

NUTRITIONAL STATUS AND DIETARY ASSESMENT OF ELITE FEMALE ARTISTIC AND RHYTHMIC GYMNASTS – A CASE STUDY

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Case study

Abstract

Pre-adolescence and adolescence athletes of aesthetic sports such as artistic and rhythmic gymnastics are at high risk of deficiency in basic nutrients. The increasing demands of puberty combined with the intense daily training without adequate nutrition, exposes the young athletes to growth disorders, severe nutritional deficiencies, problems of emotional nature, dissatisfaction with body image (i.e., obsession with physical appearance), hormonal disorders (amenorrhea), chronic fatigue, osteopenia and especially an increased risk of injuries. The purpose of this study was to assess the dietary intake and identify nutritional deficiencies and/or possible excess intake (unhealthy nutrition), thus potential dietary risks and abnormal eating habits. Self-esteem and perception of body image were also assessed. Two young female athletes, one artistic (AG) and one rhythmic gymnast (RG), members of the Greek national team were surveyed. The dietary history and the 7-day weighed food record protocol revealed an average daily energy intake of 1712 ± 165 Kcal and 1976 ± 219 kcal, respectively (or $\sim 42,5$ kcal/kg lean mass) and inadequate consumption of carbohydrates. The calcium intake had the highest deviation from the recommended daily requirements. Both athletes reported daily individual weighings. A high number of serious injuries and menstrual dysfunction were also reported with one of the athletes presenting a strong predisposition to nutritional risk factors and pathological eating behaviour, and negative emotions both with the external appearance and the body weight. The use of dietary supplements was not mentioned by any athlete. Therefore, targeted nutritional guidelines and psychological support for young elite athletes are required.

Keywords: *gymnastics, females, nutritional status, dietary intake.*

INTRODUCTION

The competitive profile of aesthetic sports such as Artistic (AG) and Rhythmic Gymnastics (RG), and diving and synchronised swimming, predisposes mainly female athletes to a constant

preoccupation with their shape, size and/or body weight, which are considered participation criteria. Furthermore, they often work under pressure to meet extremely high performance standards.

Previous research has shown that throughout their sporting careers, the vast majority of these athletes try to acquire and preserve the "perfect" body with specific body proportions and unrealistically low body weight and fat mass (Avila-Carvalho, Klentrou, da luz Palomero & Lebre, 2012; D'Alessandro, Morelli, Evangelisti, Galetta & Franzoni, 2007; Klentrou & Plyley, 2003). Under conditions of continuous self-control, low self-esteem, rigorous self-criticism and perfectionism they feel the need to constantly show the most disciplined side of themselves: their body becomes their greatest "achievement". In fact, this preoccupation with body appearance has become part of the behavioural culture of these sports, which is a gradual evolution towards subclinical forms of disordered eating behaviour, especially in elite athletes. It is estimated that 40-45% of elite athletes of these sports show symptoms of eating disorders (Beals, 2004; Bonci et al., 2008; De Bruin, Oudejans, & Bakker 2007; De Souza et al., 2014; Ferrand, Champely & Filaire, 2009; Francisco, Alarcao & Narciso, 2012; Kerr, Berman & de Souza, 2006; Klentrou, 2006; Nordin, Harris & Cumming, 2003; Sundgot-Borgen & Garthe, 2011; Torstveit, Rosenvinque & Sundgot-Borgen, 2008; Wilde, 2013).

In particular, the pre-adolescent and adolescent athletes are at high risk of deficiency in basic nutrients. The most common nutritional deficiencies identified relate to: calcium, iron, folate, zinc (Benardot, 2014; Cupisti et al, 2000; D' Alessandro et al, 2007; Michopoulou et al, 2011; Silva & Paiva, 2015). The main reason for this is the long-standing malnutrition (chronic low energy intake) in combination with the increased needs of accelerated adolescence development.

