Original Article

Elite high jumpers exhibit inadequate nutrient intakes

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Abstract:

High jumpers strive to maintain low body mass and may be at increased risk for inadequate nutrient intakes. Since there is no data on the nutritional status in this sport, this study aimed to evaluate the nutritional intake of elite high jumpers (7 males, 7 females). Athletes were in energy balance (energy intake was equal to energy expenditure and body mass was stable), but their energy intake was among the lowest reported for athletes (148 ± 23 and 142 ± 18 kJ/kg/day, for males and females). Carbohydrate intake of both males and females (3.6 ± 0.8 g/kg/day) was low compared with recommended values, and diet was deficient in several micronutrients such as vitamin D (12% of dietary reference intake, DRI), vitamin E (34% DRI), folate (46% DRI), calcium (78% DRI) and iron (55% DRI, for females only). These low carbohydrate and micronutrient intakes may negatively affect training quality and adaptations and may jeopardize the athletes' health.

Key words: nutrition, carbohydrate intake, track and field

Introduction

Elite high jumpers are characterized by tall and extremely lean somatotypes (O'Connor et al., 2007). Inspection of anthropometric data from the last Olympic Games (<http://www.london2012.com>) reveals that both male and female high jumpers have extremely low body mass for their height, while their body mass index (BMI) ranks them at the lowest quartile of the general population percentile curve (Kuczmarski et al., 2002, see Table 1). Nutrition plays a key role in maintaining optimal body mass and body composition as well as supporting the requirements of training (Stellingwerff et al., 2011).

During the general preparation phase of the yearly training cycle, high jumpers typically train for 6 days per week, performing four single and two double sessions (Freeman, 2009). At the same time, elite high jumpers aim to maintain low body mass by controlling their food intake, while remaining in energy balance, as indicated by their stable body mass (unpublished observations). We hypothesized that a possibly low energy intake and suboptimal diet composition in these elite athletes may compromise the intake of necessary macro- and micro-nutrients to support high performance and maintain health. Although there is some evidence to suggest that the diet of top-level athletes of different sports may not be adequate in terms of several macro- and micro-nutrients (Sugiura et al., 1999; Papadopoulou et al., 2002; Kabasakalis et al., 2007), there is very limited and old information regarding the nutritional intake of high jumpers (Thorland et al., 1981).

The study of nutritional status of high jumpers may offer a challenging model to study adequate nutrition in elite sport. Thus, the aim of the present study was to record and evaluate the nutritional intake of elite male and female high jumpers and compare the data between genders. Due to the fact that nutritional needs are different between training phases of the annual training plan (Stellingwerff et al., 2011), the assessment was performed during the general preparation phase where energy expenditure may be considered representative of high jump training.

Method

Participants

Fourteen elite male and female high jumpers volunteered to participate in the study (7 males, aged 24.9 ± 3.1 y and 7 females, aged 20.4 ± 4.3 y). They were involved in high jump training for 8.3 ± 3.7 y and were competing at national and international level, ranking within the best ten of the Men/Women Greek National Championships.

Their anthropometric characteristics were similar to the 2012 Olympic Games finalists (differences within ± 3 -4%), while their performance was 8% and 14.3% lower compared with the male and female Olympic Games finalists, respectively (Table 1). Prior to data collection, athletes were fully informed of the purpose and

procedures of the study and informed consent was obtained. All procedures were approved by the local ethics committee and were in accordance with the Helsinki declaration of 1975, as revised in 1996.

Table 1. Anthropometric characteristics and height jumped for male and female high jumpers from the present study compared with data from the 2012 Olympic Games finalists in men's and women's high jump (mean $\pm$ SE).

