Nutrition Research and Practice 2015;9(1):71-78

http://e-nrp.org

Comparison of total energy expenditure between the farming season and off farming season and accuracy assessment of estimated energy requirement prediction equation of Korean farmers

Eun-Kyung Kim[1§], Seo-Eun Yeon[1], Sun-Hee Lee[1] and Jeong-Sook Choe[2]

[1]Department of Food and Nutrition, Gangneung-Wonju National University, 7 Jukheon-gil, Gangneung-si, Gangwon-do, 210-702, Korea
[2]National Academy of Agricultural Science, Rural Development Administration, Jeollabuk-do, 560-500, Korea

BACKGROUND/OBJECTIVES: The purposes of this study were to compare total energy expenditure (including PAL and RMR) of Korean farmers between the farming season and off farming season and to assess the accuracy of estimated energy requirement (EER) prediction equation reported in KDRIs.
SUBJECTS/METHODS: Subjects were 72 Korean farmers (males 23, females 49) aged 30-64 years. Total energy expenditure was calculated by multiplying measured RMR by PAL. EER was calculated by using the prediction equation suggested in KDRIs 2010.
RESULTS: The physical activity level (PAL) was significantly higher ($P < 0.05$) in the farming season (male 1.77 ± 0.22, female 1.69 ± 0.24) than the off farming season (male 1.53 ± 0.32, female 1.52 ± 0.19). But resting metabolic rate was significantly higher ($P < 0.05$) in the off farming season (male $1,890 \pm 233$ kcal/day, female $1,446 \pm 140$ kcal/day) compared to the farming season (male $1,727 \pm 163$ kcal/day, female $1,356 \pm 164$ kcal/day). TEE ($2,304 \pm 497$ kcal/day) of females was significantly higher in the farming season than that ($2,183 \pm 389$ kcal/day) of the off farming season, but in males, there was no significant difference between two seasons in TEE. On the other hand, EER of male and female ($2,825 \pm 354$ kcal/day and $2,115 \pm 293$ kcal/day) of the farming season was significantly higher ($P < 0.05$) than those ($2,562 \pm 339$ kcal/day and $1,994 \pm 224$ kcal/day) of the off farming season.
CONCLUSIONS: This study indicates that there is a significant difference in PAL and TEE of farmers between farming and off farming seasons. And EER prediction equation proposed by KDRI 2010 underestimated TEE, thus EER prediction equation for farmers should be reviewed.

Nutrition Research and Practice 2015;9(1):71-78; doi:10.4162/nrp.2015.9.1.71; pISSN 1976-1457 eISSN 2005-6168

Keywords: Energy expenditure

INTRODUCTION

Actually for the past decade, the obesity (BMI > 25 kg/m^2) prevalence in Korean adults with aged 30 years and above increased from 29.0% in 1998 to 34.2% in 2011. But in agricultural regions, it increased from 26.1% to 33.8% in the same period and its increasing rate was higher than that of the total population [1].

This fact suggests the possibility of an energy imbalance between energy intake and energy expenditure in farmers may be more serious in agricultural regions than in the city. In particular, obesity caused from this imbalance increases the risk of metabolic syndrome, which may relate to prevalence of not only hypertension, diabetes and hyperlipidemia but also angina, myocardial infarction, stroke and other cardiovascular diseases [2,3].

The Korean agricultural season is divided into a farming season in which farming is possible and an off farming season in which it is too cold to farm. The farming season is generally from mid-June to early November when harvesting and planting of rice and barley overlap each other. The off farming season is the period between the two farming seasons. Therefore, there is a great difference in time spent for agricultural activities and daily activities between the farming and off farming seasons. Much time was being spent for highly intense physical activities conducting diverse agricultural activities (harvesting, rice-planting, weeding, using hoes, etc.) in the farming season [4,5]. In contrast, in the off farming season, farmers spent much time for very low intense physical activity, such as sleeping and resting, house management, social and leisure activities [4-6]. Although Choi and Hwang *et al*. [7] reported that farmers adapt to seasonal fluctuations, especially temperature changes, and

This study was supported by a grant from The Rural Development Administration of Korea (RDA: 20120401-037-501-001-03-00)
§ Corresponding Author: Eun-Kyung Kim, Tel. 82-33-640-2336, Fax. 82-33-640-2330, Email. ekkim@gwnu.ac.kr
Received: March 13, 2014, Revised: October 23, 2014, Accepted: November 3, 2014

are maintaining internal homeostasis, differences in physical activities in two periods may be related to differences in total energy expenditures and energy balances.

Thus measuring total energy expenditure precisely in two seasons is very important for determining energy requirements for Korean farmers. Although the most accurate method in evaluating energy expenditure is the doubly labeled water (DLW) method, it is difficult to apply this method because of its high cost and equipment. In 1985, the World Health Organization (WHO) proposed that TEE can be calculated by multiplying the physical activity level (PAL) with resting metabolic rate [8].

On the other hand, in Korea, estimated energy requirement (EER) is calculated by substituting gender, age, weight, height and physical activity status in the predictive equation derived using DLW method for Americans/Canadians. However, it remains unclear whether these equations are appropriate for Asian populations, who have different genetic factors and lifestyles from those of Western countries [9]. Therefore estimated energy requirements proposed in dietary reference intakes for Koreans (KDRI) may be under or overestimated compared to the ideal energy intake for Koreans [10].

Therefore, the purposes of this study are to compare total energy expenditure between the farming season and off farming season and to assess the accuracy of estimated energy requirement (EER) prediction equation derived by KDRI. The study aimed to propose supporting evidence for the need to set up a separate estimated energy requirement for farmers with basic data by examining the appropriateness of estimated energy requirement stated in KDRI.