A combination of various parameters such as the increased needs of nutrient intake due to the accelerated pubertal development, the need to maintain low body weight (and indirectly low fat mass), the potential long-term poor in nutrients and possibly limited energy intake (chronic

malnutrition), the intense training required especially in aesthetic and endurance sports, expose the young athletes to growth disorders (Caine, Russell & Lim, 2013), severe nutritional deficiencies (Benardot, 2014; Desrow, 2014; Meyer & Manore, 2011; Weimann et al, 2000; Wilde, 2013), problems of emotional nature, hormonal disorders (amenorrhea), chronic fatigue, eating disorders, osteopenia and increased risk of stress fractures and other injuries (Caine, Russell & Lim, 2013; De Bruin, Oudejans, & Bakker, 2007; Maïmoun et al, 2013; 2014; Mallinson & Souza, 2014; Meyer & Manore, 2011; Nordin, Harris, & Cumming, 2003; Rottstein, 2013; Smith, 2000). All these disorders are central to the pathogenesis of the "*female athlete triad*", whose main components are: reduced energy availability (with or without eating disorders), menstrual dysfunction and decreased bone mineral density (osteopenia). These components are interrelated in causality, pathogenesis and effects (Ackerman & Madhusmita, 2011; Bahner, 2009; De Souza et al., 2014; Ducher et al., 2011; Sundgot-Borgen et al., 2013; Zach, 2011; Wilde, 2013). For athletes at the highest competitive level of AG and RG, the high volume, intensity, frequency and duration of training (6 days/wk, 4-6 h/day) often reach exhausting levels. Dual training sessions are the norm with a total length of training approaching or surpassing 30 h/wk. The age of first engagement usually lies between 5 to 7 years of age, and at the age of 10 the training level and volume are intensified (Benardot, 2014; Caine, Russell & Lim, 2013). During growth, energy availability should be in positive balance, beyond the typical daily energy intake needs and the total energy expenditure, due to the higher requirements of the accelerated pubertal development and the needs of composing new tissue (Desbrow et al., 2014; Klentrou, 2006). However, this surplus of available energy cannot be accurately calculated because of the multivariate pubertal development needs.

Discrepancies between the total daily energy expenditure and the actual energy intake (~ 20-35%) have been observed in published surveys of nutritional assessment of athletes (Thompson, 1998). These discrepancies have been attributed to the under-reporting of energy intake by the athletes and not to the overestimation of the energy expenditure when using indirect calculations (Crenshaw, 2009). It is reported that especially athletes of aesthetic sports intentionally record either lesser amounts, or completely fail to declare selected intake such as various snacks. Likewise, they may either declare larger quantities of "desirable" foods, or temporarily positively alter their nutritional behaviour. The most common recording errors are observed in athletes who are dissatisfied with their body image. One of the reasons of underestimating the energy intake is the fear of disclosing improper dietary practices and the need to positively impress the researchers (Beals, 2004; Black, 2001; De Bruin, Oudejans & Bakker, 2007; Meyer & Manore, 2011). In survey studies, where the record of dietary intake (with weighed food) was performed under the guidance of a qualified dietitian, the reporting of lower values was significantly reduced as verified by the double labeled water method (Martin et al., 1996).

Nutritional assessment is the first of the four stages of the nutritional care process. The other stages include diagnosis, intervention and dietary control/monitoring. A qualified dietitian detects signs of malnutrition and/or excess dietary intake, and assesses the maintenance of normal body development and good state of health while recognising the predisposition to nutritional risk factors. In addition, low self-esteem is associated with an increased risk of eating disorders and negative perception of body image (Desbrow et al., 2014; Steinmuller et al., 2014). The purpose of this study was: i) to assess the dietary intake of two elite female gymnasts during a typical training period, ii) to identify nutritional deficiencies and/or excess intake, and iii) to evaluate the self-esteem and

perception of body image of these young athletes. This information would then be used to evaluate possible health risks and abnormal eating attitudes in young female athletes involved in high performance aesthetic sports.

METHODS

After having informed the respective Greek national coaches, two female athletes, members of the respective Greek national Artistic Gymnastic (AG) (age 18.5 years) and Rhythmic Gymnastic (RG) (age 16.1 years) teams, were randomly selected (through a draw) among 20 eligible members of these teams. These two athletes consented to participate in the study which was conducted during the preparation period, when both female athletes had prescribed times of eating and training. The study was approved by the Ethics Board of the University of Athens.