	<u>Present study</u>		<u>2012 Olympic games finalists#</u>		<u>Comparison: Jumpers in present study vs. Olympic finalists</u>	
	Males (n=7)	Females (n=7)	Males (n=14)	Females (n=12)	Males (%)	Females(%)
Height (m)	1.86 $\pm$ 0.03	1.77 $\pm$ 0.03*	1.92 $\pm$ 0.01	1.83 $\pm$ 0.01	-3.2%	-3.1%
Body mass (kg)	75.4 $\pm$ 1.7	58.7 $\pm$ 2.1**	78.2 $\pm$ 1.7	61.2 $\pm$ 1.3	-3.6%	-4.0%
BMI (kg m ⁻²)	21.9 $\pm$ 0.7	18.7 $\pm$ 0.8**	21.2 $\pm$ 0.4	18.3 $\pm$ 0.3	+3.3%	+2.4%
BMI percentile (%) [‡]	34.9 $\pm$ 8.6	20.8 $\pm$ 7.4**	27.4 $\pm$ 4.6	10.5 $\pm$ 2.4		
Height jumped (m)	2.09 $\pm$ 0.08	1.68 $\pm$ 0.06**	2.28 $\pm$ 0.01	1.97 $\pm$ 0.02	-8.0%	-14.3%

BMI: body mass index; BMI percentile: age and gender adjusted percentile of BMI; * $p < 0.05$ and ** $p < 0.01$ from males. # source: official results of the 2012 Olympic games <http://www.london2012.com/>; ‡Percentile values were calculated using the LMS method http://www.cdc.gov/growthcharts/percentile_data_files.htm (Kuczmarski et al., 2002), Comparison: Jumpers in present study vs. Olympic finalists: each comparison is expressed relative to the corresponding mean values of males and females from the present study.

Procedures

Dietary intake assessment

Data collection was performed in a standard week of the General preparation phase. The participants' dietary intake and activity/training logs were collected via self-reporting diaries. Participants were provided with digital kitchen scales and were asked to weigh and record all food items and beverages consumed, except water, for three days (two typical training weekdays and one weekend day). To ensure accurate recording of food consumed, participants were given instructions by a registered dietician. The 3-day food record was chosen with the aim to avoid respondent fatigue and thus obtain an accurate and representative record. The 3-day food record has been previously validated for assessing dietary intake for both macro and micro nutrients (Yang et al., 2010). Brand names, methods of preparation and recipes for the mixed dishes consumed where requested. The timing of the meals or snacks was also recorded.

Dietary records were analyzed using custom-made software based on a standard nutritional databases (Food Standards Agency, 2002), including data for local dishes and recipes, (Trichopoulou, 2004). This software allowed us to analyze diet composition for both macronutrients (proteins, carbohydrates and fat) and micronutrients (vitamins and minerals).

For the macronutrients, total amount in grams (g), g per kg body mass and percentages of total energy were calculated. The intake of the following micronutrients was evaluated: calcium, iron, magnesium, copper, zinc, selenium and vitamins A, C, D, E, B1, B2, B6, B12, pantothenic acid, biotin, niacin, and folate.

Energy expenditure and energy balance

Total energy expenditure was calculated as the sum of resting metabolic rate (RMR) and the energy expenditure during exercise training. Resting metabolic rate was estimated using the equation of Schofield (1985) which is based on body mass, age and gender. To account for energy expenditure of daily living, the RMR was multiplied by 1.2 and then the exercise training energy expenditure was added. Exercise energy expenditure was calculated from the daily training logs of the participants, taking into account the average energy cost of training for track and field jumps provided by Ainsworth et al. (2000).

Statistics

Statistical analyses were performed using the STATISTICA v.8.0 software (StatSoft Inc., Tulsa, OK, USA). Statistical comparisons between data of male and female jumpers were made using independent t-tests. Energy balance was assessed by comparing energy intake and expenditure for male and female jumpers using

two-way Analyses of Variance (ANOVA) with repeated measures on one factor (Energy). Data are presented as means and standard error of the mean. Statistical significance was accepted at $p < 0.05$.

