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Dietary Recommendations and Athletic Menstrual Dysfunction

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Abstract

Exercise-induced or athletic menstrual dysfunction (amenorrhoea, oligomenorrhoea, anovulation, luteal phase deficiency, delayed menarche) is more common in active women and can significantly affect health and sport performance. Although athletic amenorrhoea represents the most extreme form of menstrual dysfunction, other forms can also result in suppressed estrogen levels and affect bone health and fertility. A number of factors, such as energy balance, exercise intensity and training practices, bodyweight and composition, disordered eating behaviours, and physical and emotional stress levels, may contribute to the development of athletic menstrual dysfunction. There also appears to be a high degree of individual variation with respect to the susceptibility of the reproductive axis to exercise and diet-related stresses.

The dietary issues of the female athlete with athletic menstrual dysfunction are similar to those of her eumenorrhoeic counterpart. The most common nutrition issues in active women are poor energy intake and/or poor food selection, which can lead to poor intakes of protein, carbohydrate and essential fatty acids. The most common micronutrients to be low are the bone-building nutrients, especially calcium, the B vitamins, iron and zinc. If energy drain is the primary contributing factor to athletic menstrual dysfunction, improved energy balance will improve overall nutritional status and may reverse the menstrual dysfunction, thus returning the athlete to normal reproductive function. Because bone health can be compromised in female athletes with menstrual dysfunction, intakes of bone-building nutrients are especially important. Iron and zinc are typically low in the diets of female athletes if meat products are avoided. Adequate intake of the B vitamins is also important to ensure adequate energy production and the building and repair of muscle tissue.

This review briefly discusses the various factors that may affect athletic menstrual dysfunction and two of the proposed mechanisms: the energy-drain and exercise-intensity hypotheses. Because energy drain can be a primary contributor to athletic menstrual dysfunction, recommendations for energy and the macro- and micronutrients are reviewed. Methods for helping the female athlete to reverse athletic menstrual dysfunction are discussed. The health consequences of trying to restrict energy intake too dramatically while training are also reviewed, as is the importance of screening athletes for disordered eating. Vitamins and minerals of greatest concern for the female athlete are addressed and recommendations for intake are given.

Over the last 10 to 15 years, we have come to realize that many active women, especially competitive athletes, experience some type of athletic menstrual dysfunction. Initially, there was limited concern for this phenomenon by the athlete, coach or physician until research showed that amenorrhoeic athletes were at risk for premature osteoporosis.[1] Subsequent research has shown that reduced levels of reproductive hormones, especially estrogen, significantly affect bone turnover and resorption,[2] thus increasing the athlete's risk for sport-related injuries[3,4] and premature osteoporosis.[1] Since these early reports on poor bone density in young female athletes, numerous studies have examined the effect of exercise on the menstrual cycle. This review briefly discusses the various factors that may play a role in the development of athletic menstrual dysfunction and then addresses the unique nutritional issues of this population.

1. Mechanisms of Athletic Menstrual Dysfunction

A number of factors, such as energy balance, exercise intensity and training practices, bodyweight and composition, disordered eating behaviours, and physical and emotional stress levels, may contribute to the development of athletic menstrual dysfunction. Research now indicates that there is a high degree of individual variation in the susceptibility of the reproductive axis to these factors. Thus, it is difficult to identify which of the factors must be present for the development of menstrual dysfunction, especially amenorrhoea, in any individual athlete. What produces athletic menstrual dysfunction in one woman may not have the same effect in another.

Athletic menstrual dysfunction is characterised by a significant decrease in reproductive hormones, especially estrogen, and disruption of the normal menstrual cycle. The degree of disruption to the reproductive axis can come in many forms and is related to the severity of deficiency in gonadotropin-releasing hormone secretions from the hypothalamus and the subsequent decrease in estrogen production.[5] In addition, low leptin levels have been measured in amenorrhoeic athletes, which may provide an additional signal to the hypothalamus that there is insufficient energy to maintain normal reproductive function.[6,7] The typical forms of menstrual dysfunction seen in athletes are amenorrhoea (one period or fewer per year), oligomenorrhoea (six or fewer cycles per year), anovulation (no ovulation but bleeding may occur), luteal phase deficiency (ovulation may occur but inadequate progesterone support for endometrial development) and delayed menarche.[5,8,9] Although amenorrhoea is the most severe form of menstrual dysfunction associated with exercise, all forms of dysfunction have the potential to affect bone health depending on the degree of estrogen insufficiency.[10]

The mechanisms behind athletic menstrual dysfunction have been primarily associated with energy drain (inadequate energy to cover the energy demands of the body),[11-13] excessive exercise stress or intensity,[14] or a combination of these factors. Current review articles discuss these hypotheses in detail.[8,14,15] Figure 1 shows the adaptive responses of the body to stresses caused by these factors (excessive exercise, poor energy balance, psychological stress of sport and competition), which eventually suppress reproductive function and affect health. The energy-drain and exercise intensity hypotheses are briefly reviewed here.

