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Nutritional knowledge, eating habits, factors affecting muscle damage, and antioxidant enzyme levels of Korean wrestlers

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[Purpose] The aim in this study was to investigate the diet and nutritional knowledge of elite Korean wrestlers and verify the differences in their exercise performance, muscle damage indicators, and antioxidant enzyme levels according to wrestler level.

[Methods] A 7-day dietary and nutrition knowledge survey was administered to 30 adult male elite wrestlers (national team: n=11; professional team: n=19). The Wingate test was conducted for 60 seconds to analyze muscle damage indicators and antioxidant levels. Blood and blood lactate concentration analyses were performed four times; the statistical significance level of all data was $p<0.05$.

[Results] Significant differences were found in general nutrition knowledge questionnaire (GNKQ) scores ($p=0.043$), diet ($p=0.001$), anaerobic performance ($p=0.001$), muscle damage indicators ($p=0.026$), antioxidant levels, and blood lactic acid concentrations (30 min after exercise, $p=0.007$; 90 min after exercise, $p=0.038$) between the national and the professional groups.

[Conclusion] To the findings confirm the relationship between the differences in diet, nutrition, and motor function for wrestlers of different expertise levels. In a follow-up, a comprehensive study on nutrition knowledge, athlete training , and weight loss is needed that considers a wider scope of subjects and analyzes additional variables.

[Keywords] nutritional knowledge, eating habits, exercise performance, muscle damage, lactic acid, antioxidant enzymes, elite wrestlers

INTRODUCTION

Anaerobic exercise may result in repetitive eccentric contractions[1] and tissue vibrations[2], potentially causing muscle damage and delayed-onset muscle soreness (DOMS). Alterations in blood creatine kinase (CK) and C-reactive protein (CRP) levels, which are typically observed post-exercise and are linked to DOMS onset, can serve as indicators of skeletal muscle recovery. Intense anaerobic exercises, whether performed for prolonged or brief durations, have also been shown to elevate the cellular production of reactive oxygen species (ROS)[3,4], potentially resulting in oxidative stress and cellular damage. Under typical exercise conditions, oxidative equilibrium is maintained within physiological thresholds, thereby mitigating the risk of oxidative injury[5]. This equilibrium is maintained through a multifaceted antioxidant defense system comprising antioxidant enzymes, such as superoxide dismutase (SOD), catalase, glutathione peroxidase (Gpx), peroxiredoxin, and thioredoxin, which neutralize ROS. Additionally, endogenous antioxidant substrates, such as glutathione, actively scavenge both ROS and RNS[6].

Nutrition is important for the prevention and recovery of antioxidant levels and muscle damage. Various supplements can be used to achieve this; however, nutrition through the diet is more important[7]. Even small performance improvements in sports can lead to substantial differences in results. Nutrition is an important factor determining athlete performance and physical health[7,8]. Additionally, proper nutritional knowledge can lead to positive changes for athletes, whereas incorrect nutritional knowledge can have unexpected effects. As such, an analysis of athlete knowledge and eating habits is necessary to identify their motor functional effects, as eating habits vary according to individual taste and nutritional knowledge.

The nutritional knowledge of weight-class athletes affects their body weight reduction strategies[9], and the function of athletes differs according to their level of nutritional knowledge[10]. However, studies analyzing athlete diet and nutritional knowledge together are lacking, and researchers have not analyzed differences in athlete levels, diet, and nutritional knowledge with respect to hematological variables.

Therefore, the aim in this study was to investigate and understand the differences in the diet, nutritional knowledge, motor function, muscle damage indicators, and antioxidant enzyme levels of elite Korean wrestlers, according to athlete level. In addition, we prepared a plan to use educational materials to improve athletes' nutritional knowledge, based on study results and prior overseas education data.

METHODS

Participants

This study enrolled 30 elite wrestlers affiliated with the Korea Wrestling Association, each with over seven years of experience. These participants were categorized based on their competitive proficiency and assigned to either 1) the national team (nat group, n=11), or 2) the professional team (pro group, n=19). Throughout the study period, the wrestlers adhered to a regimen of three daily meals and engaged in four hours of training per day.