SUBJECTS AND METHODS

Subjects and research period

This study was conducted throughout the farming season (June 28, 2011 - July 22) and off farming season (December 14, 2011 - February 17, 2012) for 113 farmers (42 males, 71 females) residing in Gangwon-do(Gangneung, Pyeongchang, Jeongseon, Yangyang, Hongcheon, Hoengseong, Samcheok and Chuncheon etc.). Among these participants, 72 farmers (23 males, 49 females) aged between 30 to 64 years old who participated in both seasons were selected as final subjects for this study. Table 1 shows the distribution of subjects by gender and age group. All subjects were fully informed about the contents and procedures of the research after which consent was signed. The study protocol was approved by the Committee on Institutional Review Board of Gangneung-Wonju National University. Every measurement was taken twice for same subjects in the farming and off farming seasons by applying the same procedures. For examples, same researchers had an interview with subjects twice for two seasons and same conditions (including humidity and temperature) for anthropometric and RMR measurement was prepared.

Table 1. Distribution of subjects by gender and age groups Unit : N(%)

Age group (yrs)	Male	Female	Total	χ^2 (*P*)
30-49	7 (30.4)	17 (34.7)	24 (33.3)	$\chi^2 = 0.128$ ($P = 0.721$)
50-64	16 (69.6)	32 (65.3)	48 (66.7)	
Total	23 (100)	49 (100)	72 (100)	
Mean Age (yrs)	50.4 ± 7.6	52.4 ± 6.1	51.8 ± 6.6	

Not significantly different in mean age between male and female.

Anthropometric and blood pressure measurement

Height, body weight and body compositions were measured using Inbody 720 (Biospace Co. Korea), which is a type of bioelectrical impedance analyzer. All measurements took place after an 8-hr fasting period and the same person took the measurements with the same procedure to reduce measurement error. By using height and body weight of the subjects, body mass index (BMI) and fat free mass (FFM) were computed. The BROCA method was used to calculate the obesity index (ideal body weight %, IBW%) and sphygmomanometer (HEM-770A, OMRON) was used to measure systolic and diastolic blood pressure.

- Body mass index (BMI) = Weight (kg) / Height $(m)^2$
- Fat free mass (kg) = Weight (kg) - Fat mass (kg)

Resting metabolic rate measurement

Resting metabolic rates of the subjects were measured using a ventilated hood system (TrueOne2400 Parvo Medics, USA) with application of open-circuit indirect calorimetry. In order to have accurate measurements of resting metabolic rate, subjects were informed that they must not consume alcohol and not smoke the day before the measurement and to avoid participating in active exercise for 24 hours. They were also asked to fast for at least 12 hours before the measurement and to arrive at the laboratory with physical activity restrained as much as possible on the morning the measurements were to take place. Subjects were given 30 minutes of rest after arrival at the laboratory and were asked to lie down for at least 10 minutes. After resting, oxygen expenditure and carbon dioxide production rate were measured at intervals of 10 seconds by using the ventilated hood system (TrueOne2400 Parvo Medics, USA) with subjects wearing the canopy and breathing comfortably for at least 15 minutes. The respiratory quotient (RQ) was calculated by obtaining average values for oxygen expenditure and carbon dioxide production rate in the measurement except for the first five minutes after the beginning of the measurement. Finally, the resting metabolic rate was calculated by using Weir equation [11].

24-hours physical activity diary

Through face to face interview with a trained interviewer to investigate the physical activity level of subjects, a physical activity diary including major farming activities was completed by 24-hour recall. Based on the collected physical activity diaries, the times spent for each physical activity stage were calculated after agricultural activities were categorized to the 18 stages of activities of the fifth Japanese dietary allowance [12], referring to the energy expenditures of various farming activities [13] published by The Rural Development Administration. Agricultural activities in the farming season (field preparation, tending to crops, spraying pesticides, applying compost, weeding, etc.) were mainly included in stage 8 and stage 13 (Table 2). The sum of the multiplication between time

Table 2. Physical activity category according to level of intensity

Type of activity category	PAR[1)]	Level of intensity
1. Sleeping	0.9	Sedentary activity
2. Resting, talking, calling, watching TV	1.2	
3. Eating food and snack	1.4	
4. Personal hygiene, Playing cultivator machine operation	1.5	
5. Agricultural diary writing, desk work	1.6	
6. Transportation, movement (bus) crop selling, pesticide manufacturing	2.0	Light activity
7. Dress oneself, slow walk	2.1	
8. Strolling, indoor exercise, field observation	2.5	
9. Cooking, tidy away, harvesting vegetables	2.6	
10. Kitchen work, indoor errand	2.7	
11. House cleaning, outdoor work	3.0	
12. Walking moderately, agricultural tools buying	3.1	
13. Arranging dress, sweeping, weed control, spray agricultural pesticide	3.2	
14. Giving a piggyback	3.3	
15. Mopping floor, cleaning and dusting agricultural tools	4.0	Moderate activity
16. Walking fast	4.5	
17. Outdoor exercise.	6.0	
18. Climbing, jogging and sports *et al.*	7.0	Vigorous activity

1) Physical activity ratio expressed as multiples of basal metabolic rate (BMR).

spent and resting energy expenditure (REE) factor was divided by 1,440 minutes (Total minutes in a 24 hour day period) to obtain the physical activity level (PAL).

Calculation of total energy expenditure

Total energy expenditure (TEE) of subjects was calculated by multiplying the physical activity level (PAL) with resting metabolic rate measured through open-circuit indirect calorimetry, which is the method proposed by the WHO (1985) [8].