1.1 Energy-Drain Hypothesis

The energy-drain hypothesis suggests that athletic amenorrhoea or other reproductive hormone abnormalities observed in female athletes may be due in part to periods of energy deficiency, or a combination of high energy expenditure, low energy intake, and/or high psychological and physical stress. Exercise-induced changes in the menstrual cycle may be an energy-conserving strategy to protect more important biological and reproductive processes.[11,12] The prevalence of athletic menstrual dysfunction in female athletes is high (6 to 79%),[14] especially in athletes who restrict energy intake.[16,17]

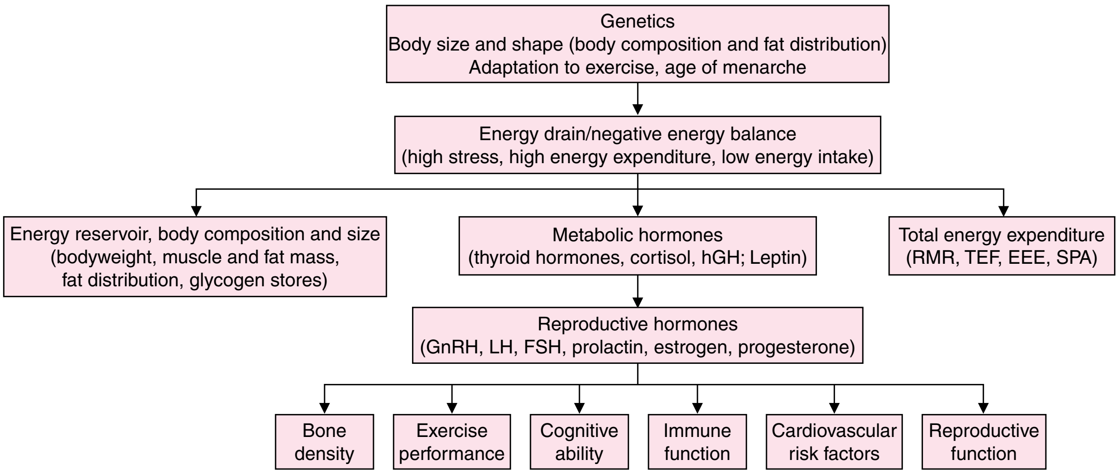

Fig. 1. A model illustrating the influence of energy drain and high stress on the development of menstrual dysfunction in active women, and the potential health and performance outcomes due to low reproductive hormones and high cortisol levels (reprinted, with permission, from CA Dueck et al.[11]); **FSH** = follicle-stimulating hormone; **GnRH** = gonadotropin-releasing hormone; **hGH** = human growth hormone; **LH** = luteinising hormone; **RMR** = resting metabolic rate; **SPA** = spontaneous physical activity; **TEF** = therapeutic effect of food.

1.2 Exercise-Intensity Hypothesis

Not all menstrual dysfunction observed in the active woman can be explained by the energy-drain hypothesis. The exercise-intensity hypothesis suggests that menstrual dysfunction in female athletes can also be due to high exercise intensity[14] or abrupt changes in exercise level. This hypothesis has been supported by animal research showing that various degrees of menstrual dysfunction can be induced in exercising monkeys in the presence of adequate energy intake and the absence of weight loss.[18] Regardless of the underlying mechanism for athletic menstrual dysfunction in the female athlete, the effect on the reproductive axis is similar and blood estrogen levels are decreased. For most female athletes experiencing menstrual dysfunction, many of the factors mentioned above may be present in varying degrees, thus making the identification of a specific cause more difficult.

Regardless of the cause, there is a high probability that a female athlete may have some type of menstrual dysfunction.[11,14,17,19-21] However, it is important to realise that an athlete can have athletic amenorrhoea or other forms of menstrual dysfunction without having a clinical eating disorder.[12,22] Unfortunately, many female athletes are reluctant to discuss their menstrual histories with health professionals because they fear being classified with an eating disorder.

2. Energy and Macronutrient Needs

For the female athlete, weight maintenance occurs when adequate energy is consumed to cover the energy costs of daily living, exercise training and competition, building and repair of muscle tissue, menstrual function, and any additional energy costs related to life stressors, such as illness or psychological stress. Young active women must also cover the energy costs of growth.

Female athletes, like their sedentary counterparts, are often preoccupied with their bodyweight and shape. Thus, it is not unusual for these women to want to lose an extra 2.5 to 5kg (5 to 10lb), although their weight is often normal or below normal by all medical standards. Depending on the sport, the impetus for this weight loss is the belief that a lower bodyweight will improve exercise performance and enhance body shape and appearance. This is especially true for athletes who compete in thin-build sports where both appearance and performance are important (e.g. figure skating, dance, gymnastics, diving) or sports where revealing clothing must be worn. In addition, a smaller body size is easier to move through space and may reduce the risk of injury in high-impact sports, such as gymnastics. For many female athletes, constant energy restriction has become a normal part of their lifestyle and is one of the primary factors contributing to menstrual dysfunction in this population.

2.1 Energy

Because menstrual dysfunction is associated with energy drain or negative energy balance, it is important to examine energy intake and expenditure in the active woman. For most healthy active women, short-term periods of dieting for weight loss present few nutritional or long-term health problems. However, for the female athlete who exercises intensely while purposefully dieting or does not eat adequately, there is an increased risk of sport-related injuries, especially stress fractures, poor bone mineral density, and menstrual dysfunction. Negative energy balance (e.g. where energy expenditure is greater than energy intake) can take many forms. For some athletes, watching what they eat and restricting energy intake is a way of life that in extreme cases can lead to an eating disorder. Conversely, other athletes are not consciously restricting energy intake, but their current dietary practices do not provide enough energy to cover the cost of their exercise training. In these individuals, weight loss usually occurs during times of high exercise training or competition. They experience the same energy-deficit health problems as athletes who consciously restrict energy intake. Disordered eating behaviours can also contribute to the poor energy intakes that are frequently seen in active women and are discussed later in this section.