Ethical approval

This study was conducted according to the guidelines of the Declaration of Helsinki. This study was approved by the Research Ethics Committee of Yongin University (approval No. 2-1040966-AB-N-01-20-1911-HSR-166-7). Written informed consent was obtained from all subjects.

Experimental design

The experimental setup used in this study is shown in Figure 1. Body composition assessments (InBody 720; InBody Co., Ltd., Seoul, Korea) were conducted at 08:00, followed by the Wingate test at 8:30 to evaluate anaerobic power. The Wingate test, facilitated by Excalibur Sports Equipment (Lode B. V., Groningen, Netherlands), involved maximal load exercises (with load tailored to each participant's body weight). Prior to the test, each participant underwent a 5-minute warm-up comprising intermittent cycling (alternating 30 seconds of exercise with 30 seconds

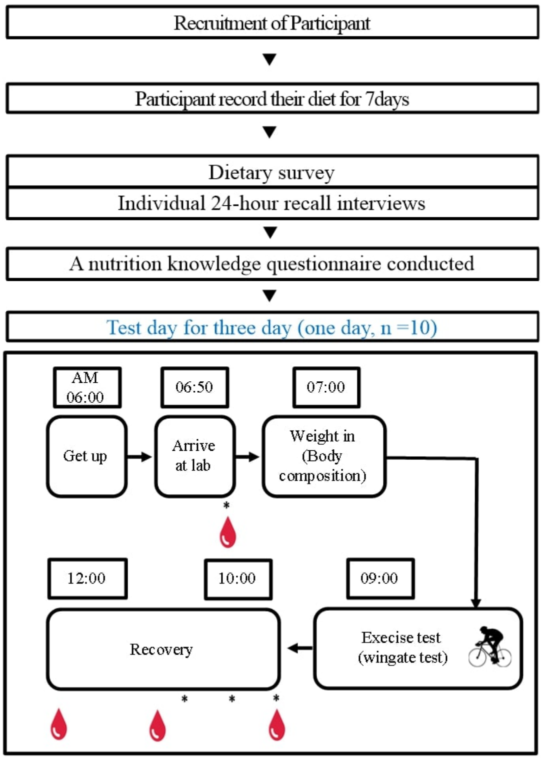

Figure 1. Diagram of the experimental design.

Table 1. Overview of participants' fundamental characteristics, nutritional knowledge, and dietary caloric intake.

Variable	Nat	Pro	f	t	*p*	Recommendation
Age (years)	25.0 ± 2.9	24.5 ± 2.7	.285	.508	.616	NA
Height (cm)	170.3 ± 5.4	169.5 ± 4.3	.882	.884	.401	NA
Body weight (kg)	72.7 ± 5.6	69.5 ± 5.4	.698	1.859	.074	NA
Skeletal muscle mass (kg)	36.2 ± 3.7*	33.7 ± 2.6	1.279	2.118	**.043**	NA
Fat mass (kg)	9.4 ± 3.5	8.8 ± 2.4	1.071	.546	0590	NA
Body fat (%)	25.3 ± 1.4	24.6 ± 1.5	.036	1.116	.274	NA
Body mass index (kg/m^2)	23.6 ± 1.2	23.4 ± 2.1	1.613	.136	.893	NA
GNKQ score	58.4 ± 2.6***	51.1 ± 1.6	2.528	3.420	**<.001**	
Carbohydrate (g/day)	667.4 ± 87.6	815.7 ± 116.3***	6.097	7.904	**<.001**	8-12 g/kg/da
Carbohydrate (kcal/day)	2669.7 ± 350.6	3263.1 ± 465.1***	6.090	7.906	**<.001**	NA
Carbohydrate (En%)	53.1 ± 6.0	62.7 ± 1.8***	52.520	10.270	**<.001**	NA
Protein (g/day)	252.3 ± 42.5***	204.7 ± 36.9	1.157	-6.194	**<.001**	1.2-2 g/kg/da
Protein (kcal/day)	1019.5 ± 179.4***	812.1 ± 148.0	2.462	-6.494	**<.001**	NA
Protein (En%)	19.9 ± 2.8***	15.6 ± 1.6***	12.291	-9.299	**<.001**	NA
Fat (g/day)	150.6 ± 22.7***	125.4 ± 18.3	1.286	-6.261	**<.001**	NA
Fat (kcal/day)	1355.3 ± 204.4***	1128.8 ± 165.0	1.287	-6.260	**<.001**	NA
Fat (En%)	26.8 ± 3.5***	21.6 ± 1.6	27.898	-9.339	**<.001**	25-30 % of Eb
Mean Kcal (7days)	5251.7 ± 747.8	5113.9 ± 386.2	33.891	1.331	.186	NA