Calculation of estimated energy requirement

Estimated energy requirement (EER) of subjects was calculated by the equations proposed by dietary reference intakes for Koreans (KDRI 2010) [14]. The equations are as shown below:

- Adult male
  EER (kcal/day) = 662-9.53 × Age (years) + PA [(15.91 × Body Weight (kg) + 539.6 × Height (m)]
- Adult female
  EER (kcal/day) = 354-6.91 × Age (years) + PA [(9.36 × Body Weight (kg) + 726 × Height (m)]

Physical activity level (PAL)		Physical activity coefficient (PA)	
		Men	Women
Sedentary	1.00-1.39	1.00	1.00
Low active	1.40-1.59	1.11	1.12
Active	1.60-1.89	1.25	1.27
Very active	1.90-2.50	1.48	1.45

Statistical analysis

All gathered data was analyzed by using SAS statistics program (Ver. 9.2). All measurements of subjects were expressed as mean ± SD. The paired t-test was used to verify the significance of values of all variables to be compared seasonally (farming and off farming seasons). Also, the χ^2- test was used to verify seasonal difference in distribution of obesity and hypertension prevalence rates.

The Bland-Altman test was used to evaluate the agreement between estimated energy requirement (EER) calculated by the equation from KDRI (2010) and total energy expenditure (TEE) calculated using measured RMR and physical activity level. Here, the mean difference and limits of agreement between EER and TEE were calculated (± 1.96SD) wherein it was assessed that the closer the mean difference towards '0' and the narrower the limits of agreement, the higher the accuracy of EER.

RESULTS

Anthropometric and blood pressure measurement of subjects

Anthropometric measurements of the subjects are as shown in Table 3. Average ages of male and female subjects in the farming season were 50.4 ± 7.6 and 52.4 ± 6.1, respectively. Body weight of male farmers in the off farming season (74.5 ± 10.4 kg) was significantly higher ($P < 0.001$) than in the farming season (72.2 ± 9.7 kg). BMI, obesity index (%), body surface area (BSA), body fat mass (kg) and body fat percentage (%) in the off farming season were significantly increased compared to the farming season ($P < 0.05$). On the other hand, fat-free mass (FFM) in female farmers decreased in the off farming season (39.3 ± 3.7 kg) compared to the farming season (40.0 ± 3.5 kg). In male subjects, systolic and diastolic blood pressures were very significantly ($P < 0.001$) increased in off farming season (140.9 ± 13.7 mmHg and 89.9 ± 10.4 mmHg) compared to farming season (128.3 ± 7.5 mmHg and 80.0 ± 7.7 mmHg). In female subjects, systolic and diastolic blood pressure in the off farming season was significantly ($P < 0.01$, $P < 0.05$ respectively) higher than in the farming season.

Prevalence of obesity and hypertension

Obesity and hypertension prevalence of the subjects are as shown in Table 4. Based on BMI criteria for the Asia-Pacific region as proposed by the WHO [15], there were no underweight subjects. About 75.0% and 77.8% of the subjects in the farming and off farming seasons, respectively, were overweight (including obese). However, there was no significant difference in obesity prevalence by seasons (farming and off farming seasons).

On the other hand, there was a significant difference in distribution of systolic and diastolic blood pressures between farming and off farming seasons ($P < 0.01$). The rate of hypertension (SBP ≥ 140 mmHg or DBP ≥ 90 mmHg) was higher in the off farming season (47.2%) compared to the farming season (20.8%) ($P < 0.01$), whereas the rate belonging to pre-hypertension (120 mmHg < SBP < 140 mmHg or 80 mmHg < DBP < 90 mmHg) was higher in the farming season (55.6%) compared to the off farming season (33.3%). The sum of pre-hypertension and hypertension was 76.4% for the farming season and 80.5% for the off farming season. There was no one belonging to the range of blood pressure except for the above three categories.

Table 3. Comparison of anthropometric measurements for the same subjects by season

	Male(n = 23)		Female(n = 49)	
	Farming season	Off farming season	Farming season	Off farming season
Age (yrs)	50.4 ± 7.6[1)]	50.4 ± 7.6	52.4 ± 6.1	52.4 ± 6.1
Height (cm)	170.0 ± 7.5	169.8 ± 7.6	156.2 ± 4.9	155.9 ± 5.0**
Body weight (kg)	72.2 ± 9.7	74.5 ± 10.4***	61.1 ± 7.4	61.5 ± 7.4
Body mass index (kg/m^2)	25.0 ± 2.7	25.8 ± 2.8***	25.0 ± 3.1	25.3 ± 3.1*
Obesity Index (%)	114.7 ± 12.5	118.6 ± 13.0***	115.4 ± 13.7	116.5 ± 13.8*
Body surface area (m^2)	1.83 ± 0.15	1.85 ± 0.16***	1.60 ± 0.10	1.61 ± 0.10
Body fat mass (kg)	16.4 ± 5.2	18.9 ± 5.5***	21.0 ± 5.1	22.2 ± 5.3***
Body fat (%)	22.5 ± 5.7	25.1 ± 5.6***	34.1 ± 4.7	35.7 ± 5.1***
Fat free mass (kg)	55.8 ± 7.2	55.6 ± 7.6	40.0 ± 3.5	39.3 ± 3.7***
Waist circumference (cm)	89.1 ± 7.5	89.7 ± 8.8	82.3 ± 7.5	81.9 ± 7.5
Hip circumference (cm)	99.6 ± 5.7	99.9 ± 6.0	97.5 ± 5.3	97.8 ± 5.8
Waist/Hip ratio	0.89 ± 0.04	0.9 ± 0.04	0.84 ± 0.06	0.84 ± 0.05
Systolic blood pressure (mmHg)	128.3 ± 7.5	140.9 ± 13.7***	127.1 ± 20.2	131.9 ± 17.9**
Diastolic blood pressure (mmHg)	80.0 ± 7.7	89.9 ± 10.4***	81.0 ± 10.3	83.3 ± 9.8*

Measurement was taken twice for same subjects in farming and off farming seasons.
[1)] Mean ± SD
Significantly different between farming season and off farming season at * P< 0.05, ** P< 0.01, *** P< 0.001 by paired t-test.