Most female athletes require at least 2300 to 2500 kcal/day (9623 to 10 460kJ) to maintain bodyweight (45 to 50 kcal/kg).[23,24] If they are involved in endurance sports, such as training for a marathon or triathlon, their energy requirements may be as high as 4000 kcal/day (16 736kJ). Researchers have extensively examined the energy intakes in female athletes, including those classified with various types of menstrual dysfunction. Almost all of these studies[22,25-35] reported 5- to 7-day mean energy intakes (kcal/day or kJ/day) below that predicted to maintain bodyweight, regardless of menstrual classification (table I). To date, there are no consistent data showing that amenorrhoeic athletes consume less energy than eumenorrhoeic athletes in similar sports. However, just comparing energy intake data between these two groups is not adequate. Measuring energy intake does not address the specific issue of the energy-drain hypothesis, which is based on decreased energy stores (e.g. stored glycogen and body fat) and availability of daily energy intake to meet energy demands. This assessment is difficult to do without doing expensive measures of total energy intake and expenditure. Of the four studies that have carefully reported energy balance data in eumenorrhoeic and amenorrhoeic female athletes,[12,25,26,36] all have found amenorrhoeic athletes to have more negative energy balance than active controls. For example, De Souza et al.[25] found that over a 3-month period sedentary women had no inconsistent menstrual cycles and 90% of the cycles were ovulatory, while 46% of the active women had inconsistent cycles and only 45% were ovulating. Energy balance and energy availability were significantly lower ($p < 0.05$) during the anovulatory cycles in the active women compared with other menstrual cycle categories. In addition, Dueck et al.[12] found that improving energy balance in an amenorrhoeic competitive runner resulted in resumption of menstruation. Collectively, these studies support the energy-drain hypothesis, but sample sizes were small and more accurate measurements of energy expenditure (doubly labelled water) have not been done.

Improving an athlete's overall energy balance can go a long way in reversing diet-induced men-

Table I. Mean energy and macronutrient intakes in female athletes with and without menstrual dysfunction

Reference	Menstrual function (n)	Sport	Athleticism	Age (y)	Weight (kg)	Body fat (%)	BMI (kg/m^2)	Energy (kcal/day)[a,b]	Energy (kcal/kg/day)[b]	Protein (g/day)	Protein (g/kg/day)	CHO (g/day)	CHO (g/kg/day)	Fat (g/day)	Fat (% of energy)	Classification of menstrual status	Screen for eating disorders	Diet record
Gremion et al.[27]	Eumen (10)	Long-distance runners	National	25.6	52.8	15.0	19.3	2129	40.3	76	1.44	265	5.0	83	35	Self reported + hormones	Yes	5-day
	Oligo/Amen (11)			25.3	50.9	12.3	18.8	2292	45.0	87	1.71	362	7.1	69	27			
Thong et al.[28]	Eumen (8)	Runners, cyclists and aerobic dancers	National	22.9	52.9	15.2	19.3	2277	43.0	78.3	1.48	358	6.8	63	25	Self reported + hormones	Yes	7-day
	Amen (5)			22	52.6	14.6	18.9	**1672**	**31.8**	54.9	1.04	290	5.5	39	21			
Kopp - Woodroffe et al.[22]	Amen (4)	Runners and cyclists	Competitive recreational	24.5	61.3	17.7	21	1892	30.9	74.3	1.21	329	5.4	36	15	Self reported + hormones	Yes	7-day
De Souza et al.[25]	Eumen/Ovul (24)	Runners	Recreational	27.8	58.1	NA	NA	1837	31.6	64.5	1.11	270	4.6	54	27	Urine metabolites	Yes	7-day
	Luteal PD (21)				56.9			1993	35.0	66.8	1.17	274	4.8	64	29			
	Anov (8)				64.9			**1326**	**20.4**	54.8	0.84	217	3.3	36	25			
Laughlin & Yen[29]	Eumen (5)	Runners and triathletes	Recreational	30.7	58.1	15.9	19.6	1736	29.9	57	0.98	256	4.4	50	26	Self reported + hormones	Yes	7-day
	Amen (5)			26.3	55.2	16.0	19.4	2106	38.2	67	1.21	283	5.1	32	14			
Baer[30]	Eumen (10)	Runners	High school	16.5	52.1	17.4	19.4	1994	38.3	68.3	1.31	243	4.7	78	36	Self reported + hormones	Yes	7-day
	Amen (10)			16.0	50.0	16.1	19.1	**1627**	**32.5**	65.1	1.30	199	4.0	63	35			
Baer & Taper[31]	Eumen (6)	Runners	High school	15.5	51.1	17.3	19.3	1644	32.2	56.3	1.10	206	4.0	66	36	Self reported + hormones	Yes	7-day
	Amen (6)			16.1	51.0	16.3	18.9	1912	37.5	77.2	1.51	238	4.7	75	35			
Loucks et al.[26]	Eumen (9)	Runners and triathletes	Competitive recreational	26.5	56.7	15.2	20.5	1894	33.4	65.0	1.15	267	4.7	55	27	Self reported + hormones	Yes	7-day
	Amen (9)			24.0	52.5	13.8	18.3	**1668**	**31.8**	56.7	1.08	261	5.0	47	25			
Snead et al.[32]	Eumen (19)	Runners	49 km/wk	31.9	59.0	22.1	21.8	1965	33.3	74.4	1.26	250	4.2	69	32	Self reported + hormones	Yes	7-day
	Oligo/Amen (12)		46 km/wk	23.5	57.4	20.1	20.3	2036	35.5	69.8	1.22	283	4.9	66	29			