Dietary Intake, Physical Activity and Training Records

Dietary intake was assessed using three different methods: a) an Arbitration history (emphasis on basic and customary intake) via personal interviews; b) a 7-day record of weighed food and drink consumption; and c) a Food Frequency Questionnaire (FFQ) with emphasis on foods rich in calcium and vitamin D. The dietary analysis was conducted using the NUTRITICS (Nutrition Analysis Software) v 3.74 *Professional Edition*.

Selected Food Frequency Consumption Questionnaire (rich in calcium and vit. D)

Dairy group

Milk

Milk type.....

Yoghurt ...

Soft cheese.

Hard chesse

Fish / Seafood (salmon, sardines, anchovies, mackerel)

Eggs (yolks)

Liver

Enriched Cereal

Enriched Margarine

Special nutritional supplements of vit. D, in cps or syrup (cod liver oil, fish oil)

Both gymnasts received a sealed envelope with instructions on how to keep the 7-day dietary record, as well as other self-report questionnaires which they were requested to answer. In the 7-day diet record, a detailed manual with pictures and detailed examples of how to correctly complete the diary were attached. Particular attention was paid to reducing error in the self-reporting of food and liquid consumed. In parallel, the participants were given instructions and technical recommendations on how to record both their daily habitual and their training activities. For additional clarifications and questions they could communicate by telephone with the researchers. To ensure confidentiality, it was highlighted to the female athletes that all information would be treated as private and confidential by the researchers, and that the code of conduct would be observed. During their diet history interview, the gymnasts also provided results from recent blood test. There was no clinical observation worthy of our attention.

Dietary history interview

Please answer as precisely as possible:

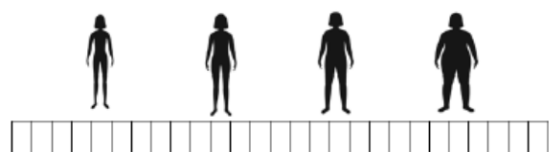
(1) How frequently do you go on a diet? What diet do you follow and for how long?

(2) Do you feel fat (overweight) and/or frustrated by your weight, appearance and body size?

▶ Are you pleased with your current weight?

▶ If not, what is your ideal weight?

▶ Place an X in the box of the body shape that you believe represents your current physical appearance:



(3) Do you weigh yourself daily?

(4) Is food a great concern of yours and do you constantly think about food? Do you worry and have persistent thoughts that you will gain weight?

(5) Are you strict in the choice of food you consume? If yes, which kinds of food do you avoid eating?

(6) Are there times when you eat nothing all day?

(7) Do you secretly eat "forbidden" foods?

(8) How many meals do you consume daily?

(9) Have you ever purged (induced vomiting) after eating to avoid gaining weight?

(10) After a big meal do you eat less (than usual) during the following days?

(11) Have you ever attempted to "control" your weight with medicines (anorectics, laxatives, diuretics)?

(12) Are you concerned when others watch you eat?

Special attention should be paid to the following warning signs :

- Heavy bleeding during the menstruation
- Longer menstrual period
- Fluctuations / variations in the rhythm of the menstrual cycle (in particular in the absence of 3 consecutive cycles)
- Repeated dieting and avoiding meal intake
- Early, unexplained fatigue
- Systematic, persistent refusal for food and liquids.

(1) At what age did you have your first period? [What was your mother's equivalent age?]

(2) How many times did you have your menstrual period during the last 12 months?

(3) In the last 12 months have you missed 2 or more consecutive periods?

(4) When was your last period and how long did it last?

(5) Have you lost weight during the last three years?

▶ If yes, how much and for how many months in a row?

▶ When you lost weight did your period continue normally?

(6) To date have you ever endured severe injuries or fractures?

Anthropometric Measurements

Height was measured using a measuring rod (Stadiometer 222, SECA) and body mass was measured with a precision scale $\pm 0,1$ kg (type 711, SECA - Hamburg, Germany). Body composition was estimated from skinfold thickness (Jackson and Pollock, 1980) using a Lange-type skinfold caliper. The skinfolds measurements were performed on the right side of the body at four sites (triceps, superilliac, abdominal and thigh). The circumference of the left arm was also measured. The resting metabolic rate (RMR) was calculated according to the equations for gymnasts proposed by Pavlou (1992).

