy balance is an important goal for athletes, particularly during vigorous training that may include multiple daily workouts. Maintaining energy balance along with adequate nutrient intake optimizes exercise performance and overall health [14]. Yet, due to the strict weight-class in Taekwondo, athletes continually strive to “make weight” and to maintain a lean, light body mass. As a result, energy intake may intentionally fall short of energy...
requirements, which can result in malnutrition. However, the energy demands of Taekwondo have not been well quantified in conjunction with dietary factors, especially in young Taekwondo athletes.

The age groups in this study were chosen because of physiological changes that occur during this developmental stage. The KDRI recommendations for macro and micronutrients intake are different for youth ages 15-19 years compared with young adults ages 20-29 [10]. Thus, this study recruited Taekwondo players in college (aged 20.1-24.2 years) and high school (aged 17.2-19.7 years).

Accuracy in estimation of energy expenditure is a problem in both the general public and in athletic populations. Accelerometers have been increasingly utilized as a valid instrument for studies on physical activity [9,15]. Accelerometers measure the acceleration of the body and can quantify the intensity, frequency, and duration of physical activity, and provide estimations of energy expenditure. For these reasons, estimates of TEE, EEL, EEM, and EEV were obtained using an accelerometer and the resulting data were compared with energy intake and EER. When comparing energy expenditure between the groups, EER in the HP was 54.2 kcal per day (8.5 kcal/kg bodyweight) greater than that of the CP, and TEE in the HP group was 151.2 kcal per day (5.7 kcal/kg bodyweight) greater than that of the CP. In other words, EER and TEE appear to be age-dependent, which is consistent with reports by Klaas and others [15,16]. In young adults, for example, exercise increases TEE up to 25%, whereas non-practice physical activity does not affect TEE. On the other hand, exercise practice has no effect on TEE in older persons due to an equivalent compensatory decline in non-practice physical activity. In this study, the analysis of energy expenditure suggests that appropriate energy intake is required based on volume of exercise practice.

Dietary surveys of athletes often report inadequate or inappropriate dietary intake compared to athletes’ nutritional or population dietary reference recommendations [17-19]. Nutrient intake in athletes is usually compared to age-, gender-, and country-specific nutrient intake recommendations developed for the general population [20]. Susan et al. [21] reported that the Nutrient Reference Values (NRV) and Dietary Reference Intake (DRI) include the Estimated Average Requirement (EAR) and RDI/A (Recommended Dietary Intake/Allowance), which specify the nutrient intake required to meet the needs of half (50%) and nearly all (97-98%) healthy individuals, respectively. However, the mean nutrient intake for athletes is most often reported and used to assess nutritional adequacy [2,5,21]. A more appropriate approach is to assess the proportion of athlete groups above and below the relevant NRV in order to provide information about the number of individuals who may be at increased risk of inadequate nutrient intake [12,22]. NAR is used for qualitative evaluation of nutrient intake and to evaluate the dietary adequacy of each nutrient. MAR is a method used to assess dietary adequacy of overall nutrients. NAR and MAR values ≥1.0 indicate adequate nutrition [12,22]. To evaluate dietary adequacy, both NAR and MAR should be analyzed and used for assessment, and this study utilized both methodologies. MAR assessment of overall nutrients found that both groups had adequate nutrient intake. In this study, the precise standards and nutrient intake appropriate for Taekwondo practice were difficult to evaluate since there are no standardized data specific to Taekwondo players. Thus, significant differences in KDRI were recognized in this study. NAR analysis showed that energy, vitamin C, calcium, and folate intake in both groups were inadequate. These data raise serious concerns about nutritional inadequacy in elite Korean Taekwondo players. For example, energy intake failed to meet the EER. Further, micronutrient intake, including vitamin C, calcium, and folic acid, did not meet KDRI standards.

Taekwondo players in both the CP and HP in this study met the minimum sport nutrition recommendations of 1.2 g/kg protein [23], and 5.0 g/kg carbohydrate [12] per day. Suboptimal intake and deficiency of vitamin C and folate in high school and college-aged athletes has also been reported previously [2,24]. Inadequate folate intake has the potential to affect sports performance since folic acid plays a key role in red blood cell formation. According to a study on nutrient intake in Korean male athletes [24], the average vitamin C intake for Korean male high school boxing and wrestling athletes was 68 mg and 86 mg, respectively, and their folate intake was 323 ug and 349 ug, respectively. The present study found that vitamin C intake for Taekwondo athletes was higher and folate intake was lower compared
to athletes in other sports such as boxing and wrestling. Vitamin B2 and niacin had NAR values of 1.83 and 1.41, respectively, but a study by Jang and Lee [24] reported that Korean male high school boxing, wrestling, track and field, weight lifting, cycling and swimming athletes had an average NAR for vitamin B2 and niacin intake of 2.3 and 2.1, respectively. Thus vitamin B2 and niacin NAR values for Taekwondo athletes were lower on average compared to other types of athletes.

