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FINA Consensus Meeting

Disordered eating and eating disorders in aquatic sports

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Abstract

Disordered eating behaviour (DE) and eating disorders (EDs) are of great concern due to their associations with physical and mental health risks and, in the case of athletes, impaired performance. The syndrome originally known as the Female Athlete Triad, which focused on the interaction of energy availability, reproductive function and bone health in female athletes, has recently been expanded to recognise that Relative Energy Deficiency in Sport (RED-S) has a broader range of negative effects on body systems with functional impairments in both male and female athletes. Athletes in leanness-demanding sports have an increased risk for RED-S and for developing EDs/DE. Special risk factors in aquatic sports related to weight and body composition management include the wearing of skimpy and tight-fitting bathing suits, and in the case of diving and synchronized swimming, the involvement of subjective judgements of performance. The reported prevalence of DE and EDs in athletic populations including athletes from aquatic sports ranges from 18-45 % in female athletes and 0-28 % in male athletes. To prevent EDs, aquatic athletes should practice healthy eating behaviour at all periods of development pathway, with coaches and members of the athletes' health care team being able to recognize early symptoms indicating risk for energy deficiency, DE and EDs. Coaches and leaders must accept that DE/EDs can be a problem in aquatic disciplines and that openness regarding this challenge is important.

Keywords: *(3-6 words) Disordered eating continuum, diving, synchronized swimming, swimming*

Introduction

In many sports body weight and body composition are crucial variables for performance (Ackland et al., 2012). Many elite athletes struggle with disordered eating (DE) behaviour and eating disorders (EDs) as they attempt to conform to the "ideal" body in their sport (Sundgot-Borgen and Garthe, 2011). Persistent restricted energy intake and low energy availability (EA) with or without DE/EDs are associated with changes in the endocrine system affecting metabolism and function of many body systems in both female and male athletes (Warren, 2011). Discussion on the syndrome originally known as the Female Athlete Triad, which focused on the interaction of energy availability, reproductive function and bone health in female athletes (Nattiv et al., 2007) has recently been expanded with the instigation of an umbrella term Relative Energy Deficiency in Sport (RED-S) (International Olympic Committee, 2014). This term more accurately recognises the additional range of effects on other body systems (e.g. immune system, cardiovascular health, muscle protein synthesises) with a range of functional outcomes (e.g. increased illness and injury risks, impaired performance) in both male and female athletes (International Olympic Committee, 2014). In general, DE and EDs are of great concern due to their associations with physical and mental health risks (Presnell et al., 2009; Swanson et al., 2011) and, for most athletes, these conditions are also associated with impaired performance (Torstveit and Sundgot-Borgen, 2013).

Some sports seem to be more "at-risk sports" for development of DE or EDs due to the focus on weight categories, a thin pre-pubertal appearance, or a clearly defined muscularity with low percentage of body fat (Greydanus et al., 2010; Sundgot-Borgen et al., 2013). Sports including gymnastics, diving and synchronized swimming can be labelled "leanness-demanding" since they are aesthetically judged sports with emphasis on a lean appearance

(Ackland et al., 2012; Meyer et al., 2013). Athletes who participate in endurance sports, such as distance running, cycling and swimming and sports that implement weight categories for competition, such as lightweight rowing and wrestling, also struggle with issues surrounding weight and body composition. Athletes in these sports are considered at high risk for developing RED-S, including the involvement of DE and EDs (Greydanus et al., 2010;Torstveit and Sundgot-Borgen, 2013). Risk factors associated for the development of poor eating habits in swimmers include an intense exercise pattern and/or experience of pressure to achieve a low body weight (Greydanus et al., 2010). The pressure that comes with the perception held by many top swim coaches; that lower body weight and body fat improves swimming times (Thompson and Sherman, 2010), increases the risk for restricted eating behaviour and for developing DE/EDs (Torstveit and Sundgot-Borgen, 2013). A negative self-image regarding appearance and perception of how others evaluate their physique have been reported among adolescent competitive synchronized swimmers compared to athletes in sports with no emphasis on leanness and non-athletic controls (Ferrand et al., 2005a). There is also evidence that swimmers often feel pressure to lose weight and that they may be especially vulnerable to DE due to the display of their bodies in tight and revealing swim suits (Benson et al., 1990). Furthermore, there is also considerable research suggesting that revealing sport attire contributes to unhealthy body image and dieting, and also facilitates it by making unhealthy body comparisons easier (Reel and Gill, 2001;Steinfeldt et al., 2013).

