

The effect of weight loss by ketogenic diet on the body composition, performance-related physical fitness factors and cytokines of Taekwondo athletes

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The purpose of this study was to investigate the effects of the weight loss through 3 weeks of ketogenic diet on performance-related physical fitness and inflammatory cytokines in Taekwondo athletes. The subjects selected for this research were 20 Taekwondo athletes of the high schools who participated in a summer camp training program. The subjects were randomly assigned to 2 groups, 10 subjects to each group: the ketogenic diet (KD) group and the non-ketogenic diet (NKD) group. Body composition, performance-related physical fitness factors (2,000 m sprint, Wingate test, grip force, back muscle strength, sit-up, 100 m sprint, standing broad jump, single leg standing) and cytokines (interleukin-6, Interferon- γ , tumor necrosis factor- α) were analyzed before and after 3 weeks of ketogenic diet. No difference between the KD and

NKD groups in weight, %body fat, BMI and fat free mass. However, the KD group, compared to the NKD group, finished 2,000 m sprint in less time after weight loss, and also felt less fatigue as measured by the Wingate test and showed less increase in tumor necrosis factor- α . This result suggests that KD diet can be helpful for weight category athletes, such as Taekwondo athletes, by improving aerobic capacity and fatigue resistance capacity, and also by exerting positive effect on inflammatory response.

Key words: Taekwondo, Ketogenic diet, Physical fitness factors, Cytokines

INTRODUCTION

Taekwondo is a sport that determines the winner by the score obtained by blowing the opponent (Lee et al., 2012). Therefore if a competition is allowed between athletes whose weights are much different, the physiological shock of a blowing caused by the difference in weight can directly affect not only the safety of the athlete with a lighter weight but also competition outcome itself (Tsai et al., 2011). For this reason, a weight category system has been established to ensure the comparing of Taekwondo skills under fair competition conditions. Accordingly, many Taekwondo athletes attempt to lose weight before competition by abnormal methods, so as to take part in competition under more advantageous physical strength conditions than the athletes of lower weight categories

(Elsawy et al., 2014).

The methods generally used for short-term weight loss by the athletes of weight categories include the use of a diuretic, vomiting, restricted diet, excessive training, sauna, and the wearing of perspiration-inducing clothes (Oppliger et al., 2003). Such weight loss methods, however, not only can negatively affect performance by causing homeostatic imbalance, but also may result in the deterioration of athletes' health, such as decrease in immune function or in resistance to infection, by causing problems with respiration, circulatory, thermoregulatory and renal function (Shimizu et al., 2011; Tsai et al., 2011).

Accordingly, the necessity of a more effective weight control method is being suggested that can eliminate the damage of athletes' performance and health, while recently there has been an in-

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creasing interest in ketogenic diet, which has been known to be a possible method for losing weight without negative effects on muscle strength and muscle size (Paoli et al., 2012).

Ketogenic diet, a kind of low carbohydrate high fat diet, is a method of reducing carbohydrates intake while allowing a large amount of lipids intake and a proper amount of proteins intake, to reach a physiological state called ketosis, a medical term. Ketosis means the state of using lipids instead of carbohydrates as a fuel for the body (Pethick et al., 1982). Carbohydrate combustion is fast and drastic compared to lipids and proteins, whose combustion is slow and constant without acceleration. Therefore replacement of carbohydrates with lipids as an energy source of the body results in less variations in physiological condition and in desire for food intake, consequently effectively leading to decrease in weight and body fat mass (Astrup et al., 2004; Paoli et al., 2011; Pethick et al., 1982).

Nevertheless, there has been insufficient research on the effect of ketogenic diet on the performance of weight category athletes, and additional research is essential in this regard to make a clear conclusion. Especially, no research has been conducted concerning the effect of ketogenic diet on the athletes of Taekwondo, a comprehensive physical exercise involving high intensity movement of the muscles and joints of the whole body at the mean 85-95% HR-max, and thus research in this particular participants area is considered necessary. In addition, although there have been a few research reports concerning the effect of high intensity exercise, such as Taekwondo, or of restricted diet on the inflammatory cytokines involved in the defense mechanism of the body (Gleeson et al., 2004; Lee et al., 2012), there has yet been no research at all that involved Taekwondo athletes to investigate the effect of restricted diet, especially ketogenic diet, on immune function.

Accordingly, the present research chose male high school Taekwondo athletes as participants to verify the efficacy of ketogenic diet, by examining the effect of the weight loss through 3 weeks of ketogenic diet on their physical fitness and inflammatory cytokines.