The current study was conducted to evaluate nutrient intake and training in elite Taekwondo players. Of the many powerful variables associated with nutrient intake, however, fluid intake was not included in the current study, because the Can-pro program cannot analyze the water content of foods. In addition, due to lack of existing data, it was not possible to directly compare data from the present study with other studies of Taekwondo players. Thus, another limitation of the present study is that comparisons were made with players of other sports. Therefore, more studies on the nutrient intake of Taekwondo players are needed to provide more comprehensive data and ultimately promote optimal health and performance in Taekwondo players.

The results indicate that there are significant inadequacies in NAR intake of energy (0.82), vitamin C (0.97), calcium (0.78), and folate (0.75) in elite Korean Taekwondo players. In particular, college Taekwondo players had a considerably low total energy intake, which was even lower than the energy intake observed in high school players (0.77 vs. 0.87). Therefore, a sports nutrition program based on energy balance is suggested in order to promote performance in elite Korean Taekwondo players.

REFERENCES

1. Mohsen K, Giovanni P, David S. A profile of 2008 Olympic Taekwondo competitors. J Can Chiropr Assoc 2010;54:243-9.
2. Cho KO, Jun TW, Shin HM. Effects of a winter practice camp on physical fitness, physical self efficacy and nutrients intake in juvenile Taekwondo players. Korean J Exerc Nutri 2009;13:69-74.
3. Song JG, Jung HC, Kang HJ, Kim HB. Gender-related difference of body composition, aerobic, anaerobic capacity and isokinetic muscle strength in collegiate Taekwondo athletes. Korean J Spor Leis Stud 2010;40:699-708.
4. Úbeda N, Palacios GN, Montlvo ZA, Garcia JB, Garcia A, Iglesias GE. Food habits and body composition of Spanish elite athletes in combat sports. Nutric Hosp 2010;25:414-21.
5. Kang HS, Kim SJ. Study on the nutrient intakes status of the female athletes in Korea. Korean J Exerc Nutri 2003;7:167-74.
6. Garber CE, Blissmer B, Deschenes MR, Franklin BA, Lamonte MJ, Lee IM, Nieman DC, Swain DP. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. Med Sci Spor Exerc 2011;43:1334-59.
7. Garthe I, Raastad T, Refnes PE, Koivisto A, Sundgot-Borgen J. Effect of two different weight-loss rates on body composition and strength and power-related performance in elite athletes. Int J Spor Nutri Exerc Met 2011;21:97-104.
8. Hendelman D, Miller K, Baggett C, Debold E, Freedson P. Validity of accelerometry for the assessment of moderate intensity physical activity in the field. Med Sci Spor Exerc 2000;32:442-9.
9. Song BK, Cho KO, Jo YJ, Oh JW, Kim YS. Colon transit time according to physical activity level in adults. J Neuro Med 2012;18:64-9.
10. Korean Nutrition Society. Dietary reference intakes for Koreans. Korean Nutrition Society Publication, 2010.
11. Burke LM, Stater G, Broa d EM, Haukka J, Modulon S, Hopkins WG. Eating patterns and meal frequency of elite Australian athletes. Int J Spor Nutri Exerc Met 2003;13:521-38.
12. Guthrie HA, Scheer JC. Validity of dietary score for assessing nutrient adequacy. J Am Diet Assoc 1981;78:240-5.
13. Cho KO, Jo YU, Song BK, Oh JW, Kim YS. Colon transit time according to physical activity and characteristics in Korean adults. W J Gastro 2013;19:550-5.
14. Patlar S, Boyali E, Baltaci AK, Mogulkoe R, Gunay M. Elements in sera of elite taekwondo athletes: Effects of vitamin E supplementation. Bio Tra Ele Res 2011;139:119-25.
15. Klaas RW. Physical activity as determinant of daily energy expenditure. Physiol Behav 2008;93:1039-43.
16. Klaas RW. Impacts of vigorous and non-vigorous activity on daily energy expenditure. Proc Nutri Soc 2003;62:645-50.
17. Burke LM, Cox GR, Cummings NK, Desbrow B. Guideline for carbohydrate intake: Do athletes achieve them? Spor Med 2001;31:267-99.
18. Rosenbloom CA, Jomnalagadda, SS, Skinner R. Nutrition knowledge of collegiate athletes in a division 1 national
collegiate athletic association institution. J Am Diet Assoc 2002;102:418-20.
19. Burke LM, Kiens B, Ivy JL. Carbohydrate and fat for practice and recovery. J Spor Sci 2004;22:15-30.
20. Barr SI, Murphy SP, Poos MI. Interpreting and using the dietary references intakes in dietary assessment of individuals and group. J Am Diet Assoc 2002;102:780-8.
21. Susan H, Helen O, Janelle G, Geraldine N. Comparison of strategies for assessing nutritional adequacy in elite female athletes’ dietary intake. Int J Spor Nutri Exerc Meta 2010;20:245-56.
22. Cho KO, Nam SN, Kim YS. Assessments of nutrient intake and metabolic profiles in Korean adolescents according to exercise regularity using data from the 2008 Korean National Health and Nutrition Survey. Nutri Res Prac 2011;5:66-72.
23. Tipton KD, Wolfe, RR. Protein and amino acids for athletes. J Spor Sci 2004;22:65-79.
24. Jang HS, Lee SY. A study on body composition and nutrient intakes of male athletes by sports types. Korean J Exerc Nutri 2006;10:199-209.