Table 4. Prevalence of obesity and hypertension among the subjects Unit : N (%)

Criteria of classification			Farming season			Off farming season			χ^2 - test
			Male	Female	Total	Male	Female	Total	
BMI (kg/m^2)	Underweight	BMI ≤ 18.5	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	χ^2 = 0.156 P = 0.925
	Normal weight	18.5 < BMI ≤ 22.9	5 (21.7)	13 (26.5)	18 (25.0)	5 (21.7)	11 (22.4)	16 (22.2)	
	Overweight	23 ≤ BMI ≤ 24.9	5 (21.7)	16 (32.7)	21 (29.2)	4 (17.4)	18 (36.7)	22 (30.6)	
	Obesity	BMI ≥ 25	13 (56.5)	20 (40.8)	33 (45.8)	14 (60.9)	20 (40.8)	34 (47.2)	
	Total		23 (100)	49 (100)	72 (100)	23 (100)	49 (100)	72 (100)	
Blood pressure (mmHg)	Normal	DBP < 80 and SBP < 120	2 (8.7)	15 (30.6)	17 (23.6)	2 (8.7)	12 (24.5)	14 (19.4)	χ^2 = 11.658 P = 0.003
	Prehypertension	80 ≤ DBP < 90 or 120 ≤ SBP < 140	19 (82.6)	21 (42.9)	40 (55.6)	5 (21.7)	19 (38.8)	24 (33.3)	
	Hypertension	DBP ≥ 90 or SBP ≥ 140	2 (8.7)	13 (26.5)	15 (20.8)	16 (69.6)	18 (36.7)	34 (47.2)	
	Total		23 (100)	49 (100)	72 (100)	23 (100)	49 (100)	72 (100)	

Table 5. Time spent on each activity by physical activity category Unit : minutes (%)

Physical activity category	Male				Female			
	Farming season		Off farming season		Farming season		Off farming season	
1. Sleeping	402.2 ± 93.2	(27.9)[1)]	423.7 ± 85.7	(29.4)	419.7 ± 91.0	(29.2)	468.9 ± 87.7	(32.6)***
2. Resting, talking, calling, watching TV	274.9 ± 123.4	(19.1)	464.7 ± 215.1	(32.3)***	319.2 ± 172.3	(22.2)	422.6 ± 147.9	(29.4)***
3. Eating food and snack	76.6 ± 46.6	(5.3)	78.0 ± 33.7	(5.4)	72.6 ± 30.3	(5.0)	64.6 ± 27.2	(4.5)
4. Personal hygiene, playing cultivator machine operation	85.9 ± 47.7	(6.0)	115.9 ± 88.7	(8.1)	122.8 ± 99.8	(8.5)	135.2 ± 91.2	(9.4)
5. Agricultural diary writing, desk work	87.3 ± 137.1	(6.1)	117.2 ± 209.7	(8.1)	34.1 ± 86.9	(2.4)	25.7 ± 65.7	(1.8)
6. Transportation, movement crop selling, pesticide manufacturing	12.9 ± 32.6	(0.9)	39.4 ± 149.3	(2.7)	19.1 ± 44.3	(1.3)	26.2 ± 47.5	(1.8)
7. Dress oneself, slow walk	8.0 ± 13.2	(0.6)	4.8 ± 7.2	(0.3)	35.7 ± 73.3	(2.5)	17.5 ± 20.3	(1.2)
8. Strolling, indoor exercise, field observation,	161.9 ± 143.4	(11.2)	10.0 ± 16.7	(0.7)***	69.6 ± 74.4	(4.8)	32.7 ± 80.6	(2.3)*
9. Cooking, tidy away, harvesting vegetables	45.8 ± 79.7	(3.2)	19.1 ± 75.0	(1.3)	136.0 ± 135.1	(9.5)	108.4 ± 77.4	(7.5)
10. Kitchen work, indoor errand	6.3 ± 19.6	(0.4)	43.9 ± 141.3	(3.1)	6.0 ± 20.2	(0.4)	23.4 ± 62.7	(1.6)
11. House cleaning, outdoor work	32.4 ± 76.0	(2.3)	44.1 ± 96.7	(3.1)	18.4 ± 55.9	(1.3)	20.9 ± 49.1	(1.5)
12. Walking moderately, agricultural tools buying	8.7 ± 16.0	(0.6)	27.1 ± 64.4	(1.9)	34.3 ± 47.4	(2.4)	32.3 ± 48.7	(2.2)
13. Arranging dress, sweeping, weed control, spray agricultural pesticide	234.5 ± 221.2	(16.3)	0.0 ± 0.0	(0.0)***	144.6 ± 167.3	(10.0)	42.4 ± 52.3	(2.9)***
14. Giving a piggyback	0 ± 0	(0)	0.0 ± 0.0	(0.0)	0 ± 0	(0.0)	0 ± 0	(0.0)
15. Mopping floor, cleaning and dusting agricultural tools.	0 ± 0	(0)	9.1 ± 37.8	(0.6)	0 ± 0	(0.0)	5.8 ± 20.7	(0.4)
16. Walking fast	0 ± 0	(0)	3.9 ± 13.7	(0.3)	0 ± 0	(0.0)	1.8 ± 12.9	(0.1)
17. Outdoor exercise.	0 ± 0	(0)	30.0 ± 84.4	(2.1)	0.1 ± 0.71	(0.0)	5.3 ± 23.5	(0.4)
18. Climbing, jogging and sports *et al.*	2.6 ± 12.5	(0.2)	9.1 ± 37.8	(0.6)	7.8 ± 22	(0.5)	7.3 ± 27.6	(0.5)
Total	1,440 (100)		1,440 (100)		1,440 (100)		1,440 (100)	

[1)] Mean ± SD (%)
Significantly different between farming season and off farming season at * P< 0.05, ** P< 0.01 and *** P< 0.001 by paired t-test.