Despite the risk factors associated with various aspects of aquatic sports for DE and ED, the absence of comprehensive analyses of the specific problems in these sports is noted, as is the lack of recommendations on how to prevent and manage these issues. The aim of this review is to address these gaps in knowledge and practice by 1. defining the DE continuum and

reviewing the prevalence of DE/EDs, 2. summarizing the risk factors and consequences that are generally associated with RED-S and finally, 3. suggesting strategies for the management and prevention of DE/EDs in athletes competing in diving, synchronized swimming and swimming.

The disordered eating continuum

Most EDs typically begin as a voluntary restriction of food intake, where the restricted eating behaviour progresses to chronic dieting and frequent weight fluctuation, with increasingly pathological eating and weight-control behaviours with/or without excessive exercise (Torstveit and Sundgot-Borgen, 2013). The DE continuum therefore starts with appropriate eating and exercise behaviours, including healthy periodic dieting or occasional use of more extreme weight loss methods such as short-term restrictive diets with low EA (<125 kJ (30 kcal)/kg fat free mass (FFM)/per day) (Sundgot-Borgen and Torstveit, 2010a). Energy availability is defined as the availability of metabolic fuels (glucose and fatty acids) for basal physiological function when the exercise energy expenditure has been subtracted from total energy intake (Loucks and Thuma, 2003; Loucks et al., 2011). In healthy young adults, the average energy intake for weight stable women has been reported to be ~189 ±25 kJ (45 ±6 kcal)/kg fat free mass (FFM)/day (Loucks et al., 1998; Loucks and Thuma, 2003; Loucks et al., 2011). Meanwhile, exposure of as little as five days of low EA has been shown to reduce blood glucose levels and carbohydrate availability, suppress the pulsatility of gonadotropin releasing hormone (GnRH), reduce hypothalamic-pituitary-axis hormones like triiodothyronine (T_3) and oestrogen, and elevate cortisol (Loucks and Thuma, 2003).

At the end of the DE behaviour continuum are the overt clinical EDs where the athlete struggles with abnormal eating behaviours, distorted body image, weight fluctuation and

extreme dieting with regular use of pathological compensatory strategies such as fasting, dehydration, purging e.g. vomiting, laxatives and weight loss drugs (Torstveit and Sundgot-Borgen, 2013).

Diagnostic criteria

The athlete with DE is usually preoccupied with achieving a low body weight or a perceived "ideal body composition" to compensate for a strong dissatisfaction with body image or experienced discrepancy from the "ideal" sport specific body image. Athletes with DE often continuously feel too fat for their sport and the DE might intensify to such a degree that the athlete meets the criteria for a clinical ED. Athletes can be underweight, normal weight or overweight, irrespective of the presence of extreme dieting periods or EDs (Torstveit and Sundgot-Borgen, 2011).

Using the previous (DSM-IV-TR) diagnostic criteria as a framework, the most frequently reported ED diagnosis among elite athletes has been that of an ED not otherwise specified (EDNOS). Relatively few elite athletes meet the specific criteria for bulimia nervosa and especially for anorexia nervosa from this diagnostic tool (Sundgot-Borgen and Torstveit, 2004; Martinsen and Sundgot-Borgen, 2013). The recently updated diagnostic manual (DSM-V) now recognises clinical EDs of anorexia nervosa, bulimia nervosa, binge eating disorder and other specified and unspecified feeding or ED (OSFED) (American Psychiatric Association, 2013). These ED have many features in common, and patients/athletes frequently move between the diagnoses (Sundgot-Borgen and Torstveit, 2010a). The criteria for these disorders are listed in Tables 1-4, and a short description of the disorders and the changes in the new DSM-V criteria follows below.