MATERIALS AND METHODS

Participants

The participants selected for this research were 20 Taekwondo athletes of the high schools located in the C area who participated in a summer camp training program without a physical or mental disease. The experiment was conducted after they and their guardians each signed an agreement stating that he or she had understood the objective and content of the experiment. The participants

Table 1. Physical characteristics of the subjects

Group (n=20)	Age (yr)	Height (cm)	Weight (kg)
KD (n=10)	16.40±0.92	173.86±5.57	64.11±7.19
NKD (n=10)	16.70±0.78	172.79±6.27	63.69±7.64

Values are means ± SD. KD, ketogenic diet; NKD, non-ketogenic diet.

were randomly assigned to 2 groups, 10 participants to each group: the ketogenic diet (KD) group, and the non-ketogenic diet (NKD) group. Their physical characteristics are described in Table 1.

Experimental procedures

1) Evaluation of body composition

Both before and 3 weeks after weight loss, every participant fasted for 12 h and then, wearing a simple cloth, was participated to measurement of height and weight, as well as of changes in BMI, %body fat and lean body mass by the electrical resistance method. Their body composition was evaluated based on the measurement.

2) Performance-related physical fitness tests

Performance-related physical strength was evaluated by measuring the items related to aerobic capacity, anaerobic capacity, muscle strength, muscle endurance, instantaneous reactionary force, and balance. Aerobic capacity was evaluated by measuring the time taken to finish a 2,000 m sprint. Whereas anaerobic capacity was evaluated by the Wingate test (Bar-Or, 1987), by measuring peak power, mean power and fatigue index using a Monark cycle ergometer (Monark 894-E, Sweden). Muscle strength was evaluated based on the measurement of: (1) grip force (TKK 5401, Takei, Japan) and back muscle strength (TKK 5402, Takei, Japan) using a digital measuring instrument, (2) muscle endurance by measuring the number of sit-ups performed in 60 sec, (3) instantaneous reactionary force by measuring time and distance on 100 m sprint and standing broad jump, respectively, and (4) balance by measuring duration on single leg standing with eyes closed.

3) Method and procedure for weight loss

Before the weight loss experiment began, all the participants prepared a document stating calorie intake for 3 days, to calculate daily mean calorie intake. Then each of the 2 groups was provided with a different menu containing 75% of the calculated daily mean calories.

Before the experiment, the KD group was provided with a list of foods showing what foods are allowed or banned for ketogenic diet. The menu for this group consisted of high lipid foods such

as beef, pork, fish, bean, egg and cheese, excluding banned foods such as bread, boiled rice, noodles, coffee and tea. This menu limited daily carbohydrate intake to 22 g, and its lipid, protein and carbohydrate ratios were 55.0%, 40.7%, and 4.3%, respectively. Whereas the NKD group was provided with a menu whose lipid, protein and carbohydrate ratios were 30%, 30%, and 40%, respectively, which were the dietary ratios recommended by the Korean Nutrition Society.

4) Exercise program

Six days a week for 3 weeks during the weight loss period, both groups participated in a training program that emphasized physical strength improvement. The daily plan of the program consisted of 1 h of low intensity dawn exercise; 2 h of morning exercise, mostly for physical strength improvement; and 2 h of afternoon exercise, mostly for Taekwondo skills training.

5) Blood analysis

Before and after the diet, all the participants whose body composition had been measured took a rest for 30 min. Then their blood was collected from the antecubital vein using 22 gage needles, and the collected blood was subjected to analysis of interleukin (IL)-6, tumor necrosis factor (TNF)- α , and interferon (IFN)- γ by ELISA using a R&D system.

Statistical analyses

Data are presented as means \pm standard deviation (SD). The significance of differences among mean values between pre and post-training, as well as between KD and NKD groups, were determined by two-way analysis of variance (ANOVA) using SPSS

18.0 for Windows. Statistical significance was set at $\alpha = 0.05$.

RESULTS

Body composition

Changes in body composition after weight loss, compared to before weight loss, by the diet control groups are presented in Table 2. Compared to before the weight loss period, there was significant decrease in weight after the period, as well as in %body fat, fat free mass and BMI ($P < 0.05$). However, no difference was found between the 2 groups, and there was also no effect of interaction between the independent variables.

Performance-related physical fitness

Changes in performance-related physical strength after weight loss, compared to before weight loss, by the diet control groups are presented in Table 3. The results of 2,000 m sprint showed interaction effect between before and after weight loss and between groups. The main effect analysis showed that the time taken by the KD group to finish the sprint was significantly decreased after weight loss compared to before weight loss ($P < 0.05$). According to the Wingate test, there were significant decreases in peak power and mean power after weight loss compared to before weight loss, but with no difference between the 2 groups. In the case of aerobic fatigue, however, the KD group showed a decrease after weight loss but the NKD group showed an increase. As for the results of back muscle strength and the number of sit-up, there were significant increases after weight loss compared to before weight loss ($P < 0.05$). In the cases of grip force, 100 m sprint, standing broad jump, and single leg standing with eyes closed, no sig-