Values expressed as mean±*SD* *: *p*=.05, ***: *p*=.001 Nat vs. Pro groups per Tukey's test; Nat, national team group; Pro, professional team group; GNKQ score, general nutrition knowledge questionnaire score; En, energy; a source : reference 30; b source: reference 27.

of rest). Upon the command "Start," participants pedaled as swiftly as possible against no resistance. A predetermined load equivalent to 7.5% of the participant's body weight in kilograms was then applied, and participants were encouraged to sustain pedaling for 60 s. Following the test, a cooling phase lasting 2–3 min involved pedaling against light resistance.

Dietary survey and nutrition knowledge analysis

A seven-day dietary survey was conducted, encompassing all meals and snacks consumed by the athletes. Participants photographed their food intake, and a 24-hour recall method was employed through interviews to ascertain the quantity and types of food consumed throughout the week. Collected dietary intake data were analyzed using CAN-Pro 4.0 software (Korean Nutrition Society, Seoul, Korea).

The Nutritional Knowledge Survey was administered before the Wingate test. The General Nutrition Knowledge Questionnaire (GNKQ) utilized in this study was translated into Korean based on the GNKQ-R revised by Kliemann et al.[11]. The GNKQ-R is comprised of 88 items organized into four sections. Participants received one point for each correct response and zero points for uncertain or incorrect answers. Sections are divided as follows: Section 1, dietary recommendations (18 questions); Section 2, food groups (36 questions); Section 3, healthy food choices (13 questions); and Section 4, diet, disease, and weight associations (21 questions).

Blood sampling and analysis

Blood samples were collected from the brachial vein at four distinct time points: before training, immediately after exercise, and 30 and 90 min post-exercise. Plasma aliquots were obtained and stored in a freezer after centrifugation for subsequent analyses. Green Cross Laboratories (Korea) analyzed all eight blood cell types and lipid parameters (CK, SOD, d-ROM, and CRP levels).

Blood lactate concentrations were assessed at four distinct time intervals: prior to training, immediately post-exercise, and at 10 and 30 minutes post-exercise. Blood samples were collected from fingertips and analyzed for lactate concentration using an electroenzymatic system employing a lactate analyzer (Lactate Pro 2, Arkray, Kyoto, Japan).

Statistical Analysis

All statistical analyses were performed using SPSS Statistics for Windows (version 25.0; IBM Corp., Armonk, NY, USA). The data are expressed as means ± standard deviation (SD). The basic characteristics, nutritional knowledge levels, and dietary intake frequencies within groups were assessed using paired t-tests. Two-way repeated-measures ANOVA with post-hoc Tukey tests were employed to detect disparities in blood parameters and exercise performance among the groups. Statistical significance was set at $p<0.05$. significant.

RESULTS

Baseline demographic characteristics and GNKQ scores

The baseline demographic characteristics of the groups, including age, height, body weight, and body composition, are presented in Table 1. Only the skeletal muscle mass of the participants differed between the groups ($p=0.043$). The GNKQ scores are shown in Table 1, which shows that those of the nat group were significantly higher than those of the pro group ($p=0.043$).

Nutritional intake

The nutritional intake results are shown in Table 1. Significant differences in carbohydrate intake were found, with that of the pro group being higher ($p=0.001$). In addition, the carbohydrate energy ratio (%) of the pro group was significantly higher than that of the nat group ($p=0.001$). The daily fat and protein intakes of the nat group were higher ($p=0.001$). Moreover, the fat and protein energy intakes of the nat group were significantly higher than those in the pro group ($p=0.001$).