Questionnaires

To identify potential eating disorders and to evaluate the dietary behaviour of female athletes, the following questionnaires were used:

The Eating Attitude Test EAT-26 (Garner, Olmsted, Bohr and Garfinkel, 1982) is a dietary attitudes test that has been validated for use in Greek populations. It is a leading diagnostic evaluation marker for the early identification of subclinical cases of disordered eating behaviour. In addition to the single factor "eating attitudes" (26 questions in a 4-point Likert-type scale), the questionnaire includes 3 separate sub-scales dealing with: slimming diets (dieting), "bulimia and pre-occupation with food" and "oral control". Overall performance of ≥ 20 at EAT-26 indicates abnormal eating behaviour and appearance of symptoms of disordered food intake.

The specialised diagnostic gymnast test FAST (Female Athlete Screening Tool) includes 33 questions tailored to the needs of the gymnasts (Beals, 2004; Bonci et al., 2008; Knapp, Aerni and Anderson, 2014; McNulty, Adams, Anderson and Affenito,

2001). It is designed to assist in the early identification of a gymnast who exercises intensively to achieve weight loss, is a perfectionist, worries excessively about body size and external appearance, and/or is already exhibiting disordered eating behaviour. This diagnostic tool scores on a 4-point Likert-type scale, where 4 increases the probability of disordered eating behaviour. The overall performance and severity of symptoms are classified as a) subclinical symptoms that range between 77 and 94, b) clinical symptoms with values > 94 .

The Body-esteem scale for adolescents and adults (Mendelson, 2001) has already been used in various studies of Greek female gymnasts (Kosmidou, 2014). It is composed of 22 questions, which form three subscales using a 5-point Likert-type scale (0 = never, 4 = always). The questionnaire is used in two ways, either as a single agent or using all three sub-scales that assess the individual's evaluation of their external appearance, their weight and the way they perceive that others view their appearance. The higher scores indicate higher physical self-esteem.

RESULTS

The anthropometric characteristics and body composition of both athletes are presented in Tables 1 and 2, respectively.

Table 1
Gymnast's general physical characteristics

	AG	RG
Age (years)	18.5	16.1
Body Height (cm)	154,3	167,5
Body mass (kg)	45,8	55.2
BMI (kg/m ²)	19.3	19.6
Upper limbs width (cm)	163	170
Standing height (cm)	81.5	91.3
Upper limbs width / Body height	1.058	1.016
Standing height / Body height x 100	52.9	54.6
Arm circumference (mm)	215	228
Mid-arm muscle area (cm ²)	37.3	42.2
Start of systematic Training (age)	6.5	6.2
Number of days of training per week	6	6
Hours of training per week	30	46
First menstruation (age in years)	15.2	12
Situation of menstruation cycle	Normal	Secondary amenorchea / oligomenorchea
Injuries (absence > 7 ημ.)	4	2
Stress injuries	2	1
Changes of weight during a competitive year	≤ 1 kg	≤ 1 kg
EAT - 26 (score)	14	23
FAST (score)	68	89
Adolescents' scale of self-respect of body	54	39

Table 2
Body composition and gymnast's anthropometric characteristics

	3/10/15 - 11/10/15	3/10/15 - 11/10/15
Body weight (kg)	45,8 - 45,9	55,0 - 55,3
Sum of skinfolds (mm)	37,5 - 37	47,5 - 48
Body Fat (%)	11,84 - 11,63	15,11 - 15,38
Nonfat body mass (kg)	40,37 - 40,65	46,7 - 46,8
Somatometric circumferenes (cm)		
Chest	84 - 84	82 - 82
Arm	24 - 24	25 - 25
Waist	65 - 65	67 - 67,5
Belly	68 - 68	71 - 72
Hip circumference	85 - 85	92 - 92
Thigh circumference	46 - 47	50 - 50