Anorexia nervosa primarily affects adolescent girls and young women and is characterized by distorted body image with a pathological fear of becoming fat that leads to excessive dieting and severe weight loss. The DSM-V criteria (American Psychiatric Association, 2013) have several minor but important changes from the DSM-IV-TR criteria (American Psychiatric Association, 1994). Criterion A focuses on behaviour like restricting calorie intake and no longer includes the word "refusal" in terms of maintaining body weight, since that implies intention on the part of the patient and can be difficult to assess. Criterion D from the DSM-IV-TR which required amenorrhea or the absence of at least three menstrual cycles, as well as the weight criterion, has also been removed.

Bulimia nervosa is characterized by frequent episodes of binge eating followed by behaviours to avoid weight gain such as self-induced vomiting, abuse of laxatives, diuretics or other medications, fasting, or excessive exercise. The number of binge episodes to meet the diagnostic criteria for bulimia nervosa has been reduced from three to one time per week in the DSM-V version.

Binge eating disorder is defined as recurring episodes of eating significantly more food in a short period of time than most people would eat under similar circumstances, with episodes marked by feelings of lack of control. The person may have feelings of guilt, embarrassment, or disgust and may binge eat alone to hide the behaviour. This disorder is associated with marked distress and occurs, on average, at least once a week over three months. This change from the DSM-IV-TR is intended to increase awareness of the substantial differences between binge eating disorder and the common phenomenon of overeating. While overeating is a challenge for many, recurrent binge eating is much less common, far more severe and is associated with significant physical and psychological problems.

Other Specified (or Unspecified) Feeding or Eating Disorder acknowledges the existence and importance of a variety of eating disturbances that do not necessarily fall into the specific category of anorexia nervosa, bulimia nervosa, or binge eating disorder. Such eating disturbances can cause clinically significant distress or impairment in social, occupational, or other important areas of functioning (American Psychiatric Association, 2013).

As a result of the new categories such as OSFED and binge eating disorder; and the changed criteria for anorexia nervosa and bulimia nervosa, many patients or athletes who previously would have been diagnosed with EDNOS, will be reassigned with a diagnosis of greater clinical utility (Call et al., 2013). These changes will hopefully increase the possibility for earlier treatment and therefore a better prognosis.

Prevalence of disordered eating and eating disorders

The reported prevalence of DE and EDs in athletic populations from a number of sports including aquatic sports ranges from 18-45% in female athletes (Sundgot-Borgen 1994; Nichols et al., 2007; da Costa et al., 2013), and 0-28% % in male athletes (Torstveit and Sundgot-Borgen, 2005b). Studies aiming to investigate the prevalence of DE or EDs among female athletes where *all* or a large proportion of the subjects included are from aquatic disciplines are shown in Table 5, while there are no such studies involving male athletes from aquatic sports. The wide range in reported prevalence may be explained by differences in methodological factors such as definitions of DE and EDs and assessment tools as well as differences in athlete characteristics (e.g. age, performance level) and sport disciplines. It has been claimed that the prevalence seems to be higher in elite athletes than in athletes at lower competitive level and controls (Byrne and McLean, 2001; Byrne and McLean, 2002; Sundgot-Borgen and Torstveit, 2010b). Furthermore, athletes seem to be in more advanced

stages of the DE behaviour continuum (i.e. showing a higher frequency of menstrual dysfunction) in comparison with non-athletes (Coelho et al., 2010).

Risk factors for developing energy deficiency, disordered eating or eating disorders

Scientific evidence and clinical experience show that the etiological factor underpinning the RED-S is an energy deficiency, relative to the balance between dietary energy intake and the energy expenditure required to support homeostasis, health and the activities of daily living, growth and sporting activities (International Olympic Committee, 2014). However, it is important to realise that in theory and in practice, there are several ways that energy deficiency develops that might affect both the type and severity of the outcomes.

The most prevalent cause of RED-S appears to be DE or EDs in which the energy deficiency produced by under-eating and/or over-exercising is underpinned by the psychopathology described above. Predisposition to develop an ED is dependent on sociocultural, demographic, environmental, biological, psychological and behavioural factors (Sundgot-Borgen et al., 2013). Important risk factors for DE seen in athletes include personality factors such as perfectionism and pressure to lose weight, frequent weight cycling, and early start of sport-specific training, overtraining, injuries, and certain coaching behaviours (Sundgot-Borgen and Torstveit, 2010a).