Table 6. Physical activity level (PAL) of the subjects

Age group (yrs)	Male		Female	
	Farming season	Off farming season	Farming season	Off farming season
30-49	1.70 ± 0.24[1)]	1.64 ± 0.43	1.68 ± 0.24	1.51 ± 0.20**
50-64	1.79 ± 0.21	1.48 ± 0.26**	1.70 ± 0.25	1.53 ± 0.18***
Total	1.77 ± 0.22	1.53 ± 0.32*	1.69 ± 0.24	1.52 ± 0.19***

[1)] Mean ± SD
Significantly different between farming season and off farming season at * $P < 0.05$, ** $P < 0.01$, and *** $P < 0.001$ by paired t-test.

Time spent of physical activity categories

The time spent for 18 physical activity levels of the fifth Japanese dietary allowance [12] is shown in Table 5. There were clear differences in farmer activity patterns between the farming and off farming seasons. The time spent for stage 8 (field preparation) and stage 13 (weeding dry field, spraying of pesticides, etc.) were significantly higher in the farming season (161.9 min. and 234.5 min. in male, 69.6 min. and 144.6 min in female) compared to those in the off farming season (10.0 min. and 0 min. in male, 32.7 min. and 42.4 min in female). On the other hand, time spent for stage 1 (sleeping) and stage 2 (resting, watching TV,etc.) was significantly higher in the off farming season (423.7 min. and 464.7 min. in male, 468.9 min. and 422.6 min in female) compared to the farming season (402.2 min. and 274.9 min. in male, 419.7 min. and 319.2 min in female). Significant difference was higher in male farmers than female farmers.

The physical activity level (PAL) of both males and females in the farming season (1.77 ± 0.22, 1.69 ± 0.24) was significantly higher ($P < 0.05$) than that of the off farming season (1.53 ± 0.32, 1.52 ± 0.19) (Table 6). There was no significant difference observed in PAL according to age group.

Resting metabolic rate of subjects

Energy for resting metabolism(RMR, resting metabolic rate) of subjects measured by using indirect calorimetry are shown in Table 7. For both males and females, the resting metabolic rate (RMR) was significantly higher in the off farming season (1,890 ± 233 kcal/day, 1,446 ± 140 kcal/day) compared to the farming season (1,727 ± 163 kcal/day, 1356 ± 164 kcal/day ($P <$ 0.001). In addition, RMR adjusted by body weight in both males and females ($P < 0.001$) was also significantly higher for the off farming season (25.2 ± 1.9 kcal/day and 23.6 ± 1.6 kcal/day) compared to the farming season (23.7 ± 2.0 kcal/day and 22.2 ± 1.3 kcal/day). Likewise, RMR adjusted by fat-free mass (FFM) was significantly higher in the off farming season (33.9 ± 2.9 kcal/kg, 36.8 ± 2.8 kcal/kg) compared to the farming season (30.9 ± 2.6 kcal/kg, 33.7 ± 2.4 kcal/kg) ($P < 0.001$). It was also observed that the off farming season has a significantly higher

Table 7. Measured resting metabolic rate(RMR) of the subjects by indirect calorimeter and adjusted RMR

Age group (yrs)	Variables	Male		Female	
		Farming season	Off farming season	Farming season	Off farming season
30-49	RMR (kcal/day)	1,756 ± 259	2,017 ± 350**	1,352 ± 205	1,457 ± 160***
	RMR (kcal/kg Wt/day)[1)]	23.0 ± 2.4	25.6 ± 2.4**	22.3 ± 1.4	23.8 ± 1.7***
	RMR (kcal/kg FFM/day)[2)]	29.1 ± 0.9	32.9 ± 1.3**	33.4 ± 2.9	36.8 ± 2.6***
50-64	RMR (kcal/day)	1,717 ± 126	1,845 ± 170***	1,358 ± 142	1,440 ± 131***
	RMR (kcal/kg Wt/day)	24.0 ± 1.8	25.0 ± 1.8*	22.1 ± 1.3	23.5 ± 1.5***
	RMR (kcal/kg FFM/day)	31.5 ± 2.7	34.2 ± 3.3***	33.9 ± 2.0	36.8 ± 3.0***
Total	RMR (kcal/day)	1,727 ± 163	1,890 ± 233***	1,356 ± 164	1,446 ± 140***
	RMR (kcal/kg Wt/day)	23.7 ± 2.0	25.2 ± 1.9***	22.2 ± 1.3	23.6 ± 1.6***
	RMR (kcal/kg FFM/day)	30.9 ± 2.6	33.9 ± 2.9***	33.7 ± 2.4	36.8 ± 2.8***

[1)] Resting energy expenditure adjusted for body weight (kg)
[2)] Resting energy expenditure adjusted for fat-free mass (kg)
Significantly different between farming season and off farming season at * $P < 0.05$, ** $P < 0.01$, and *** $P < 0.001$ by paired t-test.
Not Significantly different between age group.

Table 8. Comparison of measured energy expenditure with estimated energy requirement

Age group (yrs)	Variables	Male		Female	
		Farming season	Off farming season	Farming season	Off farming season
30-49	TEE (kcal/day)[2)]	2,956 ± 661[1)]	3,415 ± 397	2,300 ± 630	2,181 ± 423
	EER (kcal/day)[3)]	2,953 ± 444	2,884 ± 143†	2,164 ± 323	1,970 ± 219**††
50-64	TEE (kcal/day)	3,061 ± 475	2,750 ± 537	2,309 ± 431	2,185 ± 379
	EER (kcal/day)	2,778 ± 368†††	2,502 ± 350*††	2,088 ± 264†††	1,914 ± 256**†††
Total	TEE (kcal/day)	3,015 ± 482	2,885 ± 590	2,304 ± 497	2,183 ± 389*
	EER (kcal/day)	2,825 ± 354†††	2,562 ± 339*†††	2,115 ± 293†††	1,944 ± 224***†††

[1)] Mean ± SD
[2)] Total energy expenditure(TEE) = Resting metabolic rate (RMR) × Physical activity level (PAL)
[3)] Estimated energy requirement(EER) calculated by the equations reported in KDRIs 2010
Significantly different between farming season and off farming season at * $P < 0.05$, ** $P < 0.01$ and *** $P < 0.001$ by paired t-test.
Significantly different between TEE and EER at $^{\dagger}P < 0.05$, $^{\dagger\dagger}P < 0.01$ and $^{\dagger\dagger\dagger}P < 0.001$ by paired t-test.