Results

Energy balance

The average daily energy intake as calculated from the 3-day analysis was higher in males compared with females when expressed in absolute terms, but did not differ between genders when expressed per kg body mass (table 2). Estimated energy expenditure was not significantly different from energy intake (average difference +0.1 to -0.3 MJ or +25 to -62 kcal per day, $p=0.88$, table 2), suggesting that the athletes were in energy balance. This was corroborated by the unchanged body mass of the athletes over the course of three weeks.

Table 2. Energy balance (energy intake vs. energy expenditure) for male and female high jumpers (mean $\pm$ SE).

	Males (n=7)		Females (n=7)	
	Energy Intake	Energy Expenditure	Intake	Energy Expenditure
(kcal/d)	2673 $\pm$ 445	2647 $\pm$ 40	1984 $\pm$ 262*	2046 $\pm$ 46*
(MJ/d)	11.2 $\pm$ 1.9	11.1 $\pm$ 0.2	8.3 $\pm$ 1.1*	8.6 $\pm$ 0.2*
(kcal/kg/d)	35 $\pm$ 6	35 $\pm$ 1	34 $\pm$ 4	35 $\pm$ 1
(kJ/kg/d)	148 $\pm$ 23	147 $\pm$ 1	142 $\pm$ 18	147 $\pm$ 3

* $p < 0.05$ from corresponding value of males

Macronutrients

Diet composition was similar for male and female jumpers (40% carbohydrates, 16-20% proteins and 40% fat, $p=0.22$ to 0.76, Table 3) Macronutrient intake expressed per kg body mass did not differ between male and female jumpers and was 3.6 $\pm$ 0.8 vs. 3.5 $\pm$ 0.5 g/kg for carbohydrate, $p=0.95$, 1.6 $\pm$ 0.1 vs. 1.3 $\pm$ 0.2 g/kg for protein, $p=0.24$ and 1.6 $\pm$ 0.3 vs. 1.6 $\pm$ 0.2 g/kg for fat, $p=0.92$ (table 3). However, the total amount of proteins (in grams) was greater for males compared to females ($p < 0.05$). Compared with the recommended macronutrient intake for this type of training (Houtkooper et al., 2007; Stellingwerff et al. 2011), carbohydrate intake was lower and fat intake was higher in both males and females (table 3).

Table 3. Energy balance (energy intake vs. energy expenditure) for male and female high jumpers (mean $\pm$ SE).

Macronutrient	Males (n=7)	Females (n=7)	Recommended
	Intake	Intake	
Carbohydrates (g)	271 $\pm$ 58	206 $\pm$ 33	
(g/kg)	3.6 $\pm$ 0.8	3.5 $\pm$ 0.5	5-7 g·kg ⁻¹ ·day ⁻¹ ¥
(%energy)	40 $\pm$ 4	41 $\pm$ 9	50-60% [#]
Proteins (g)	118 $\pm$ 11	76 $\pm$ 11*	
(g/kg)	1.6 $\pm$ 0.1	1.3 $\pm$ 0.2	1.2 -1.7 g·kg ⁻¹ ·day ⁻¹ †‡
(%energy)	20 $\pm$ 3	16 $\pm$ 1	10-30% [†]
Fat (g)	123 $\pm$ 24	93 $\pm$ 13	
(g/kg)	1.6 $\pm$ 0.3	1.6 $\pm$ 0.2	1.0-1.2 g·kg ⁻¹ ·day ⁻¹ †
(%energy)	40 $\pm$ 3	42% $\pm$ 2	20-35% ^{†§}

* $p < 0.05$ from corresponding value of males; ¥: Burke (2004, 2011); †: Rodriguez et al. (2009); ‡: Houtkooper et al. 2007; § EFSA (2010)

Micronutrients

Daily vitamin intake for male and female high jumpers is presented in table 4, along with the dietary reference intake (DRI). Fig. 1 shows vitamin intake expressed as a percentage of DRI. There were no statistically significant differences in vitamin intake between male and female jumpers, although there was a tendency for differences between genders in vitamins B1, B2, B12 ($p=0.12$), and pantothenic acid ($p=0.06$). A low intake (below 50% of DRI) was found for both male and female jumpers for vitamin D (12% of DRI), vitamin E (34% of DRI) and folate (46% of DRI).