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Table I. Contd

Reference	Menstrual function (n)	Sport	Athleticism	Age (y)	Weight (kg)	Body fat (%)	BMI (kg/m^2)	Energy (kcal/day)^{a,b}	Energy (kcal/kg/day)^b	Protein (g/day)	Protein (g/kg/day)	CHO (g/day)	CHO (g/kg/day)	Fat (g/day)	Fat (% of energy)	Classification of menstrual status	Screen for eating disorders	Diet record
Myerson et al.[33]	Eumen (6)	Runners	83 km/wk	29.1	51.1	15.0	19.5	1934	37.8	68.7	1.34	271	5.3	67	31	Self reported + hormones	Yes	7-day
	Amen (9)		84 km/wk	29.9	51.4	14.6	19.4	**1730**	**33.7**	53.4	1.04	239	4.6	53	27			
Howat et al.[34]	Eumen (9)	Gymnasts, bodybuilders	College athletes	19.2	55.4	14.9	22.6	1933	34.9	61	1.10	220	4.0	83	39	Self reported	No	7-day
	Oligo/Amen (5)			19.6	62.3	17.4	21.4	**1551**	**24.9**	53	0.85	173	2.8	69	40			
Pettersson et al.[35]	Eumen (10)	Runners	Recreational	22.8	59.0	23.6	21.2	2091	35.4	72	1.22	370	6.3	58	25	Self reported + hormones	No	7-day
	Amen (10)			21.8	52.4	18.4	19.8	**1842**	**35.2**	73	1.39	302	5.8	40	20			

a To convert kcal/day to kJ/day, multiply by 4.184.

b Values in bold type are lower in amenorrhoeic athletes than eumenorrhoeic athletes.

Amen = amenorrhoeic; **Anov** = anovulatory; **BMI** = body mass index; **CHO** = carbohydrate; **Eumen** = eumenorrhoeic; **Luteal PD** = luteal phase deficiency; **NA** = not available; **Oligo** = oligomenorrhoeic; **Ovul** = ovulatory.

strual dysfunction. This may require increased energy intake, while reducing exercise energy expenditure (e.g. adding a rest day to their weekly routine). Total daily energy intake (kcal/day) should be increased in small increments (e.g. 200 to 300 kcal/day or 837 to 1255 kJ) and the athlete should be warned that a small weight gain may occur, but that mood and athletic performance may improve. It is important to be sure that the athlete is in positive energy balance before beginning any physical activity for that day.[37] For example, if the athlete has a 4 pm workout, she needs to be well fed before that workout. After lunch she may need a 3 pm snack before going to practice, which will provide the body with energy to fuel both the brain and the muscles during the workout. Table II gives some guidelines to help determine if a female athlete is not consuming enough energy for optimal health and performance.

2.2 Health Consequences of Poor Energy Intakes

There can be significant health consequences to athletic menstrual dysfunction,[39] which are compounded if energy intake is too low.[40,41] The most significant problems can be poor bone health, infertility, poor nutritional status, and the development of disordered eating patterns. The effect of menstrual dysfunction on bone health has been reviewed in detail elsewhere.[42] Development of the female athlete triad (eating disorders, amenorrhoea and osteoporosis) has also been addressed elsewhere.[43] However, the long-term effects of diminished reproductive hormones, especially estrogen, on other body systems (e.g. cardiovascular health, cognitive function, immune function) have not yet been clearly established.

It is not uncommon for female athletes with poor energy intakes, especially those with some type of menstrual dysfunction, to complain of fatigue, frequent injuries, irritability and poor athletic performance.[11,12] These complaints can increase psychological and emotional stress, another risk factor for the development of menstrual dysfunction. Psychological stresses reported by ath-

Table II. Factors to consider when determining if a female athlete is consuming enough energy to maximise health and performance (adapted from Manore[38], with permission from the copyright owners Lippincott Williams and Wilkins)

A female athlete who is not eating enough may have the following complaints:
Hungry and irritable, with a difficult time concentrating before or during the exercise routine. She may also report feeling shaky and lightheaded, especially if she exercises around 3 to 4 pm and has not eaten since lunch, or if she exercises before eating breakfast in the morning. The athlete must provide energy, especially glucose, for the muscles and brain. Without this energy, the body will have to make glucose from body protein
Weight loss, which is a clear sign that the athlete is not providing enough fuel for both exercise and weight maintenance. If weight is being lost, the body uses stored fat and muscle tissue for fuel. The goal is to maintain or increase muscle tissue, not use it as an energy source
Inability to make it through a workout or training run without feeling worn out and overly fatigued. Heart rate may be higher than expected, and she may report feeling shaky, irritable and unable to concentrate. This is a clear sign that the athlete is coming to the training run or workout without adequate fuel, and/or is not providing the body with adequate fuel during the exercise event. Once the body becomes fatigued during a workout, it is too late to refuel the body for maximal performance. It is important to fuel the body before exercise, and to begin adding fuel early in the workout
Amenorrhoea or irregular periods. An undernourished athlete may develop some type of menstrual dysfunction. This can be a sign that the body does not have enough energy to fuel exercise and the reproductive functions of the body. A female athlete does not have to have an eating disorder to stop having her menstrual period or to have irregular periods. Many female athletes stop menstruating if they are exercising hard and not eating enough food, even if they are making good food choices
Frequent injury, sickness or fatigue may be a sign that the female athlete is demanding too much of her body, without providing the body with adequate rest and energy. The athlete may actually be in a state of overtraining
Arrested growth in young athletes. The energy challenge to young growing athletes is even greater than for adult athletes. Energy is needed for physical growth plus the demands of their sport and lifestyle. For the young female athlete, energy must be adequate to cover growth, reproductive function, demands of daily living and her sport

letes who use severe dieting practices include increased depression, obsession with food and bodyweight, increased incidence of binge-purge eating behaviours, increased stress of constantly trying to 'make-weight' or maintain an unrealistic bodyweight, and increased risk of developing an eating disorder.[19,20]