RMR in two age groups (30-49 age and 50-64 age) compared to the farming season ($P < 0.05$) and there was no significant difference between the two age groups.

Total energy expenditure and estimated energy requirement

Table 8 shows total energy expenditure (TEE) and estimated energy requirement (EER) of the subjects. TEE (2,304 ± 497 kcal/day) of females was significantly higher in the farming season than that (2,183 ± 389 kcal/day) of the off farming season, but in males, there was no significant difference between two seasons in TEE. On the other hand, EER (2,825 ± 354 kcal/day and 2,115 ± 293 kcal/day) of the farming season was significantly ($P < 0.05$) higher than those (2,562 ± 339 kcal/day and 1,994 ± 224 kcal/day) of the off farming season in males and females. In both males and females, TEE was significantly higher ($P < 0.001$) than EER in the farming season and off farming season.

Bland-Altman plots between TEE and EER for male and female in farming season and off farming season are shown in Fig. 1 and Fig. 2. The females in the farming season had the smallest mean difference (-189.3 kcal/day) and the females in the off farming season had the narrowest limits of agreement (-678.3 to 177.8 kcal/day). In the males, the mean difference was smaller and the limits of agreement were narrower in the farming season than off farming season.

DISCUSSION

The doubly labeled water method has become the gold standard for measuring total energy expenditure (TEE) of free living human. But actually DLW method cannot easily be used in the field because of high costs of isotopes and equipment for isotope analysis as well as expertise required for analysis [9]. In this study, total energy expenditure (TEE) of subjects was calculated by multiplying the physical activity level (PAL) with measured resting metabolic rate [8] in the farming and off farming seasons. By comparing TEE with EER proposed in KDRI, the appropriateness of EER for Korean farmers in the farming season and off farming seasons was evaluated.

The results of this study showed that the farming season was mostly comprised of physical activity of stage 8 (field preparation, etc.) and stage 13 (weeding of dry field, spraying of pesticides, etc.) except for (sleeping) and stage 2 (resting, having conversation and watching TV), whereas the off farming season was comprised of activities of stage 4 (personal hygiene, hobbies and driving).

The results of the investigation by Lim and Yoon [5] on seasonal physical activity level in females residing in agricultural regions showed that time spent for sleeping and resting was 943 minutes, which is 65.9% of the day in the off farming season (February) but only 708 minutes, which is 49.2% of the day in the farming season (April).

In the farming season of this study, time spent for farming activities (sum of stage 8 and 13) by male and female farmers was 396 minutes (6 hours 36 minutes) and 214 minutes (3 hours 34 minutes), respectively. According to the results by Schultink *et al*. [16] conducted in the Benin region of West Africa, time spent for agricultural activities was significantly higher in the farming season (March-April, August-September) compared to the off farming season (May-June). In addition, another research [17] conducted in the Upper Volta region of Africa reports that agricultural housewives spend significantly more time for agricultural activities in the farming season of July-August (271.1 minutes) compared to other seasons. Based on physical activity level (PAL), which is TEE divided by BEE (basal metabolic rate or RMR), categorization into 4 stages being sedentary (1.0 and above, below 1.4), low active (1.4 and above, below 1.6), active (1.6 and above, below 1.9) and very active (1.9 and above, below 2.5) is possible (KNS; The Korean Nutrition Society, 2010) [8]. With this as the basis, physical activity level for the farming season (males 1.77, females 1.69) and off farming season (males 1.53, females, 1.52) in this study can be categorized as active and low active, respectively. PALs of 50-64 year old Korean (males 1.57, females 1.79) [18], normal weight adults (males 1.65 and females 1.64) [19], dietitians in the Yeongdong region (weekday 1.56, weekend 1.52) [20] and farmers in the off farming season (males 1.53, females 1.52) of this study are almost exclusively categorized as 'low active' level.

BMI, obesity index, body fat mass and body fat percentage of the subjects significantly increased in the off farming season compared to the farming season. In agricultural females of Korea [5] and India [21], body fat percentage in the off farming season was also significantly higher than the farming season. This is understood to be due to decreased farming activities and physical activity in the off farming season compared to the farming season. On the other hand, the results of Westerterp *et al*. [22] and Seong and Kim *et al*. [23,24] assessing the effects of exercise on body composition have reported that in exercise, body weight, body fat mass and body fat percentage decrease while fat-free mass increases. Accordingly, it can be predicted that changes in body composition similar to the changes from effects of exercising have taken place as a result of differences in agricultural activities according to season (farming and off farming) as well.

Based on the BMI of subjects, the rate of obesity in farming and off farming seasons was 75.0% and 77.8%, respectively, among which the obesity (BMI > 25 kg/m^2) rate was 45.8% and 47.2% respectively. Results of observing changes in obesity index for 10 years in adults aged 40 years and above in agricultural regions by Kim *et al*. [25] showed that the obesity prevalence rate has increased by 29.8% in 1999 (63.9%) compared to 1990 (34.1%) while BMI has increased by about 2.5 kg/m^2 in the ten years.

In this study, there was a significant increase ($P < 0.05$) in the hypertension prevalence rate in the off farming season (47.2%) compared to the farming season (20.8%). The increase of hypertension prevalence rate may be related to increased BMI or body fat (%) in the off farming season. In order to prevent this, there is a need to develop physical activity guidelines for farmers separately for the farming season and off farming season.