Table 3
Average daily nutritional intake of female gymnasts

	AG		RG	
Average daily Energy Intake (kcal)	1712		1976	
Resting Metabolic Rate (RMR) (kcal)	1050		1243	
Energy intake: RMR	1.63		1.59	
Energy / kg (kcal)	37.3		35.8	
Energy / kg Nonfat body mass (kcal)	42.4		42.3	
Carbohydrates (%)	51.6		56.7	
Fat (%)	33.5		28.1	
Proteins (%)	14.8		15.1	
Carbohydrates (gr/kg)	4.8		5.1	
Fat, gr/kg	1.4		1.1	
Proteins, gr/kg	1.37		1.35	
Water, total (L)	2,9		2.6	
Water, during training (L)	1.6		1.1	
Fiber (gr)	14.7		20.4	
		Dietary Recommended Intakes (DRI's) (%)		Dietary Recommended Intakes (DRI's) (%)
Ca (mg)	878	67.5	1143	88
P (mg)	994	79.5	1326	106
Fe (mg)	11.6	77.3	16.2	108
Zinc (mg)	9.4	104.4	11.2	124.4
Mg (mg)	287	79.7	385	106.9
Vit. B 6 (mg)	2.2	185	2.5	208.3
Vit. B 12 (µg)	1.9	79.1	2.9	120.8
Vit. C (mg)	152	233,8	185	284.6
Vit. E (mg)	12.8	85	15.8	105.3

Table 4
A typical example of the daily food consumption of a gymnast of AG (double workout, totaling 6.5 hours)

Breakfast	500 mL Tea with lemon and 1 tablespoon sugar	5 Crackers whole grain
Morning workout	Nothing	
Noon	300 gr Pasta with 50gr parmesan cheese	Broiled cabbage salad (260gr) with 30gr olive oil
Afternoon (training)	only four glasses of water	
Evening	1 cup milk (300 ml) 1,5% fat	1 medium banana

Compared to national development standards (i.e. non-athlete peers), the height of the AG athlete was found to be in the 10th percentile for the corresponding age and gender, and the RG athlete was found to be

in the 75th percentile. The weight of the female gymnasts ranged between \pm 1 kg annually. Both the muscle mass of the perimeter of the arm and muscular arm area (mid-arm muscle area) of our athletes were

found to be at very satisfactory levels. The gymnast of AG was in the 75th and the gymnast of RG was in the 90th percentile position for their corresponding age and gender. The average daily total energy intake ranged at 1712 ± 165 and 1976 ± 219 kcal, for the gymnasts of AG and the RG respectively (or $\sim 42,5$ kcal/kg lean mass). With respect to intake of vitamins and minerals, only vitamin C, zinc (Zn) and vitamin B6 exceeded the daily recommended amounts for the AG athlete. The calcium intake was insufficient and had the highest deviation from the recommended daily amounts (Table 3). It was not possible to carry out full nutritional analysis of all foods consumed because they were not included in the nutrient database (eg some various Greek dishes such as giouvarlakia/rice meat-balls in egg lemon sauce, lahano-dolmades/stuffed cabbage leaves, etc.). This was the reason that individual and complete analysis of saturated / unsaturated fat, omega-3 fatty acids, and vit. D was not carried out.

There were no exclusions (or limitations) of specific foods or food groups. Of particular interest was the zero egg consumption by both gymnasts according to their 7-day intake records. Use of dietary supplements was not mentioned by any athlete. During training it was found that the gymnasts had only water intake and no other snack. Both female athletes on repo days, systematically had decompensatory behavior with high energy intake (~ 3000 kcal). For their daily intake of dietary fibers it was noted that both athletes systematically consumed whole grain cereals.

Daily weighting was reported by both athletes. The most common weight control behaviour involves the drastic reduction of energy intake the day following a day of

pre-determined (deliberate) increased intake. This compensatory behaviour was applied periodically (3-4 times / month). No other pathological eating behaviours were reported (induced vomiting, use of laxatives or diuretics, fasting). Both athletes reported feeling that they were on a permanent (chronic) dieting regimen. The RG athlete showed a strong predisposition to abnormal eating behaviour and a negative self-assessment of emotions concerning both her external appearance and her body weight.