Table 4. Daily vitamin and mineral intake for male and female high jumpers (mean $\pm$ SE).

Micronutrient	Males (n=7) Intake	DRI [†]	Females (n=7) Intake	DRI
Vitamin A (μ g)	974 $\pm$ 330	900	490 $\pm$ 111	700
Vitamin D (μ g)	2.3 $\pm$ 1.0	15	1.2 $\pm$ 0.5	15
Vitamin E (mg)	6.2 $\pm$ 1.5	15	3.9 $\pm$ 1.1	15
Vitamin B1 (mg)	1.6 $\pm$ 0.2	1.2	1.2 $\pm$ 0.2	1.1
Vitamin B2 (mg)	1.5 $\pm$ 0.1	1.3	1.0 $\pm$ 0.2	1.1
Vitamin B6 (mg)	1.8 $\pm$ 0.2	1.3	1.5 $\pm$ 0.5	1.3
Vitamin B12 (μ g)	3.7 $\pm$ 1.0	2.4	1.5 $\pm$ 0.8	2.4
Pantothenic acid (mg)	3.9 $\pm$ 0.7	5	2.2 $\pm$ 0.5	5
Biotin (μ g)	27.1 $\pm$ 5.9	30	16.0 $\pm$ 6.8	30
Niacin (mg)	21.1 $\pm$ 3.4	16	17.4 $\pm$ 4.6	14
Folate (μ g)	218 $\pm$ 40	400	154 $\pm$ 34	400
Vitamin C (mg)	80.6 $\pm$ 18.6	90	101.7 $\pm$ 19.5	75
Calcium (mg)	785 $\pm$ 127	1000	779 $\pm$ 161	1000
Iron (mg)	13.5 $\pm$ 2.5	8	10.0 $\pm$ 1.4	18
Magnesium (mg)	241 $\pm$ 46	400	221 $\pm$ 42	310
Zinc (mg)	8.6 $\pm$ 0.7	11	7.2 $\pm$ 1.0	8
Copper (mg)	1.4 $\pm$ 0.4	0.9	1.3 $\pm$ 0.3	0.9
Selenium (μ g)	46 $\pm$ 14	55	45 $\pm$ 9	55

DRI: dietary reference intakes; [†]Institute of Medicine (2000, 2001, 2010).

Fig. 1. Daily vitamin intake expressed as percentage of dietary reference intake (DRI) for male and female high jumpers [mean (SE)].

Daily mineral intake for male and female high jumpers is presented in Table 4, along with the dietary reference intake (DRI). The only difference between male and female jumpers was in % DRI of iron intake which was 55% in females ($p < 0.01$, fig. 2). This was mainly due to the higher DRI values for females (8 vs. 18 mg per day for males and females, respectively). A relatively low intake was found for calcium (78% of DRI), magnesium (66% of DRI), zinc (84% of DRI) and selenium (83% of DRI).

Fig. 2. Daily mineral intake expressed as percentage of dietary reference intake (DRI) for male and female high jumpers [mean(SE)]. **: $p < 0.01$ from corresponding value of males