Table 2. Changes in body composition

Variables	KD (n=10)		NKD (n=10)		F-value
	Pre	Post	Pre	Post	
Weight (kg)	64.11 \pm 7.19	60.34 \pm 6.59	63.69 \pm 7.64	61.16 \pm 7.84	G 0.004 T 89.927* G \times T 3.484
%Body fat (%)	12.59 \pm 3.96	12.21 \pm 3.59	11.31 \pm 2.77	10.23 \pm 2.63	G 1.283 T 4.486* G \times T 1.122
Lean body mass (kg)	54.65 \pm 3.93	52.47 \pm 4.67	54.94 \pm 6.50	53.55 \pm 8.16	G 0.067 T 10.457* G \times T 0.520
BMI (kg/m ²)	21.44 \pm 2.10	20.18 \pm 1.79	21.08 \pm 1.94	20.23 \pm 1.97	G 0.032 T 86.936* G \times T 3.282

Values are means \pm SD. KD, ketogenic diet; NKD, non-ketogenic diet. * $P < 0.05$.

Table 3. Changes in performance related physical fitness factors

		KD (n=10)		NKD (n=10)		F-value	
		Pre	Post	Pre	Post		
2,000 m sprint (min)		516.0±37.7	484.0±35.6	513.8±59.0	512.4±50.8	G	0.443
						T	5.560*
						G×T	4.667*
Wingate test	Peak power (w/kg)	9.61±0.53	8.56±1.10	9.06±0.76	8.45±1.38	G	0.670
						T	18.497*
						G×T	1.316
	Mean power (w/kg)	7.94±0.28	7.31±0.73	7.60±0.61	6.94±0.92	G	1.684
						T	27.356*
						G×T	0.014
	Anaerobic fatigue	55.37±6.16	52.31±7.26	54.48±3.84	59.16±7.66	G	1.640
						T	0.238
						G×T	5.365*
Grip force	Left	33.70±4.46	33.74±4.03	32.71±7.18	33.32±6.39	G	0.773
						T	0.176
						G×T	0.812
	Right	35.76±11.21	35.10±6.04	36.45±7.23	34.76±6.00	G	0.003
T						0.510	
G×T						0.098	
Back muscle strength		103.85±12.34	107.20±14.92	104.15±21.60	109.30±20.22	G	0.024
						T	5.716*
						G×T	0.256
Sit-up (times/60 min)		59.20±10.39	64.50±9.77	55.30±9.32	56.80±7.97	G	2.007
						T	12.512*
						G×T	3.907
100 m sprint (sec)		13.67±0.56	13.85±0.71	13.90±1.05	14.12±1.33	G	0.370
						T	3.961
						G×T	0.050
Standing broad jump (cm)		229.96±9.97	227.55±10.15	228.98±18.65	226.95±18.97	G	0.014
						T	3.027
						G×T	0.022
Single leg standing with eyes closed (sec)	Left	13.69±8.35	15.34±9.41	19.37±10.27	17.30±5.24	G	1.330
						T	0.012
						G×T	0.968
	Right	10.74±6.83	14.62±5.95	14.65±11.98	14.06±11.98	G	0.164
T						2.009	
G×T						3.736	

Values are means±SD. KD, ketogenic diet; NKD, non-ketogenic diet. * $P < 0.05$.

nificant difference was found between the independent variables.

Cytokines

Changes in cytokines after weight loss, compared to before weight loss, by the diet control groups are presented in Table 4. In the cases of IL-6 and IFN- γ , no significant difference was found between the independent variables. In contrast, in the case of TNF- α , interaction effect was found when comparison was made between before and after weight loss and between the 2 diet control groups ($P < 0.05$). According to result of the main effect anal-

ysis, both the KD and NKD groups showed an elevated TNF- α level after weight loss compared to before weight loss ($P < 0.05$).

DISCUSSION

Weight category athletes, such as Taekwondo athletes, try to loose weight to the limit in order to take part in competition in stabilized psychological state and under advantageous physical strength conditions. Most of the methods used by weight category athletes for short-term weight loss have been reported to involve

Table 4. Changes in cytokines

Variables	KD (n=10)		NKD (n=10)		F-value	
	Pre	Post	Pre	Post		
IL-6	3.87±1.48	3.66±0.76	3.89±0.28	3.47±0.50	G	0.068
					T	2.142
					G×T	0.205
TNF-α	6.94±1.96	8.35±1.78	6.07±2.23	9.90±1.95	G	0.227
					T	23.405*
					G×T	5.076*
IFN-γ	31.71±3.35	31.25±1.98	33.11±3.91	31.29±1.96	G	0.476
					T	1.760
					G×T	0.627

Values are means±SD. KD, ketogenic diet; NKD, non-ketogenic diet. * $P<0.05$.