For the gymnasts of RG the individual level of self-esteem / self-perception of her image and body size, was classified as low whereas the corresponding level for the gymnast of AG was assessed as moderate. Concerning the medical history of the female athletes, normal values of haematological indices were observed. The athletes did not report using oral contraceptive pills. Particularly impressive is the high number of serious injuries reported by both athletes during their sporting careers. The AG athlete reported 4 injuries including 2 stress fractures of the ankle and spine. The RG athlete reported 2 injuries including one stress fracture of the ankle.

DISCUSSION

This research is one of the few published studies with a 7-day record of weighed food consumption in the sport of gymnastics. Compared with similar surveys, there were no significant differences in dietary intakes between the two female athletes. However, in our study dietary intake was higher ($\sim 42,5$ kcal/kg lean mass) than previously reported for female gymnasts. Specifically, in Thompson's (1998) review of 5 surveys with 56 female gymnasts, aged 15-18, the average daily energy intake was 1789 kcal or 35,6 kcal/kg. The reported daily energy intake of $\sim 42,5$ kcal/kg lean mass also approaches the

recommended minimum energy intake of 45 kcal/kg lean mass/day required during periods of intense training and pubertal development (Meyer & Manore, 2011). In addition, according to several experimental protocols (via the double labeled water method), the proposed recommendation for overall energy consumption in adolescent girls is about 40 kcal/kg or 1.75 times x RMR (Thompson, 1998). However, the calcium intake for both gymnasts was below the daily recommendations (DRA's), which is in agreement with previous studies (Cupisti, D'Alessandro, Gastrogiovanni, Barale, & Morelli, 2000; D'Alessandro, Morelli, Evangelisti, Galetta & Franzoni, 2007; Jonnalagadda, Benardot & Dill, 2000; Michopoulou et al., 2011; Silva & Paiva, 2015; Soric, Misiqoi-Durakovic & Pedisis, 2008). The AG athlete had significantly low daily intakes of other essential micronutrients. The RG athlete offset the recommended amounts of micronutrients through daily consumption of fortified wholegrain cereal (there were days where consumption exceeded 200 gr). The water intake exceeded the recommended values in both female athletes (2,3 L / date).

There seems to be an overestimate of predicted energy consumption in both the equations of RMR and consumed energy expenditure in aesthetic sports. Crenshaw (2009) found an overestimation of >200 kcal when using equations both for the forecasted RMR and the projected total energy balance. The review of Thompson (1998) also reports a systematic overestimation of the recommended total daily energy intake in adolescents. In our estimation, the equation to calculate the RMR, which has arisen solely from measurements of female Greek gymnastic athletes (Pavlou, 1992), seems to be appropriate in this investigation, since our athletes maintained a stable body weight [balance energy balance, SD (7-day): RMR = $\geq 1,6$]. Indeed the projected RMR proposed by Pavlou (1992) coincides with the boundary values proposed by McMurray (2011), i.e. 0.9 kcal/kg/h for females in the general population and 1,15 kcal/kg lean

mass/h for athletes. Something similar was noted in recent research by Silva and Paiva (2015). The discrepancies between the actual energy balance and the actual energy needs of female gymnasts, are a cause for reflection. The athletes of aesthetic sports appear to have a negative energy balance (between 250 and 1200 kcal) with a greatly reduced energy intake (Deutz, Benardot, Martin and Cody, 2000). In these studies, the reason seems to be the self-declared energy intake of athletes. However, there are studies that have questioned the validity and reliability of the calculation equations of both the RMR and the total daily energy consumption of the gymnasts (Crenshaw, 2009). We believe that more specific surveys are needed, with specialised techniques in order to calculate more accurately the energy expenditure for every athlete who endures the long hours of daily training of both AG and RG (Black, 2000; 2001). Furthermore, we observed a large energy deficit during the training of the athletes, since the average 6-hour daily training is not adequately supported nutritionally with the corresponding energy coverage (qualitative and quantitative). This applies even more to rhythmic gymnasts, where the long daily training sessions (~ 8 h) permanently expose them to negative energy balance, especially following the afternoon training. This was confirmed in the research of Deutz, Benardot, Martin, and Cody (2000). They found that the large energy deficit per hour (> 300 kcal) is associated with a higher body fat percentage in elite female athletes, especially in RG. The most likely reasons to explain this phenomenon involve various homeostatic mechanisms including reduction in mean metabolic rate (MMR) and the adjusted thermogenesis (energy storage), increased muscle catabolism, decreased levels of anabolic hormones such as oestrogen, T3 and IGF-1, increased levels of stress hormones such as cortisol, and general endocrine "resistance" and impaired hormonal homeostasis of fatty tissue (Benardot, 2014; De Souza & Williams, 2004; De Souza et al., 2014; Deutz,