Wingate anaerobic test

The results of the Wingate test are presented in Table 2. The nat group exhibited a notably higher mean power output compared to the pro group ($p=0.003$). Additionally, there was a significant difference in peak power output between the nat and pro groups ($p=0.001$). Although the time to reach peak power output was shorter in the nat group than in the pro group, this disparity did not reach statistical significance. Notably, significant differences between the groups in peak power output per exercise duration emerged only after 10 seconds ($p=0.001$).

Blood parameters

Table 3 presents the values of the hematological factors for the two groups, none of which significantly differed be-

Table 2. The result of the differences in exercise performance between groups.

Variable	Nat	Pro	F	t	*p*
Peak power (w)	1227.6 ± 138.2**	1073.8 ± 116.8	.082	.776	**.003**
Peak power (w)	507.3 ± 39.4***	451.3 ± 35.3	.028	.869	**<.001**
Arrival time to peak power (sec)	4.8 ± 0.7	5.1 ± 0.7	.002	.966	.524
Peak power 10sec (w)	882.2 ± 84.8***	704.3 ± 68.9	.439	.513	**<.001**
Peak power 30sec (w)	425.6 ± 71.8	392.0 ± 41.2	2.773	.107	.113
Peak power 60sec (w)	238.0 ± 22.7	238.1 ± 46.9	2.464	.128	.992

Values expressed as mean±*SD* **: *p*=.01, ***: *p*=.001 Nat vs. Pro per Tukey's test; Nat, national team group; Pro, professional team group.

tween groups. Figure 2 shows the differences in the hematological muscle damage factors and antioxidant enzymes. Blood SOD levels in the nat group were significantly lower 30 minutes (p=0.007) and 90 minutes (p=0.038) after exercise than in the pro group. The blood CK levels were significantly higher in the nat group immediately after exercise than in the pro group (p=0.026). Finally, the blood CRP levels were significantly higher in the nat group 30 minutes after exercise (p=0.042) than in the pro group. The results of blood lactate analysis revealed a significantly higher lactic acid concentration in the nat group than in the pro group immediately after exercise (p=0.001).

Table 3. Blood cell types and fat index of blood.

Variable	Nat	Pro	F	t	*p*
FFA (μEq/L)	296.7 ± 72.4	312.12 ± 121.6	1.566	-.366	.717
TG (mg/dL)	94.2 ± 34.3	93.9 ± 34.3	.226	-.019	.985
LDL-C (mg/dL)	108.0 ± 28.6	103.3 ± 19.6	.872	.521	.606
HDL-C (mg/L)	72.9 ± 17.1	62.2 ± 13.0	.291	1.917	.065
RBC (106/lL)	5.3 ± 0.3	5.3 ± 0.3	.082	-.254	.801
WBC (106/lL)	7.4 ± 1.7	6.8 ± 1.2	.422	1.062	.297
Hb (g/dL)	16.1 ± 0.8	16.0 ± 0.8	.392	-.486	.631
Hct (%)	46.7 ± 2.1	47.2 ± 2.5	.019	.366	.717
Platelet (103/lL)	261.1 ± 55.1	259.2 ± 37.6	3.851	.114	.910
MCV (fL)	88.3 ± 2.4	88.6 ± 2.9	.795	-.279	.782
MCH (pg)	30.5 ± 1.7	29.9 ± 1.1	1.167	1.072	.293
MCHC (%)	34.4 ± 1.1	33.8 ± 0.6	5.089	2.012	.372

Values expressed as mean±*SD* *: *p*=.05, ***: *p*=.001 Nat vs. Pro groups per Tukey's test; Nat, national team group; Pro, professional team group; FFA, free fatty acid; TG, triglyceride; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol; RBC, red blood cells; WBC, white blood cell; Hb, hemoglobin; Hct, hematocrit; MCV, mean corpuscular volume; MCH, mean corpuscular hemoglobin; MCHC, mean corpuscular hemoglobin concentration.