Other causes of a mismatch between energy intake and exercise energy expenditure may occur without such a psychological overlay. In some cases, they represent a well-intentioned, and even well-justified, program to reduce body mass or body fat, whereby the athlete engineers a large energy deficit to achieve their goals quickly, without awareness of the secondary consequences of their endeavours. In this scenario, where the weight loss

behaviour is rational, but misinformed or mismanaged, evidence based recommendations for weight loss or changes in body composition overseen by professionals should be used (Sundgot-Borgen and Garthe, 2011). The final scenario involves the athlete with an extreme exercise commitment who is unaware of its energy cost or unable to consume sufficient food to match it. There is some evidence that appetite does not always track energy expenditure at high or unaccustomed levels of exercise/activity, representing a situation of inadvertent energy deficiency (Stubbs et al., 2004). It is possible that high volume exercise has a suppressive effects on appetite rather than the converse; additional lifestyle or practical factors that can exacerbate this problem include the inhibitory effect of fatigue on the effort required to obtain and prepare food, the difficulty of consuming large amounts of bulky fibre-rich high-carbohydrate foods, and reduced opportunities for food-related activities on days in which a substantial number of hours is devoted to exercise (Burke, 2014).

Health consequences of energy deficiency, disordered eating and eating disorders

The physiological and medical complications and the effect on performance that are associated with DE/EDs depend upon the severity and/or duration and frequency of energy deficiency, the amount of weight loss, rate and composition of weight loss, and the electrolyte imbalance induced by dehydration or purging. Most physiological consequences of an ED are due to persistent low EA (Nattiv and et al., 2007), and will be subsequently described. There will be additional health consequences in athletes who engage in binge-eating and purging, with complications such as dehydration, acid-base abnormalities, and cardiac rhythm disturbances (Carney and Andersen, 1996;Thompson and Sherman, 2010). Both starvation and purging are physiological stressors and, as such, produce an -up-regulation of the hypothalamic–pituitary–adrenal axis and an increase in the adrenal hormones cortisol, epinephrine and norepinephrine. These hormones have a stimulatory

effect on the central nervous system that can mask fatigue and evoke feelings of euphoria in athletes with EDs (Beals, 2004).

Typical consequences of persistent energy deficiency with or without an ED are reproductive dysfunction, impaired bone health, and decreased resting metabolic rate, increased cardiovascular risk factors, gastrointestinal problems, and deficiencies/suboptimal status of micronutrients such as iron and calcium (Eichner, 1992; Beals, 2004; Rickenlund et al., 2005; Nattiv and et al., 2007; Rauh et al., 2010). The prevalence of menstrual disturbances in female athletes varies widely depending on the type of sport and is reported to be as high as 69% in weight-sensitive sports (Beals and Hill, 2006) in comparison with 3-25 % in control groups (Coelho et al., 2010). The prevalence of menstrual dysfunction and impaired bone health in female elite athletes competing in weight-sensitive sports is higher than that among female athletes representing sports that are less sensitive to the effects of body weight (Coelho et al., 2010; Rauh et al., 2010). In addition, it is evident that energy deficiency, suppressed hormonal activity and reduced BMD also affect male athletes (Hetland et al., 1993; Smathers et al., 2009; Dolan et al., 2012). For example, Smathers et al. found that 9 % of male competitive cyclists and 3 % of age- and body mass- matched controls were classified as osteoporotic; while as many as 25 % of the cyclists compared to 10 % of the controls had low BMD (Smathers et al., 2009).