Discussion

The main finding of this study was that both male and female top level high jumpers followed a diet that did not have the optimal composition since it was low in carbohydrate and in several key micronutrients, necessary to support their training needs. Even though the athletes were in energy balance, their energy intake was low compared with that of athletes of other sports, both in absolute values or relative to body mass (van Erp-Baart 1989; Burke et al., 2006). This may be related with the importance placed on physique by elite high jumpers, who are characterized by tall and extremely lean somatotypes with a high muscle power-to-body mass ratio (O'Connor et al., 2007). The low body mass relative to body height is reflected in their body mass index (BMI), that was on average at the 35th and 21st percentile of the general population, for males and females respectively, according to age and gender adjusted standards (Kuczmarski et al., 2002; see Table, 1). This is similar to the male and female finalists of the 2012 Olympic Games who had a relatively low body mass index (BMI) that would place them in the 27th and 10th percentile, respectively, of the general population percentile curve (Table 1). It should be noted, that the long and triple jump male and female participants in the 2012 Olympics were significantly heavier for their height and are classified in the 43rd and 33rd percentile of the general population BMI percentile curve. It is interesting to note that energy intake of the elite high jumpers in the present study was lower than that reported for athletes placing high importance on body image, such as figure skaters (Ziegler et al., 2001). Low energy intakes can result in loss of muscle mass, an increased risk of fatigue; injury, and illness; and compromised immune, endocrine and musculoskeletal function (Burke et al., 2006, Rodriguez et al., 2009). Furthermore, low energy intake and low micronutrient intake may be related, since an athlete consuming a low energy diet has more chances to have inadequate consumption of micronutrients, (Rodriguez et al., 2009).

One of the most important macronutrients to support intense training and recovery is carbohydrate (CHO). In the present study, CHO intake was similarly low in male and female high jumpers (40% of total energy intake or 3.5 g per kg body mass per day). According to current recommendations, CHO intake should be at least 50-60% or 5-7 g per kg body mass per day, to support the needs for athletes with moderate training programs lasting around 1 hour per day (Burke et al., 2004, 2011). Based on those recommendations, the high jumpers in the present study may be more susceptible to fatigue and may not always attain their best possible performance during training (Maughan and Burke, 2002). The low energy and carbohydrate intake of high jumpers may be related with their perception that a low body mass is of paramount importance for success, but this nutritional practice may lead to sub-optimal training adaptations by affecting duration of quality training. Training sessions for jumpers draw significantly upon muscle glycogen stores (Houtkooper et al., 2007). It is well established that resynthesis of muscle glycogen depends on carbohydrate intake, especially during the first 1-4 hours after training (Burke et al., 2004). Recommendations for optimal glycogen resynthesis include 0.5-1.0 g per kg body mass of carbohydrate per hour for the first 1-3 hours post exercise and a total of at least 5-7 g of CHO per kg body mass per day. If carbohydrate intake is as low as observed in the present study, glycogen repletion may not be achieved (Costill and Miller, 1980) and performance in subsequent training sessions may be negatively affected. Also, muscle anabolism may be reduced when carbohydrate intake and muscle glycogen is low (Tipton et al., 2007), and thus the adaptive responses to training may be decreased (Churchley et al., 2007). Although total energy intake was relatively low, fat intake was in excess of what is recommended (Table, 3). Previous studies in high level athletes have shown that it is not uncommon to see lower carbohydrate and higher fat intakes even with low energy intakes such as those observed in female ballet dancers (Hassapidou and Mastrantoni, 2001) and volleyball players (Papadopoulou et al., 2002). Excess fat consumption at the expense of carbohydrate, combined with low total energy consumption may reveal poor nutritional knowledge (Economos et al., 1993).

Protein intake of high jumpers in the present study (Table 3) was within the range proposed to support training needs in the general preparation period (Stellingwerff et al. 2011). Male power athletes undertaking heavy resistance exercise can meet their protein needs in the early phase of training by consuming 1.5 – 1.7 g per kg body mass per day, while protein needs during an established training program are decreased to 1.0 – 1.2 g per kg body mass per day. (Tarnopolsky, 2007). Similarly, dietary estimates of protein intake by female combined events athletes, who follow a heavier training program compared with high jumpers, are around 1.4 g per kg body mass per day (Mullins et al., 2001). Thus, despite their relatively low energy intake, high jumpers in the present study follow a diet that covers their protein needs. Recent studies strongly suggest that the timing of protein ingestion is particularly important for power athletes during the period of training when they are trying to increase strength and power (Stellingwerff et al., 2011). In the present study, we interviewed each jumper to obtain some insight into their dietary habits (e.g. breakfast consumption, timing of meals, etc). Only two of the 14 jumpers reported that they consumed a carbohydrate/protein snack immediately after each training session. Also, one jumper consumed a snack immediately before each training session and one other jumper reported occasional consumption of post-exercise snacks (1-2 days per week). Due to the potentially significant effect of the timing of protein and carbohydrate ingestion in relation to exercise (Stellingwerff et al., 2011), this issue merits further investigation, especially in high jumpers who seem to consume a low energy and low carbohydrate diet.