2.2.1 Disordered Eating

The emphasis on thinness is pervasive in many sports, and constant dieting to maintain this thinness can lead to disordered eating. These behaviours can range from subclinical eating disorders to clinically diagnosed anorexia nervosa or bulimia nervosa. Athletes involved in aesthetic or lean-build sports, such as dancers, runners, gymnasts and figure skaters, report the highest incidences of athletic menstrual dysfunction and frequently use long-term dieting to maintain a competitive weight.[12,20,44-46] These athletes are usually thinner and typically report a higher incidence of dieting behaviours than athletes participating in sports allowing more normal builds, such as basketball, volleyball or soccer.[17,19,21] In addition, athletes in lean-build sports report poor energy intakes, increased risk of injury, poor ability to concentrate, and prolonged recovery time from injuries compared with athletes in normal-build sports.[19-21,47] Although the prevalence of clinical eating disorders is no higher in female athletes than non-athletes, the presence of subclinical eating disorders and/or disordered eating can be high, especially in thin-build sports.[17,21] Beals and Manore[18,20] have reviewed the nutrition and health issues of female athletes with subclinical eating disorders.

Athletic menstrual dysfunction can and does occur in the absence of an eating disorder or disordered eating behaviours; however, it is important that an athlete who reports some type of menstrual dysfunction be screened for an eating disorder.

2.3 Macronutrient Needs

If a female athlete has an energy intake of <1800 kcal/day (7 531kJ), it is almost impossible to get adequate macro- and micronutrients to maintain good health and have the energy to fuel an intense training programme. This level of energy intake is too low for most competitive athletes regardless of body size and can greatly increase the risk of developing some type of menstrual dysfunction.[37] For the young athlete, if energy restriction begins before puberty, the risk of delayed menses increases and can prevent this individual from achieving peak bone density.

Low energy intakes also increase the risk that protein, carbohydrate and essential fatty acid intakes will be below recommended levels.[22,23,48,49] Although limited data are available on the protein requirements of female athletes, it is recommended that they have higher protein intakes (1.2 to 1.4g protein/kg bodyweight)[50,51] than the Recommended Dietary Allowance (RDA) (0.8g protein/kg bodyweight).[52] Table I gives the protein intakes (g/day and g/kg/day) in eumenorrhoeic and amenorrhoeic athletes. In general, intakes are within the recommended levels unless energy intake is low. Based on these data, protein intakes of amenorrhoeic athletes are consistently lower than those of their active eumenorrhoeic counterparts. Athletes consuming vegetarian diets or those who avoid meat and dairy products are at greater risk for poor protein intakes. These athletes can improve their protein intakes by adding nonanimal high-quality protein food sources to their diet such as legumes, beans, soy milk, meat substitutes and whole grains. If these foods are not acceptable, the use of protein supplements may be necessary.

If energy intake is low, carbohydrate intake will be inadequate to replenish glycogen stores used during periods of high exercise training. Most female athletes in training need a minimum of 5g of carbohydrate/kg bodyweight to maintain glycogen stores.[9,23] If exercise intensity and duration are high and training occurs on a daily basis, carbohydrate needs may be 6 to 8g of carbohydrate/kg bodyweight.[48] Table I gives the carbohydrate intakes (g/day and g/kg/day) in eumenorrhoeic and amenorrhoeic athletes. Most of these studies examined athletes participating in endurance sports where the need for glycogen replacement is high. In general, intakes in both groups are below the recommended amounts. Based on these data, carbohydrate intakes of active women are low, regardless of menstrual status. Increasing total energy intake is usually the easiest way to assure that total carbohydrate intake will also increase; however, athletes still need to be encouraged to select high carbohydrate foods (e.g. fruit, whole grains and cereals, and vegetables) before and after exercise.

Dietary fat is almost always limited in the diets of active women who are restricting energy intake.[21] If fat intake drops below 15% of energy intake, there is a high probability that intake of essential fatty acids (linoleic acid and α-linoleic acid) and vitamin E will be low unless the athlete is consuming vegetable oils (e.g. canola oil, safflower oil), nuts, flax seeds, or fish products (e.g. salmon, tuna).[53] However, research examining fat intakes (percentage of energy) in eumenorrhoeic and amenorrhoeic athletes generally showed no differences between groups (table I). Only two studies[22,29] reported dietary energy intake from fat at 15% or less; however, examination of absolute fat intake (g/day) shows that in all but one study[31] female athletes with menstrual dysfunction had lower intakes.

3. Micronutrient Requirements

If a female athlete has menstrual dysfunction due to poor energy intakes, poor micronutrient intakes are not uncommon, especially for the bone-building nutrients and the B vitamins.[21,22,54] The bone-building nutrients are especially important for amenorrhoeic athletes because bone health may already be compromised as a result of low reproductive hormones. The B micronutrients play an important role in energy production, haemoglobin synthesis, adequate immune function, and building and repair of muscle tissue.