In this study, the resting metabolic rate of male and female subjects was higher in the off farming season (1,890 kcal/day, 1,446 kcal/day) compared to the farming season (1,727 kcal/day, 1,356 kcal/day) and the reason for this seems that having lower BMR in summer and higher BMR in winter due to metabolic

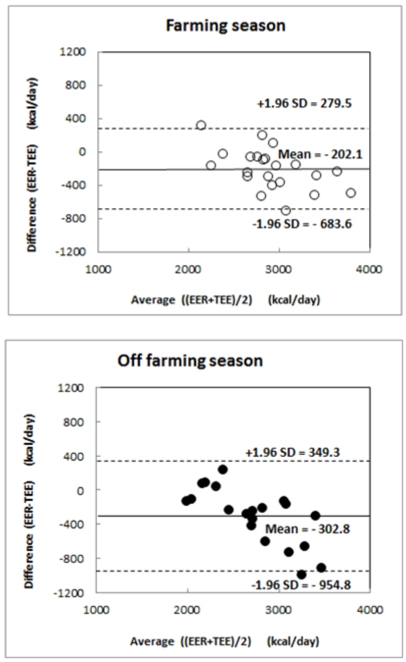

Fig. 1. Bland-Altman plots for estimated energy requirement (EER) and measured total energy expenditure (TEE) in farming season (○) and off farming season (●) of male.

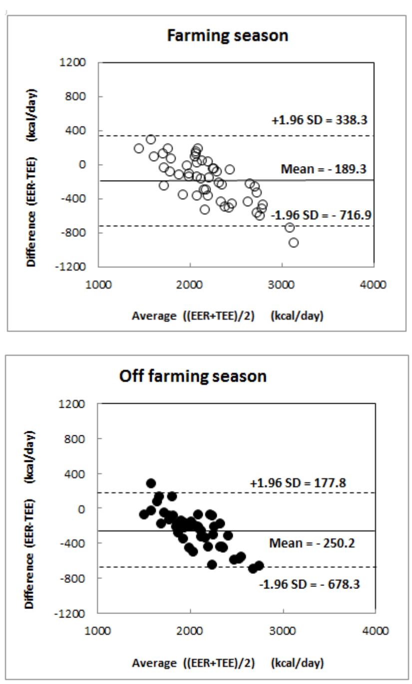

Fig. 2. Bland-Altman plots for estimated energy requirement (EER) and measured total energy expenditure (TEE) in farming season (○) and off farming season (●) of female.

adaptation caused by seasonal temperature differences affected the energy metabolism.

One of the important factors that affect BMR or RMR is climate. According to previous research [26,27]., it has been reported that BMR of Inuit People (Eskimos) who live in the northern regions have a BMR greater than standard values. This indicated that if the temperature is low, BMR would increase due to increased activity in voluntary and involuntary muscles as a reflex action. There have been many reports that energy metabolism actually increased in winter as an adaptation to low temperatures [28,29] and it is known that seasonal fluctuation of energy expenditure is greater in people who work in an outside environment [30,31]. Moreover, Lee *et al.* [32] showed that BMR per fat-free mass of young men was at its highest in December (1.43 ± 0.13 kcal/hr/kg) with the lowest value in June (1.33 ± 0.05 kcal/hr/kg). In addition, Choi and Hwang. [7] reported that there was a highly negative correlation between RMR and temperature in the farmers (males $r = -0.81$, females $r = -0.59$) who have more outside workload compared to other workers.

The results comparing EER computed by applying the KDRI equation with TEE showed that EER was significantly ($P < 0.001$) lower than TEE for both seasons, which suggests a possibility that the predictive equation of KDRI being underestimated cannot be excluded. Also, the results of evaluating agreement rate of TEE and EER by using the Bland-Altman analysis showed that the EER predictive equation of KDRI was underestimated. One reason for this is probably that the physical activity coefficient (PA) of 1.11 and 1.12, which belong to the 'low active (PAL 1.4-1.59)', were used for computation of EER as proposed by KDRI and the PA was not proper to represent the farmer's physical activity level. The other reason is that EER prediction equation in KDRI of 2010 [14] was developed from the TEE, measured using the doubly labeled water method in America. Thus, this equation may not be appropriate for Asian populations including Koreans to predict EER accurately.

The biases (% mean difference) of EER in the farming season were 6.3% in male and 8.2% in female. On the other hand, in the off farming season they were 11.2% and 11.0%, respectively. This fact showed that differences between EER and TEE were higher in the off farming season than farming season. Frankenfiel *et al.* [33] reported that a bias between - 10% and 10% of the EER may be considered an accurate prediction, because the indirect calorimetry measurement error is approximately 5%.

Therefore, this study is significant in that appropriateness of the predictive equation for EER in farmers in farming and off farming seasons was evaluated. However, the limitation of this study is that energy intake was not studied and so the balance between energy expenditure and energy intake was unable to be evaluated.

This study indicates that there is a significant difference in TEE of farmers between farming and off farming seasons. And EER prediction equation proposed by KDRI 2010 underestimated TEE, thus EER prediction equation for farmers should be reviewed or newly developed.

For future research, it is recommended that TEE of farmers is measured by the doubly labeled water method, which is not affected by age, time, place, season, agricultural activities and other factors. Based on this, the equation for EER that is appropriate for farmers should be developed and provided separately for each of the farming and off farming seasons.