Benardot, Martin & Cody, 2000; Filaire, Colombier, Beque & Lac, 2003; Gibbs et al., 2013; Lebenstedt, Platte & Pirke, 1999; Malina et al., 2013; Rottstein, 2013; Smith, 2000; Weimann, 2002; Weimann, Witzel, Schwiderqall & Bohles, 2000). Obviously, this situation seems to confirm the overestimation the daily energy consumption in research methodology of dietary assessment of gymnasts in AG and even more in RG (Figure 1).

Based on the research of Deutz et al. (2000) (Figure 1), female gymnasts are permanently exposed to a 24 hours negative energy balance, as concluded in this survey. Figure 1 begins when the athlete wakes up and ends after 24 h. Energy surplus and deficit are depicted above and below the point 0 which corresponds to the total energy balance. When the energy balance is negative then the athlete spends larger amounts of energy than the intake. Large daily energy deficits per hour (> 400 kcal), associated with a higher percentage of body fat in elite female athletes are probably due to increased muscle catabolism and a corresponding reduction in metabolic rate and thermogenesis (and other hormonal and homeostatic adjustments). The danger area of energy deficit seems to worsen during training hours (Deutz, Benardot, Martin & Cody, 2000). At the end of the day, a high density energy meal restores the athlete's energy equilibrium but most of the energy intake is stored as fat. Finally, these findings should discourage athletes from drastically reducing energy intake, since far from achieving their "ideal" body composition and their target weight, they actually increase body fat. In fact, greater energy deficit (per h) leads to higher body fat (Deutz, Benardot, Martin & Cody, 2000). They should also be discouraged from remaining without food for long hours while training. The reduced daily energy intake (qualitatively and quantitatively) crucially contributes to severe hormonal disorders, especially prolactin. Increased prolactin, reduces the secretion of the hypothalamic releasing hormone of gonadotropin (GnRH), which in turn leads to amenorrhea. This

phenomenon is exacerbated by the intense physical strain of training (volume, intensity, frequency) done without the required nutritional rehabilitation. Therefore, although menstrual disorders have a multifactorial etiology, the main one is reduced energy intake (Benson, Engelbert-Fenton and Eisenman, 1996; Caine, Russell & Lim, 2013; Dueck, Manore & Matt, 1996; Gibbs et al., 2013; Maimoun et al., 2013; Maimoun, Georgopoulos & Sultan, 2014; Malina et al., 2013; Mallinson & De Souza, 2014; Roupas and Georgopoulos, 2011; Warren & Perlroth, 2001; Williams, Helmreich, Parfitt, Caston-Balderrama & Cameron, 2001).

Following hours of intense and monotonous training and increasing strain the risk of severe acute trauma, chronic overuse syndromes, and stress fractures dramatically increases (Benardot, 2014; Caine, Russell & Lim, 2013; Malina et al., 2013; Rottstein, 2013; Smith, 2000). Researchers estimate that an elite gymnast, male or female, may miss up to 21% of annual training due to injuries (injury frequency $> 4/1000$ h training), i.e. approximately two months (Caine, Russell and Lim, 2013). This agrees with our findings, where the artistic gymnast reported a 2-month absence from training within the last year. The corresponding frequency of injuries for rhythmic gymnastics is ≤ 2 injuries/1000 h of training (Caine, Russell and Lim, 2013). Particularly during the critical developmental period of adolescence, many female champions having exceeded their high expectations/demands of themselves and having an impaired perception of their body image, i.e. the illusion of being overweight, become keen to lose extra weight and at the same time, very anxious to maintain the "ideal" weight at all costs. In general, they tend to evaluate themselves negatively. Under continuous pressure, the gymnasts aim to drastically improve their physical appearance (thinner is better) and to increase their opportunity of distinction in their sport. The pinnacle of the problem, especially in athletes of RG, is their