Achievement and maintenance of optimal BMD depend upon a combination of mechanical, hormonal and dietary factors (Lebrun, 2007). Adequate hormonal status and nutritional support (calcium, protein, and other bone-building materials), are essential especially during adolescence (Barrack et al., 2010). Mudd et al. (2007) investigated BMD among collegiate female athletes and found that swimmers and divers had significantly lower average leg

BMD than athletes in all other sports except runners and rowers ($P < 0.001$). Among Norwegian elite athletes, athletes competing in low impact sports (such as swimmers and underwater rugby athletes) were found to have lower BMD values in all measurement sites as compared to athletes competing in high impact sports (Torstveit and Sundgot-Borgen, 2005a). Whether these findings are due to insufficient mechanical load, low EA, DE or EDs is not known due to the cross sectional design of the studies, however, the latter study found that Norwegian athletes with EDs had 3–5% lower total body and lumbar spine BMD compared with athletes without EDs.

Although the health consequences of RED-S appear clear to professionals, to a young athlete, the lack of an immediate consequence may fail to provide sufficient incentive to change behaviour. Therefore, it is important to identify issues that are of more direct relevance to athletes, particularly factors that affect their capacity to perform well in competition. Illness and injury are two such concerns, with the training programs of many athletes already walking a fine line between providing the maximum stimulus to optimise adaptive outcomes and doing too much to substantially increase the risk of illness and injury. Both problems can be career limiting or threatening if they interrupt the consistency of the athlete's training or occur at a critical time such as just before or during a competition phase. Some studies provide evidence of increased problems in athletes who have restricted energy intakes or dietary restraint. For example, a survey of male and female Olympic athletes found that those who participated in lean-build sports such as diving and attempted to lose weight/body fat more frequently reported a greater prevalence of upper respiratory tract infections in the 3 months prior to the investigation than their counterparts from non-lean sports (38 % versus 22 %, $P < 0.05$) (Hagmar et al., 2008). Furthermore, high-school athletes who were found to have DE problems were twice as likely as their counterparts with normal eating behaviour to

have a sports-related musculoskeletal injury during a sports season (Thein-Nissenbaum et al., 2011).

Of course, the issue that is most likely to attract the attention of an athlete is his or her performance. A recent systematic review including 20 studies concluded that EDs have a negative effect on both physical fitness and sport performance via low EA, excessive loss of fat and lean mass, dehydration, and electrolyte disturbance (El et al., 2013). While few studies including elite athletes are available, a recent study provides information that is highly relevant to aquatic athletes. Elite junior female swimmers were monitored over a 12 week training program, comparing the sub-group of swimmers who had regular menstrual function with another who displayed ovarian suppression of their cycles (VanHeest et al., 2013). The group with disturbed menstrual function reported lower energy intake and availability, with evidence of energy deficiency being confirmed via measurements of resting energy expenditure (depressed) and T_3 and IGF-1 concentrations, which dropped over the course of the study during the heavy training phase. At the start of the study, the groups were matched for performance (400 m swim time); however, only the healthy group improved over the training period (an 8% increase in speed) while the energy deprived swimmers showed a 10 % decline in swimming speed. More investigations of this kind are encouraged.

Management and prevention

Specific strategies to prevent, detect and treat EDs in athletes can include surveillance, research, medical care, and public and professional education. Since sports not focusing on body weight or leanness seem to have the lowest prevalence of EDs (Sundgot-Borgen, 1994; Sundgot-Borgen and Torstveit, 2010), it is important to minimize the focus on weight and instead ensure a supportive environment that encourages athletes to practice training regimes

and eating behaviour that promote optimal performance. Coaches and health care teams should also be aware of other well-known triggers for the onset of EDs, such as a sudden increase in training volume or injuries (Sundgot-Borgen, 1994), and take care to prevent restricted eating behaviour and dieting and to emphasize the importance of adequate nutrition support in these situations.

If measurement of body weight and body composition is used in aquatic sports, it should be performed by a certified health care professional using a validated method in a standardized setting (Meyer et al., 2013). Preferably, anthropometric assessment should be performed in the context of other relevant sport specific strength and/or performance tests to prevent focus on body weight and body composition as the only performance enhancing factor (Meyer et al., 2013). It is highly recommended that optimal targets for body weight and body composition are set individually, since excessive leanness might compromise health and performance in one athlete, while the same body composition and body weight might enhance performance in another athlete without adversely affecting health (Meyer et al., 2013). A study investigating associations between body composition, biochemical parameters, and food intake in adolescent female swimmers, found that with those with DE had greater body fat percentage and fat mass than swimmers without DE (da Costa et al., 2013). Similarly, in a study on swimmers, EA and performance, the subgroup that were found to have low EA were heavier and had higher body fat than their counterparts (Van Heest et al., 2013). These findings indicate that a low body fat/weight or weight loss should not be considered as a prerequisite or marker of DE or energy deficiency, and that any signs of an apparent mismatch between energy intake and energy expenditure should be followed up for greater investigation.