3.1 B Vitamins

The B vitamins most commonly assessed in cross-sectional studies of female athletes are thiamin (vitamin B1), riboflavin (vitamin B2), pyridoxine (vitamin B6), vitamin B12 and folate. In general, these studies reported adequate mean intakes,[21,31,55-58] but examination of individual intakes revealed that 10 to 60% of female athletes consume <100% of the recommended levels for these nutrients.[21,22,34,59-62] Few studies have examined the intake of these nutrients in female athletes with menstrual dysfunction to determine if intakes are lower than in active controls. Of the B vitamins, riboflavin, pyridoxine and folate are most frequently low in the diets of female athletes,[23,54,63] especially those with restricted energy intakes or with disordered eating behaviours.[21]

3.1.1 Riboflavin

Based on metabolic studies, which have examined the effect of exercise, dieting or diet plus exercise on riboflavin requirements,[64-67] riboflavin needs are higher in women engaging in exercise for fitness than in sedentary controls. In these studies 1.4mg of riboflavin per 1000 kcal was required to maintain good status in active women (20 to 50 min/day, 6 days/wk), while 1.6mg of riboflavin per 1000 kcal (2 mg/day) was required to maintain good riboflavin status when individuals were dieting for weight loss and exercising (3 h/wk at 75 to 85% of maximum heart rate). This level of dietary riboflavin intake is about twice the current 1998 RDA of 1.1 mg/day for adult women.[68] Thus, it appears that exercise, dieting, and dieting plus exercise increase the need for riboflavin above the current RDA for active women.[64-67] However, it should be noted that these women performed moderate exercise (3 to 5 h/wk) for fitness. There are no metabolic data available on female athletes, with or without menstrual dysfunction, who participate in strenuous exercise and competitive sports. Only Kopp-Woodroffe et al.[22] have examined mean dietary riboflavin intakes in four amenorrhoeic female athletes. Their intake of riboflavin, using 7-day weighed food records, was 1.65 mg/day, which is 50% less than the amount reported by Belko et al.[64-66] to maintain good status. One might speculate that if moderately active women have an increased need for riboflavin, female athletes have an equal or greater need. Based on this research, dietary riboflavin intakes for female athletes should be at least 2 to 3 mg/day. This increased intake of riboflavin can easily be achieved by regularly consuming milk and milk products, eggs, whole grains and cereals, lean meats and broccoli.

3.1.2 Pyridoxine

Based on metabolic studies, approximately 1.5 to 2.3 mg/day of pyridoxine is required to maintain good pyridoxine status.[69-71] This is more than the current RDA of 1.3 mg/day for women.[68] Exercise also appears to affect pyridoxine metabolism, by increasing the chance that the active form of the vitamin, pyridoxal phosphate, will be converted to 4-pyridoxic acid – the vitamin's urinary metabolite – and be lost in the urine.[70,72-74] Thus, exercise may increase the turnover and loss of pyridoxine from the body.[71,72] Rokitzki et al.[75] calculated, on the basis of 4-pyridoxic acid excretion, that marathon runners lost approximately 1mg of pyridoxine during a race (42.2km; 26.2 miles). According to the available data, active women may require 1.5 to 2.5 times the current RDA (~2.0 to 3.0 mg/day) for pyridoxine to maintain good pyridoxine status. Although no research indicates that athletes with menstrual dysfunction have any higher needs for pyridoxine than eumenorrhoeic athletes, if energy intakes are low or food selection is poor, pyridoxine intake is probably low. Only Kopp-Woodroffe et al.[22] and Baer and Taper[31] have reported mean dietary intakes of pyridoxine in amenorrhoeic athletes and found intakes of 1.7 to 2.0 mg/day.

3.1.3 Folate

Of all the B vitamins, folate is the one vitamin that appears to be consistently low in the diets of female athletes. Using the 1998 RDA[68] for folate (400 μg/day) as the criterion, there are no studies reporting mean folate intakes of 400 μg/day or more in female athletes. Mean folate intakes for female athletes usually range from 126 to 364 μg/day.[21,31,55,57-59] In a recent study, Beals and Manore[21] found that 53% of their female athletes consumed <400 μg/day of folate, using 7-day weighed food records. In this study, 30% of the control group and 61% of the subclinical eating disorder group reported some type of menstrual dysfunction. The determination of folate status in female athletes is very limited. Matter et al.[76] examined folate status in nonsupplementing female marathon runners and found that 33% (n = 85) had poor folate status. No assessment of dietary folate was done. Beals and Manore[21] examined folate status in their female athletes (~50% reported supplementing) and found 4% of their athletes to be in negative folate balance (plasma folate ≤1.8 nmol/L or ≤3 μg/L). Kopp-Woodroffe et al.[22] examined folate status in four amenorrhoeic female athletes and found one athlete in stage 1 folate deficiency. Mean dietary folate intake in this group was 250 μg/day, and Baer and Taper[31] reported 316 μg/day in their amenorrhoeic athletes (n = 6). These limited data suggest that active women are at risk of poor folate status, primarily because of their low folate intakes. The current recommendation is for active women to increase their daily intake of folate to the current RDA of 400 μg/day. Folate content is especially high in leafy green vegetables, fortified cereals and grains, nuts, legumes, liver and brewer's yeast. If these types of foods are not consumed in the diet, supplementation may be necessary.

3.2 Minerals

In general, female athletes may have especially poor intakes of calcium, magnesium, iron and zinc. These low intakes can usually be attributed to energy restriction or the avoidance of animal products, such as meat, fish, poultry and dairy products from the diet. Since meat products are especially high in iron, zinc and magnesium, and dairy products are high in calcium, it is not surprising that intakes of these nutrients are low. The low estrogen levels found in amenorrhoeic athletes make it especially important that adequate bone-building nutrients, including vitamin D, are consumed. For the amenorrhoeic athlete, the ability to build and maintain bone is compromised by low estrogen levels and will only be further compromised if the nutrients and energy required for bone growth or maintenance are absent.