negative self-perception of their image and their body size (Beals, 2004; Bratland-Sanda and Sundgot-Borgen, 2013; Caine, Russell & Lim, 2013; De Bruin, Oudejans and Bakker, 2007; De Souza et al., 2014; Ferrand, Champely & Filaire, 2009; Francisco, Alarcao & Narciso, 2012; Martinsen et al., 2014; Nordin, Harris & Cumming, 2003; Zach, 2011).

CONCLUSION AND RECOMMENDATIONS

When assessing nutrition, it is preferable that sport nutritionists use combined techniques for the estimation of the total energy intake and expenditure of the athletes (individually), instead of being based only on indirect calculation of the corresponding equations/predictions (Burke, 2015). In any case, dietary recommendations are specified by the necessary consideration of all parameters: age, sex, type of sport, phases of annual competitive preparation, duration and weekly frequency of training, environmental conditions, nutritional assessment, medical history etc. During this investigation, we were puzzled by the low daily energy availability that was recorded. In particular, carbohydrate intake should be increased to ≥ 6 gr/kg BW per day in order to ensure optimal glycogen stores and next day training should take place in safe energy limits. Gymnasts show a permanent "deficit" of glycogen due to the long daily and weekly duration of their trainings. It is possible to gradually and individually increase 20-30% their energy intake (more snacks). It is preferable that a gymnast regularly, timely and in sufficient quantity increases the energy intake than permanently being in energy deficit during the entire day or, even worse, retrospectively trying to cover such deficit, no matter how. The qualitative adequacy of intake of B12, vit. D and omega-3 fatty acids (EPA, DHA) is a matter of specialized nutritional assessment and in athletes it is usually covered by administering dietary supplements, antioxidants etc. We also

believe that the most critical parameter for the promotion and acceleration of the rehabilitation-recovery process [faster healing of minor injuries, regeneration of injured cells / tissues, immune protection] of muscle stress / fatigue due to training is the favorable energy support strategy, recovery and replacement of fluids during training and post training, through specially designed snacks (high glycemic index). Specifically, because the usual duration of training is > 3 h, energy coverage / reinforcement with carbo-hydrates and electrolytes is required during long training sessions. These should be supplied at the right time and in sufficient quantity, according to the rule ≥ 30 gr of carbohydrates per hour (or 0.5 gr carbohydrate + 0,2 gr of protein / kg body weight / h).

It is estimated that 1 in 2 young athletes engaged in sports where special emphasis is placed on the impossible body, have significantly more nutrition related behavioural problems compared to both the general population and the athletes whose body weight is not a significant performance factor in their sport. Also, 1 in 5 gymnasts of aesthetic sports has at least two components of the female athlete syndrome (reduced energy intake and menstrual dysfunction) and is exposed to multiple risks of injuries and other health problems. It is suggested that the athlete exhibiting symptoms of the female athlete syndrome, be considered "injured", with direct intervention (combination of curative measures) and a clear restriction/abstention from training and competitions (Sundgot-Borgen et al., 2013).

The nutritional education of the athletes (individually and collectively) and coaches are enforced supported by a scientific support team (sports dietician, sports medicine physician, sports psychologist, gynecologist). We consider that in every gymnastic team is essential the basic cooperation between sports dietitian, coach and parents. In sensitive developmental ages of aesthetic sports, the role of the coach is crucial in terms of informing the athletes of

immediate and long-term negative consequences of reduced energy availability (malnutrition), of disorders of menstrual function and of loss of valuable bone density. Undoubtedly, cooperation is required between coaches and parents on all subjects (information, supervision, monitoring, guidance, compliance). Especially for chronic forms of reduced energy intake it should be emphasised that it is detrimental to athletic performance, with serious effects on future health due to weakening of the immune system, nutritional deficiencies of critical nutrients, dehydration, chronic fatigue, abnormal menstrual and hormone function, decreased bone density, increased injury susceptibility and an increased risk of eating disorders.

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