the reduction of total body water, %body fat, body fat mass, BMI and fat free mass. In contrast, according to a research by Paoli et al. (2012) that involved male gymnasts, the ketogenic diet without limiting calorie intake resulted in decrease in weight and body fat mass, but increase in muscle mass. However, according to the present research, 3 weeks of ketogenic diet resulted in decrease not only in weight and %body fat but in BMI and lean body mass as well, and also there was no difference between the 2 groups. The reason is considered that, unlike the research by Paoli et al. (2012), which did not limit calorie intake, the present research used a menu containing 25% less calories; and that the off-season exercise program used along with the menu consisted mostly of aerobic exercises. The result of a meta-analysis on 94 researches related to low carbohydrate diet showed that weight loss by diet based on low carbohydrate intake was associated with reduced energy intake and with the length of diet period, but not with reduced carbohydrate intake (Bravata et al., 2003). A limitation of this analysis, however, was suggested to be diverse differences in carbohydrate concentration after intake (Brinkworth et al., 2009). However, more recently, there was a report based on meta-regression analysis that LC diet can achieve more reduction of weight and body fat mass than HC diet (Krieger et al., 2006). In line with such conflicts, the weight loss effect of ketogenic diet, a kind of LC diet, still remains disputable without a clear conclusion (Brinkworth et al., 2009).

There have been many researches reporting that weight loss by a short-term restricted diet could cause decrease in fat free mass, then this in turn might lead to the deterioration of exercise capacity. However, Phinney et al. (1980) reported that after 6 weeks of ketogenic diet, obese individuals showed significant increase in duration of treadmill exercise at 60% VO₂max. In a follow-up research, they also reported that cyclists showed no deterioration of anaerobic capacity after 4 weeks of ketogenic diet, and that keto-

genic diet exerted no negative effect on the performance of well-trained cyclists (Phinney et al., 1983). In support of their results, the present research concerning the effect of ketogenic diet on Taekwondo performance-related physical factors showed that after 3 weeks of ketogenic diet, the KD group could finish the 2000m sprint in less time, and also felt less aerobic fatigue as measured by the Wingate test, than the NKD group (White et al., 2007). This result indicates that although Ketogenic diet may cause the reduction of fat free mass, yet when exercise time is prolonged, it can be effective for improving aerobic capacity and fatigue resistance capacity by compensating for decreased carbohydrates and causing lipids to be used efficiently as an energy source.

A violent exercise, as in a throwing event, can cause muscle pain and muscle damage, and a tissue damage caused by such an exercise induces the cytokines involved in inflammation (Lee et al., 2012). In general, cytokines secreted from a damaged tissue play the role of inducing immune response to remove damaged cells and to keep the damage from spreading to the surrounding cells; whereas in some tissues, cytokines act like hormones to regulate physiological activities (Pedersen et al., 2000). Fantuzzi (2005) reported that ketogenic diet caused decrease in such cytokines as TNF-α, IL-1, IL-6, and IL-10, which are general inflammation-inducing molecules, by increasing adiponectin; and that such an action attenuated overall inflammatory response. In addition, Mohamed et al. (2010) reported that ketogenic diet caused increased expression of adiponectin in obese individuals, leading to decrease in weight and blood TNF-α level. Thus there were some ketogenic diet-related researches that reported its anti-inflammatory effect.

However, in the present research, the result of examining changes in IL-6, TNF-α, and IFN-γ, to investigate inflammatory response induced by the damages to blood cells and tissues caused by ketogenic diet, showed no change in IL-6 or IFN-γ in both the

KD and NKD groups; moreover, there was rather increase in TNF- α after the diet in both the KD and NKD groups. Such a result is considered due to difference in research participants, for unlike the preceding researches whose participants were obese individuals with high body fat mass, the present research involved Taekwondo athletes who had lower body fat mass than common individuals. In other words, to the participants of this research, who had low body fat mass, weight loss by the diet control and by a lot of training acted as a stress that exerted negative effect on homeostasis of the body leading to increase in inflammatory response, rather than as a cause of positive effect through the reduction of body fat mass. Yet this research did not consider change in adiponectin concentration, which the preceding researches suggested as the mechanism of decrease in cytokines by weight loss. Thus, further research is necessary to elucidate a more accurate mechanism. Nevertheless, judging from the fact that, although 3 weeks of KD diet and NKD diet in this research both caused increase in TNF- α , the increase in TNF- α was less in the KD group than in the NKD group, it is considered that a ketogenic diet is effective for attenuating inflammatory response caused by weight loss.

In conclusion, KD diet can be helpful for weight category athletes, such as Taekwondo athletes, by improving aerobic capacity and fatigue resistance capacity, and also by exerting positive effect on inflammatory response.

CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

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