3.2.1 Calcium

Female athletes also have poor calcium intakes, especially if they have eliminated dairy foods from their diet. Research studies examining calcium intake in female high school and collegiate athletes reported mean intakes ranging from 500 to 1623 mg/day, with most studies reporting mean intakes below 1000 mg/day.[21,22,77] The new 1998 Dietary Recommended Intake (DRI) for calcium is 1300 mg/day for young females between the ages of 9 and 18 years and 1000 mg/day for adult females aged 19 to 50 years.[78] Studies specifically looking at the calcium intakes of amenorrhoeic athletes indicated that calcium intakes are similar to intakes reported for eumenorrhoeic athletes (~845 to 1400 mg/day),[22,31-34] with only one study reporting dietary intakes >1000 mg/day.[31]

As expected, female athletes in thin-build sports[34] (ballet, gymnastics, and track and field events) reported the lowest intakes of dietary calcium. These athletes are also at greater risk of menstrual dysfunction because of their low energy intakes and the high energy demands of their sport.[11,12] Inadequate intake of calcium increases the risk for poor bone mineral density and stress fractures. Female athletes, especially those who report menstrual disturbances, need to be encouraged to consume adequate calcium in either dairy foods, calcium-fortified products or supplements. If an athlete is lactose intolerant, care should be taken to assure adequate calcium is consumed by using other calcium-rich foods and calcium supplements. However, optimal calcium absorption and good bone health cannot occur without adequate intakes of vitamin D and normal blood estrogen levels. Thus, calcium intake alone does not assure an athlete of adequate bone density.[79] For athletes who live in northern climates, where winter light is limited, and who exercise primarily indoors, vitamin D status may be poor. For these athletes, a calcium supplement fortified with other bone-building nutrients may be necessary. In addition, adequate protein and energy are important for bone health.

3.2.2 Magnesium

The magnesium intake of the typical woman in the US is estimated to be approximately 207 mg/day (74% of the RDA) and the magnesium density of the typical American diet is ~120mg/1000 kcal. On the basis of this nutrient density, the typical woman would need to consume 2333 kcal/day (9761kJ) to meet the RDA for magnesium. These estimates demonstrate the importance of total energy intake on dietary magnesium intake. If one reduces energy intake without increasing the magnesium density of the diet (mg/1000 kcal), magnesium intake will be low.

Most studies have reported mean magnesium intakes of female athletes or active women at or above two-thirds the RDA of 310 to 320 mg/day.[78,79] If energy intake is restricted, magnesium intakes can be low. For example, Beals and Manore[21] reported that 54% of their athletes with subclinical eating disorders (66% reported menstrual dysfunction) consumed <100% of the RDA for magnesium and 8% consumed <66% of the RDA. Conversely, only 17% of the control athletes consumed less than the RDA and none consumed less than two-thirds the RDA for magnesium. In this study, the athletes with subclinical eating disorders reported consuming only 1989 kcal/day (8322kJ), while the control athletes consumed 2293 kcal/day (9594kJ), similar to the energy requirement needed to meet the RDA for magnesium. Two other studies dramatically demonstrated the effect of low energy intakes on dietary magnesium intake in female athletes. Baer and Taper[31] reported that eumenorrhoeic runners consuming 1644 kcal/day (6878kJ) received only 53% of the RDA for magnesium; conversely, amenorrhoeic runners consuming 1912 kcal/day (8000kJ) received 80% of the RDA. Kaiserauer et al.[59] also reported that when female runners consumed <1582 kcal/day (6627kJ), 55% of them had magnesium intakes less than the RDA. Kopp-Woodroffe et al.[22] and Howat et al.[34] also reported mean magnesium intakes in their amenorrhoeic athletes to be less than the RDA (263 and 258 mg/day, respectively), and Snead et al.[32] found intakes similar to the RDA (318 mg/day). As for calcium, most amenorrhoeic athletes report less than optimal intake of dietary magnesium. Foods high in magnesium include whole grains and cereals, beans and legumes, meat, fish, milk and yoghurt, and some nuts (almonds and sunflowers), vegetables (broccoli, green beans, carrots and potatoes) and fruits (bananas).

3.2.3 Iron

Iron deficiency is one of the most prevalent nutrient deficiencies observed in the female athlete,[80,81] including many amenorrhoeic athletes. Approximately 15 to 60% of female athletes are reported to have poor iron stores compared with 20 to 30% in the general female population.[77,80] Iron depletion is characterised by low ferritin levels (<20 μg/L). The higher incidence of iron depletion in female athletes is usually attributed to a number of factors. First, female athletes often have poor iron intakes, which are usually attributed to the avoidance of foods high in haem iron, such as meat, fish and poultry, and restricted energy intakes. If energy intake is restricted, total daily iron intakes decrease unless the individual is supplementing. Second, many female athletes follow vegetarian diets, which provide no haem iron; thus, the bioavailability of the iron consumed is reduced. Therefore, although the diet appears to have adequate iron, the availability of the iron is poor. Finally, female athletes may have increased iron losses through menstrual blood and iron lost in sweat, faeces and urine.[82] Although amenorrhoeic athletes do not lose iron through monthly menses, they still lose iron in sweat, urine and faeces, and have diets with low iron bioavailability. Chatard et al.[82] provide a recent review of anaemia and iron deficiency in female athletes.