There are several reasons for increasing the focus on the nutritional status of young aquatic athletes. Overall, adolescence is considered the most vulnerable time for developing DE as a result of the biological changes, peer pressure, societal drive for thinness, and body image preoccupation that occur during puberty (Ferreiro et al., 2012), and it is suggested that adolescents in the general population account for 40 % of new cases of EDs (Herpertz-Dahlmann et al., 2011). In addition, younger athletes are more likely to suffer from endocrine impairment following periods of low EA than females with an established menstrual cycle (Loucks 2006). Since adolescence is a time of skeletal growth, the effects of impaired bone health are likely to be pronounced (Hurvitz and Weiss, 2009).

Early detection and intervention of low EA including EDs are important in order to prevent long-term health consequences such as impaired bone health (Nattiv and et al., 2007; Rauh et al., 2010), but also to optimize immediate goals for performance and recovery (Nattiv and et al., 2007; Rauh et al., 2010). It is important that athletes with EDs are considered ill and receive proper medical, nutritional and psychiatric treatment (Bratland-Sanda and Sundgot-Borgen, 2013). In addition, when medically cleared, athletes are in need of close follow-up (Sherman and Thompson, 2006; Nattiv and et al., 2007). Increased knowledge among coaches and medical personal in aquatic sports of early symptoms indicating risk for RED-S with or without DE or EDs is therefore crucial.

Conclusions

The DE continuum ranges from appropriate eating and exercise behaviours and occasional use of short-term restrictive diets to overt EDs with pathological eating and weight-control behaviours with/or without excessive exercise. Important risk and trigger factors of DE include perfectionism and pressure to lose weight, frequent weight cycling, and early start of

sport-specific training, overtraining, injuries, and certain coaching behaviours. The prevalence of conditions related to RED-S including EDs is high among athletes in sports that emphasize leanness such as synchronized swimming, diving and swimming. Typical consequences of persistent energy deficiency with or without an ED are reproductive dysfunction, impaired bone health, decreased resting metabolic rate, an increase in cardiovascular risk factors, and gastrointestinal problems. To prevent RED-S, aquatic athletes have to practice healthy eating behaviour and coaches and athletes' health care teams must be able to recognize early symptoms indicating risk for energy deficiency, DE and EDs. Coaches and leaders must accept that DE/EDs can be a problem in aquatic disciplines and that openness regarding this challenge is important.

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References

Ackland, T R., Lohman, T G., Sundgot-Borgen, J., Maughan, R J., Meyer, N L., Stewart, A D., Muller, W. (2012). Current status of body composition assessment in sport: review and position statement on behalf of the ad hoc research working group on body composition health and performance, under the auspices of the I.O.C. Medical Commission. *Sports Medicine*, 42(3), 227-249.

American Psychiatric Association (1994). In: *Diagnostic and Statistical Manual of Mental Disorders*. Washington DC, 539-550.

American Psychiatric Association (2013). Feeding and Eating Disorders. In: *Diagnostic and Statistical Manual of Mental Disorders*. Washington DC, 5th, 329-354.

Anderson, C. and Petrie, T A. (2012). Prevalence of disordered eating and pathogenic weight control behaviors among NCAA division I female collegiate gymnasts and swimmers. *Research Quarterly for Exercise and Sport*, 83(1), 120-124.

Barrack, M T., Van Loan, M D., Rauh, M J., Nichols, J F. (2010). Physiologic and behavioral indicators of energy deficiency in female adolescent runners with elevated bone turnover. *American Journal of Clinical Nutrition* , 92(3), 652-659.

Beals, K A. (2004). Effects of disordered eating. In: *Disordered eating among athletes - a comprehensive guide for health professionals*. Human Kinetics, Champaign IL, 67-98.