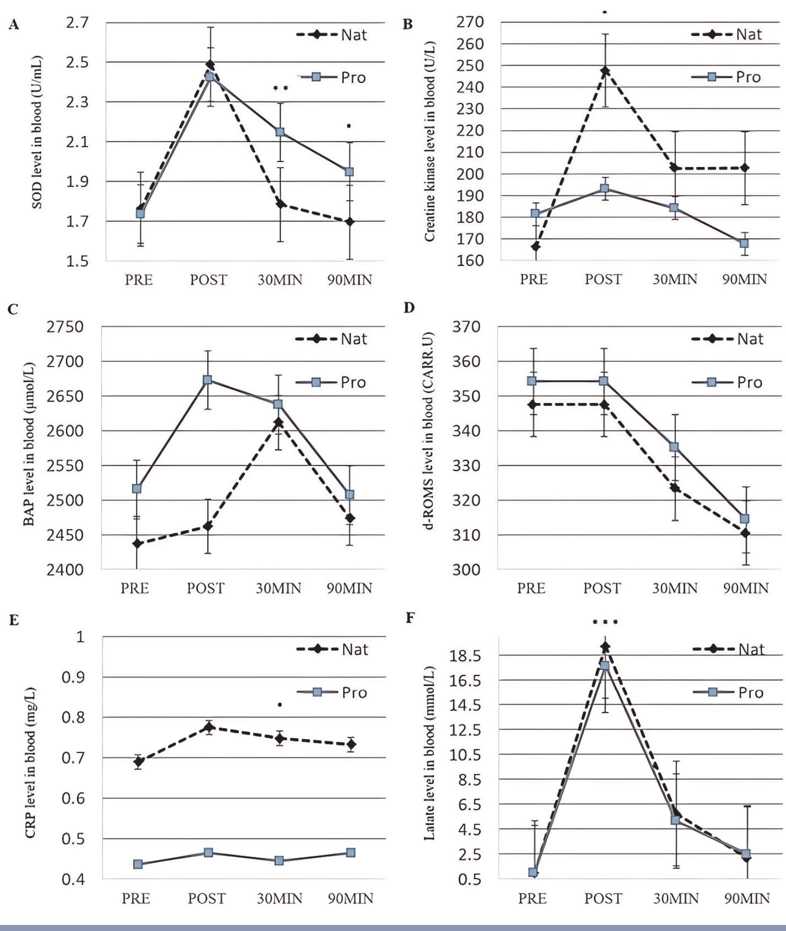

Figure 2. Change in muscle damage factors and antioxidant enzymes after exercise test. (A) SOD, (B) creatine kinase, (C) BAP, (D) d-ROMs, (E) CRP, and (F) lactate levels in blood. Nat, national team group; Pro, professional team group; PRE, prior to exercise; POST, immediately after exercise; 30MIN, 30 min after exercise; 90MIN, 90 min after exercise.

DISCUSSION

In this study, we investigated the diet and nutritional knowledge of elite Korean wrestlers and verified the differences in exercise performance, muscle damage indicators, and antioxidant enzyme levels according to athlete expertise. The results indicated differences between the groups, particularly in terms of nutritional knowledge and dietary intake.

In the pro group, carbohydrate intake accounted for 60% of total energy intake, reflecting traditional Korean dietary patterns characterized by a reliance on rice. Conversely, the dietary habits of the nat group, with carbohydrate consumption below 60%, displayed a westernized trend. The Korean diet is currently undergoing rapid westernization, evident in both the general population and athletes consuming increased quantities of protein and fat. Protein stands as a crucial nutrient for athletes, particularly those engaged in continuous training. Elevated protein intake is associated with augmented muscle size, increased cross-sectional area of muscle fibers[12], and enhanced strength and exercise performance. As suggested by Thomas et al.[13] and Beiset et al.[14], strength and power athletes are typically advised to consume protein levels near the upper end of the recommended range, with temporary increases in consumption during intense training phases, potentially offering additional benefits. In this study, the nat group exhibited a higher daily protein intake (measured in grams and kilocalories) and greater anaerobic power output.