Athletes who follow low energy and/or low carbohydrate diets may be at greatest risk of micronutrient deficiencies. Micronutrients are involved in energy production, hemoglobin synthesis, maintenance of bone health, immune function and protection of body against oxidative damage (Rodriguez et al., 2009). Exercise training may lead to increased micronutrient needs and thus athletes should consume diets that provide at least the recommended dietary reference intakes (DRI) for all micronutrients (Rodriguez et al., 2009). However, in several studies of top level athletes of different sports, sub-optimal micronutrient intake is common (Sugiura et al., 1999; Kabasakalis et al., 2007). In the present study, both male and female jumpers had intakes of vitamins D and E and folate that were all lower than 50% of DRI (Fig. 1). Vitamin D is a secosteroid with an endocrine mechanism of action (Powers et al., 2011). In female athletes, vitamin D levels have been shown to correlate positively with muscle power and jump height (Ward et al., 2009). Sunlight promotes vitamin D synthesis and thus high jumpers who mainly train indoors during the winter months may be more susceptible to vitamin D deficiency (Constantini et al., 2010). Furthermore, due to the high stress on the leg joints of high jumpers, vitamin D deficiency may have an impact on joint health, especially when it is accompanied by low calcium and zinc intake, as observed in the present study (Clark, 2007; see Fig. 2).

Antioxidant vitamins, such as vitamin C, E and A play important roles in protecting cell membranes from oxidative stress (Powers et al., 2011). Although athletes are more protected from oxidative stress by developing an increased antioxidant system, adequate intake of antioxidant vitamins is recommended, but this should not exceed the tolerable upper intake levels (Gleeson et al., 2004). In the present study, vitamin C intake was around (males) or above 100% of DRI, while vitamin E was only 34% of DRI (Fig. 1). This would suggest a low intake of foods containing vitamin E such as vegetables, nuts and seeds and oils. Iron intake in female jumpers was 55% of DRI and this was combined with low folate (<50% DRI) and low vitamin B12 intake (~60% DRI, Fig. 1 and 2). Such deficiencies may result in anemia and reduced stamina of the female jumpers (Lukaski, 2004). The low intake of folate, vitamin B12 and iron in females may be related with the low energy intake.

Conclusions

The results of the present study show that top level male and female high jumpers follow a relatively low energy diet that is deficient in carbohydrate and several key micronutrients. This may be due to the fact that these male and female high jumpers strive to maintain a low body mass relative to their height. While protein intake was within the recommended range to support training needs in this training phase, fat intake was relatively high at the expense of carbohydrate intake that was markedly low. This may have an impact on glycogen repletion between training sessions and this may, in turn, negatively affect training quality and adaptive responses to the exercise stimuli. The extremely low intake of vitamin D (12% of DRI), combined with the low calcium and zinc consumption for both male and female athletes, may have an impact on joint health, considering the high stress on the leg joints of high jumpers. Finally, the low iron, vitamin B12 and folate intake of female high jumpers (50-60% of DRI) were possibly due to the low total energy intake and can lead to anemia and reduced stamina. Nutritional counseling and guidance is recommended for those athletes to optimize nutrient intake and possibly improve training quality.

Conflicts of interest:

The authors declare that there are no conflicts of interest.

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