Beals, K A. and Hill, A K. (2006). The prevalence of disordered eating, menstrual dysfunction, and low bone mineral density among US collegiate athletes. *International Journal of Sport Nutrition and Exercise Metabolism* , 16(1), 1-23.

Benson, J E., Allemann, Y., Theintz, G E., Howald H. (1990). Eating problems and calorie intake levels in Swiss adolescent athletes. *International Journal of Sports Medicine*, 11(4), 249-252.

Bratland-Sanda, S. and Sundgot-Borgen, J. (2013). Eating disorders in athletes: overview of prevalence, risk factors and recommendations for prevention and treatment. *European Journal of Sport Sciences*, 13(5), 499-508.

Burke, L M. (2013). An update view on energy availability in the Female Athlete Triad. *British Journal of Sports Medicine* (in review).

Byrne, S. and McLean, N. (2001). Eating disorders in athletes: a review of the literature. *Journal of Science in Medicine and Sport*, 4(2), 145-159.

Byrne, S. and McLean N. (2002). Elite athletes: effects of the pressure to be thin. *Journal of Sciences in Medicine and Sport*, 5(2), 80-94.

Call, C., Walsh, B T., Attia, E. (2013). From DSM-IV to DSM-5: changes to eating disorder diagnoses. *Current Opinions in Psychiatry*, 26(6), 532-536.

Carney, C P. and Andersen, A E. (1996). Eating disorders. Guide to medical evaluation and complications. *Psychiatric Clinics of North America*, 19(4), 657-679.

Coelho, G M., Soares, E A., Ribeiro, B G. (2010). Are female athletes at increased risk for disordered eating and its complications? *Appetite*, 55(3), 379-387.

da Costa, N F., Schtscherbyna, A., Soares, E A., Ribeiro, B G. (2013). Disordered eating among adolescent female swimmers: dietary, biochemical, and body composition factors. *Nutrition* , 29(1), 172-177.

Dolan, E., McGoldrick, A., Davenport, C., Kelleher, G., Byrne, B., Tormey, W., Smith, D., Warrington, G D. (2012). An altered hormonal profile and elevated rate of bone loss are associated with low bone mass in professional horse-racing jockeys. *Journal of Bone and Mineral Metabolism*, 30(5), 534-542.

Eichner, E R. (1992). General health issues of low body weight and undereating in athletes. In: Eating, body weight and performance in athletes: *Disorders of modern society*. (Eds. Brownell KD, Rodin J, Wilmore JH). Lea and Febiger, Philadelphia, 191-201.

El, G M., Soave, F., Calugi, S., Dalle, G R. (2013). Eating disorders, physical fitness and sport performance: a systematic review. *Nutrients*, 5(12), 5140-5160.

Ferrand, C., Champely, S., Brunel, P C. (2005a). Relations between female students' personality traits and reported handicaps to rhythmic gymnastics performance. *Psychological Reports*, 96(2), 361-373.

Ferrand, C., Magnan, C., Philippe, R A. (2005b). Body-esteem, body mass index, and risk for disordered eating among adolescents in synchronized swimming. *Perceptual and Motor Skills*, 101(3), 877-884.

Ferreiro, F., Seoane, G., Senra, C. (2012). Gender-related risk and protective factors for depressive symptoms and disordered eating in adolescence: a 4-year longitudinal study. *Journal of Youth and Adolescence*, 41(5), 607-622.

Greydanus, D E., Omar, H., Pratt, H D. (2010). The adolescent female athlete: current concepts and conundrums. *Pediatric Clinics of North America*, 57(3), 697-718.

Hagmar, M., Hirschberg, A L., Berglund, L., Berglund, B. (2008). Special attention to the weight-control strategies employed by Olympic athletes striving for leanness is required. *Clinical Journal of Sport Medicine*, 18(1), 5-9.

Herpertz-Dahlmann, B., Buhren, K., Seitz, J. (2011). Anorexia nervosa in childhood and adolescence: course and significance for adulthood. *Nervenarzt*, 82(9), 1093-1099.