High-intensity training methods are important for minimizing muscle fatigue and preventing muscle injury during high-intensity exercise; additional, nutrition is crucial[15]. When muscles are damaged through high-intensity exercise, the CK levels inside the muscles substantially increase. CK is an enzyme that is abundant in skeletal muscles and is widely used as an indicator of muscle injury during exercise[16]. Blood CK concentrations are significantly higher compared with baseline levels for 24 to 48 h after downhill running[17] and high-intensity uphill running[18], which are considered renal exercises[4]. Brown et al.[19] reported an increase in blood CK concentration 72 h after lower-extremity renal exercises in young men and women. In addition, muscle damage likely leads to inflammatory reactions, and muscle damage and inflammation are related[20]. Lee et al.[21] reported that carbohydrate-based diets are more effective than fat-based diets in preventing or alleviating muscle injuries during high-intensity exercise. In this study, the blood CK and CRP levels of the pro group, who consumed a large amount of carbohydrates, were lower than those of the nat group, in alignment with the results of previous studies.

Intense physical activity can cause muscle injury and persistent fatigue, which are often attributable to the detrimental effects of free radicals[22]. We observed discrepancies in SOD activity between groups after the Wingate test. These results signify the onset of oxidative stress induced by exercise, consistent with prior research illustrating heightened oxidative stress parameters across various running exercise modalities (aerobic, anaerobic, intermittent, and continuous exercises)[23,24]. In addition, Lee[25] analyzed the free radical production via a one-time measurement using a bicycle ergometer during anaerobic exercise in 10 adult men and reported a statistically significant increase in free radical levels 120 min after exercise. However, in our study, no changes in free radical levels were identified, which was the result of a shorter time period than that considered in previous studies and focusing on elite athletes who train every day. High-intensity training induces the production of peroxide radicals ($O2-$). SOD activity, the first line of antioxidant defense, increases to protect against the harmful effects of O2 radicals[26]. Most of the generated O2 radicals are continuously neutralized by conventional antioxidant defenses, which may explain the lack of changes in SOD activity[27]. In addition, changes in SOD activity may differ from between ordinary adults and elite athletes who train every day.

The maximum blood lactic acid concentration varies depending on the subject, exercise method, and exercise intensity, increasing up to 25 mmol/L[28]. Simon et al.[29] found that the higher the exercise ability, the higher the lactic acid diffusion rate, and the faster the increase in blood lactic acid concentration after exercise, the higher the exchange area as the density of capillaries through training increases[30]. As noted by Lecoultre et al.[31], increased carbohydrate intake among athletes may elevate lactate levels, consistent with the results of our study. However, it is crucial to acknowledge several limitations in our assessment of lactate recovery, which primarily focused on dietary factors. Further investigations are warranted to explore the variation in lactate recovery among wrestlers based on their dietary intake.

The nutritional knowledge scores of national and professional adult athletes were analyzed. Nutrition management is necessary to improve performance, and nutrition education is crucial for the practice of personal nutrition management[32]. The results of this study confirmed that the nutritional knowledge scores of national team players were higher than those of professional adult athletes, and the knowledge of those who were younger was also related to eating habits and exercise function. Additionally, more than half of the participants had high compliance scores, similar to those reported in previous studies comparing the GNKQ of athletes[28]. Additionally, in the field, coaches, and athletes can use our findings to educate athletes on nutrition, manage eating habits, and set up training programs. This study provides data on maintaining the eating habits and performance of athletes who lose weight in sports. Finally, our study will positively influence on individual athletes' management and quality of life.

Nutrition is an essential component of success in sports activities. The nutritional management of athletes affects not only daily training but also competition. In this study, we examined wrestlers' understanding of nutrition and their eating habits. This provided an opportunity to verify the disparity in exercise performance and post-exercise recovery at the athlete level. However, the number of subjects was too low, and the use of surveys, such as the SGNKQ, TFEQ, and GNKQ, was insufficient. Therefore, a comprehensive study on the nutrition knowledge and training of athletes is required with a wider scope and an analysis of additional ; this future study could be used to build educational materials for active nutrition education and the management of sports leaders and athletes.

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