In the late 1980s and early 1990s typical dietary iron intakes of female athletes were less than the 1989 RDA of 15 mg/day,[52,80] whereas more recent studies report higher iron intakes in female athletes from diet alone.[21,22,32] For example, Beals and Manore[21] examined the diets of 24 female athletes classified with subclinical eating disorders (61% reported menstrual dysfunction) and

Table III. Strategies female athletes can use to identify and maintain a healthy bodyweight for their sport and to improve their overall diet (reprinted with permission from the Jacobs Institute of Women's Health[23,40])

I. Stress personal health, exercise performance and well-being, not an arbitrary weight goal
Less focus on the scales and more on healthy habits such as stress management, making good food choices, eating regular meals and snacks, and identifying a weight at which you feel good and perform well
Set realistic weight goals. Ask yourself the following questions: What is the maximum weight I find acceptable? What was the last weight I maintained without constantly dieting? How did I derive my goal weight? How much time each day do I spend thinking about my weight and body shape? At what weight do I perform best?
Mark progress by measuring changes in exercise performance and energy level, the prevention of injuries, normal menstrual function, and general overall well-being
Develop lifestyle changes that maintain a healthy weight for yourself – not your sport, coach, friends, parents, or to prove a point
II. Suggest the following realistic changes in diet and eating behaviours
Do not constantly deprive yourself of favourite foods or set unrealistic dietary rules or guidelines. Keep your dietary goals flexible and achievable. Remember that all foods can fit into a healthy lifestyle; however, some foods are chosen less frequently (e.g. desserts, a favourite food that may be high in fat). Do not develop 'good' and 'bad' food lists
If you need to reduce energy intake for weight loss, make these basic dietary changes (e.g. substitute lower fat foods for whole fat foods, reduce snacking on energy-dense foods, find strategies to prevent eating when you are not hungry). Make changes that fit into your lifestyle, and that you know you can achieve
If appropriate, reduce fat intake but remember a lower fat diet will not guarantee weight loss if a negative energy balance (reduced energy intake and increased energy expenditure) is not achieved
Eat more whole grains and cereals, beans, legumes and soy products
Eat five servings of fruits and vegetables daily
Make sure adequate dietary fibre is consumed (>25 g/day)
Do not skip meals or do not let yourself get too hungry
Consume fluids throughout the day, and before, during and after your exercise workout. Do not use dehydration as a means of reaching your bodyweight goal
Eat something for breakfast (e.g. a bagel, cereal and milk, juice, a piece of fruit). This will prevent you from being too hungry and overeating at lunch
Plan ahead and be prepared for when you might get hungry. Always have nutritious food available when and where you get hungry (e.g. an energy or granola [muesli] bar, fruit, dried fruit, crackers, a bagel)
Identify your own dietary weaknesses and plan a strategy for dealing with these difficult times
Remember that you are making life-long dietary changes that will result in weight loss or weight maintenance. You are not going on a diet that you will someday go off
Use a multivitamin and mineral supplement over single nutrient supplements unless recommended by a health professional. If you avoid animal products, iron, zinc and calcium supplements may be necessary

24 female athlete controls (33% reported menstrual dysfunction) using 7-day weighed food records. Although 20 to 30% of the athletes had low plasma ferritin levels, indicating stage 1 iron depletion, they had mean dietary iron intakes between 17 and 22 mg/day, close to or above the 2000 RDA of 18 mg/day.[83] Similarly, Kopp-Woodroffe et al.[22] examined iron status in four amenorrhoeic athletes and found that two were in stage 1 iron depletion (low ferritin levels) and one was in stage 3 iron deficiency anaemia. In this group, iron intakes ranged from 11.5 to 18.8 mg/day (mean 15.3 mg/day) using 7-day weighed food records. Although iron intakes may be at recommended amounts, much of this iron is from non-haem fortified foods such as breakfast cereal, energy and breakfast bars, and fat-free or low-fat snacks, which have low iron bioavailability.

Because of the high incidence of stage 1 iron deficiency in active women, assessment of iron status, including types of dietary iron sources, should be routinely done in the female athlete, including amenorrhoeic athletes. These individuals are still at risk for poor iron status and may need an iron supplement, even though iron losses from menses are not present and dietary iron intakes appear adequate.

3.2.4 Zinc

Mean dietary zinc intakes of active female athletes indicate that most have zinc intakes below the RDA of 8 mg/day.[21,83-86] The lower zinc intakes of active women are usually attributed to their lower intakes of animal products and their lower energy intakes. For example, Kopp-Woodroffe et al.[22] found that only one of the four amenorrhoeic athletes they examined consumed the RDA for zinc. For most of these women, meat intake was limited to less than two servings per week. Female athletes who avoid animal products and limit intakes of whole or fortified cereals and grains may need zinc supplements.

4. Recommendations

Table III outlines some strategies that female athletes can use to help identify and maintain a healthy bodyweight for their sport. This table also contains come general dietary recommendations that the active women can incorporate into her lifestyle to help improve her overall diet and health.

5. Conclusion

Menstrual dysfunction is common in active women, especially competitive athletes who participate in lean-build sports. Although the mechanism for this menstrual dysfunction has not yet been identified, it is now clear that negative energy balance, due to high energy expenditure and inadequate energy intake, is a major contributing factor. For some athletes, negative energy balance is due to purposeful energy restriction to either maintain or achieve a low bodyweight. Both the restrictive energy intake and the exercise-induced menstrual dysfunction that may result can have serious health consequences. Whenever energy is restricted, there is a high probability of poor nutritional status. For female athletes, intakes of protein, carbohydrate, essential fatty acids, pyridoxine, riboflavin, folate, calcium, magnesium, iron and zinc may be low. Some female athletes may need to supplement to achieve adequate intakes of these nutrients. Because athletes with menstrual dysfunction are at risk for poor bone density and osteoporosis, intakes of bone-building nutrients need to be carefully monitored for adequacy. Again, supplementation may be necessary, especially if dairy products are not used. Prolonged restriction of energy intake can also increase psychological stress and the risk of developing a clinical eating disorder. Regardless of menstrual status, female athletes need to meet the current DRIs for the micronutrients on a daily basis, especially the bone-building nutrients.

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