REFERENCES

1. Ministry of Health and Welfare, Korea Centers for Disease Control and Prevention. Korea Health Statistics 2011: Korea National Health and Nutrition Examination Survey (KNHANES V-2). Cheongwon: Korea Centers for Disease Control and Prevention; 2012.
2. Health Assistant for Obesity Management. Seoul: Hanmi Medical Publishing Co.; 2003.
3. Lee JA, Kong KH, Ko HY, Bae KH, Park SY, Park KM, Song YK, Park JH, Kim HJ, Park SJ, Park JS, Ko SG. Recent topics of clinical trials in obesity and metabolic study. J Soc Korean Med Obes Res 2009;9:15-22.
4. Kim HN, Jun SG, Jung HR, Lee DS. The energy expenditure of female farmer. In: Survey Improvement Nutrition of Farming. Seoul: Rural Development Administration; 1986. p. 133-51.
5. Lim WJ, Yoon JS. A longitudinal study on seasonal variations of physical activity and body composition of rural women. Korean J Nutr 1995;28:893-903.
6. Lee KY, Cho HK, Kim OS, Lee YS, Lee SM, Hong DS, Cho HS, Kim YK, Kim JH. An analysis of rural families' time-use. J Korean Home Manage Assoc 2006;24:205-22.
7. Choi JW, Hwang KS. The adaptability of Korean farmers to environment by the seasonal fluctuation of energy expenditure, cold and heat tolerance. Korean J Community Living Sci 2006;17: 49-60.
8. World Health Organization (CH). World Health Organization Technical Report Series 724: Energy and Protein Requirements. Report of a Joint FAO/WHO/UNU Expert Consultation. Geneva: World Health Organization; 1985.
9. Park J, Kazuko IT, Kim E, Kim J, Yoon J. Estimating free-living human energy expenditure: practical aspects of the doubly labeled water method and its applications. Nutr Res Pract 2014;8:241-8.
10. Kim EK, Lee SH, Ko SY, Yeon SE, Choe JS. Assessment of physical activity level of Korean farmers to establish estimated energy requirements during busy farming season. Korean J Community Nutr 2011;16:751-61.
11. Weir JB. New methods for calculating metabolic rate with special reference to protein metabolism. J Physiol 1949;109:1-9.
12. Ministry of Health, Labour and Welfare (JP). The Fifth Japanese Dietary Allowance. Tokyo: Ministry of Health, Labour and Welfare; 1985.
13. Rural Development Administration, Research and Training Institute Rural Nutrition Improvement. Energy Metabolism in Different Activities. Suwon: Research and Training Institute Rural Nutrition Improvement; 1994.
14. The Korean Nutrition Society. Dietary Reference Intakes for Koreans. Seoul: The Korean Nutrition Society; 2010.
15. World Health Organization (CH). WHO Technical Report Series 894: Obesity: Preventing and Managing the Global Epidemic. Report of a WHO consultation. Geneva: World Health Organization; 2000.
16. Schultink WJ, Klaver W, Van Wijk H, Van Raaij JM, Hautvast JG. Body weight changes and basal metabolic rates of rural Beninese women during seasons with different energy intakes. Eur J Clin Nutr 1990;44 Suppl 1:31-40.
17. Bleiberg FM, Brun TA, Goihman S, Gouba E. Duration of activities and energy expenditure of female farmers in dry and rainy seasons in Upper-Volta. Br J Nutr 1980;43:71-82.
18. Ministry of Health and Welfare (KR). A Study to Determine the Recommended Dietary Allowance of Energy and to Develop Practical Dietary Education Program for Korean Adults. Gwacheon: Ministry of Health and Welfare; 2002.
19. Park JA, Kim KJ, Yoon JS. A comparison of energy intake and energy expenditure in normal-weight and over-weight Korean adults. Korean J Community Nutr 2004;9:285-91.
20. Lee JS, Lee GH, Kim EK. Assessment of daily steps, activity coefficient and daily energy expenditures of dieticians in the Youngdong-area. J Korean Diet Assoc 2006;12:277-88.
21. Durnin JV, Drummond S, Satyanarayana K. A collaborative EEC study on seasonality and marginal nutrition: the Glasgow Hyderabad (S. India) Study. Eur J Clin Nutr 1990;44 Suppl 1:19-29.
22. Westerterp KR, Meijer GA, Janssen EM, Saris WH, Ten Hoor F. Long-term effect of physical activity on energy balance and body composition. Br J Nutr 1992;68:21-30.
23. Seong BJ, Kim CK. The effects of swimming exercise on body composition and hormone of obese adolescents. Exerc Sci 1999;8: 447-59.
24. Kim CK, Sung BJ. The effects of aerobic exercise on the serum leptin in young obese subjects. J Sports Sci Res 1999;18:61-71.
25. Kim YM, Quan ZY, Kim MK, Choi BY. Trends in obesity in rural Korean adults (1990~1999). J Agric Med Community Health 2005;30:113-20.
26. Rennie DW, Covino BG, Blair MR, Rodahl K. Physical regulation of temperature in Eskimos. J Appl Physiol 1962;17:326-32.
27. Rabinowitch IM, Smith FC. Metabolic studies of Eskimo in the Canadian eastern aretic. J Nutr 1963;12:337-56.
28. Yoshimura M, Yukiyoshi K, Yoshioka T, Takeda H. Climatic adaptation of basal metabolism. Fed Proc 1966;25:1169-76.
29. Fujimoto S, Watanabe T. Seasonal variation of energy metabolism. Acta Med Nagasaki 1965;10:1-11.
30. Nakamura M, Hori S, Sugawara K, Tsuchimoto M, Ihzuka H, Sugawara M, Nohara H, Kuwano K. Basal metabolism and serum protein bound iodine and characteristics of their seasonal variations in Okinawa-inhabitants. Jpn J Biometeorol 1980;17:78-86.
31. Hwang KS, Choi JW. Effect of occupational cold exposure on the human cold-resistance. J Korean Home Econ Assoc 1997;35:53.
32. Lee KY, Chee SH, Hong SK, Sung YH. Seasonal variations in the basal metabolic rate of Korean airmen volunteers. Korean J Physiol 1972;6:95-102.
33. Frankenfield D, Roth-Yousey L, Compher C. Comparison of predictive equations for resting metabolic rate in healthy nonobese and obese adults: a systematic review. J Am Diet Assoc 2005;105: 775-89.