Hetland, M L., Haarbo, J., Christiansen, C. (1993). Low bone mass and high bone turnover in male long distance runners. *Journal of Clinical Endocrinology and Metabolism*, 77(3), 770-775.

Hurvitz, M. and Weiss, R. (2009). The young female athlete. *Pediatric Endocrinology Reviews*, 7(2), 43-49.

International Olympic Committée Position Statement, *British Journal of Sports Medicine*, In press.

Jackson, A S. and Pollock, M L. (1985). Practical assessment of body compositon. *Physician and Sportsmedicine*, 13, 76-90.

Lebrun, C M. (2009). The female athlete triad: what's a doctor to do? *Current Sports Medicine Reports*, 6(6). 397-404.

Loucks, A B. (2006). The response of luteinizing hormone pulsatility to 5 days of low energy availability disappears by 14 years of gynecological age. *Journal of Clinical Endocrinology and Metabolism*, 91, 3158-3164.

Loucks, A B., Kiens, B., Wright, H H. (2011). Energy availability in athletes. *Journal of Sports Sciences*, 29, 7-15.

Loucks, A B. and Thuma, J R. (2003). Luteinizing hormone pulsatility is disrupted at a threshold of energy availability in regularly menstruating women. *Journal of Clinical Endocrinology and Metabolism*, 88(1), 297-311.

Loucks, A B., Verdun, M., Heath, E M. (1998). Low energy availability, not stress of exercise, alters LH pulsatility in exercising women. *Journal of Applied Physiology*, 84(1), 37-46.

Martinsen, M. and Sundgot-Borgen, J. (2013). Higher prevalence of eating disorders among adolescent elite athletes than controls. *Medicine and Science in Sports and Exercise*, 45(6), 1188-1197.

Meyer, N L., Sundgot-Borgen, J., Lohman, T G., Ackland, T R., Stewart, A D., Maughan, R J., Smith, S., Muller, W. (2013). Body composition for health and performance: a survey of body composition assessment practice carried out by the Ad Hoc Research Working Group on Body Composition, Health and Performance under the auspices of the IOC Medical Commission. *British Journal of Sports Medicine*, 47(16), 1044-1053.

Mudd, L M., Fornetti, W., Pivarnik, J M. (2007). Bone mineral density in collegiate female athletes: comparisons among sports. *Journal of Athletic Training*, 42(3), 403-408.

Nattiv, A., Loucks A B., Manore, M M., Sanborn, C F., Sundgot-Borgen, J., Warren, M P. (2007). The female athlete triad. *Medicine and Science in Sports and Exercise*, 39(10), 1867-1882.

Nichols, J F., Rauh, M J., Barrack, M T., Barkai, H S., Pernick, Y. (2007). Disordered eating and menstrual irregularity in high school athletes in lean-build and nonlean-build sports. *International Journal of Sport Nutrition and Exercise Metabolism*, 17(4), 364-377.

Presnell, K., Stice, E., Seidel, A., Madeley, M C. (2009). Depression and eating pathology: prospective reciprocal relations in adolescents. *Clinical Psychology and Psychotherapy*, 16(4), 357-365.

Rauh, M J., Nichols, J F., Barrack, M T. (2010). Relationships Among Injury and Disordered Eating, Menstrual Dysfunction, and Low Bone Mineral Density in High School Athletes: A Prospective Study. *Journal of Athletic Training*, 45(3), 243-252.

Reel, J J. and Gill, D L. (2001). Slim enough to swim? Weight pressures for competitive swimmers and coaching implications. *Sport Journal*, 4(1), 5.

Rickenlund, A., Eriksson, M J., Schenck-Gustafsson, K., Hirschberg, A L. (2005). Amenorrhea in female athletes is associated with endothelial dysfunction and unfavorable lipid profile. *Journal of Clinical Endocrinology and Metabolism*, 90(3), 1354-1359.

Schtscherbyna, A., Soares, E A., de Oliveira, F P., Ribeiro, B G. (2009). Female athlete triad in elite swimmers of the city of Rio de Janeiro, Brazil. *Nutrition*, 25(6), 634-639.

Sherman, R T. and Thompson, R A. (2006). Practical use of the International Olympic Committee Medical Commission Position Stand on the Female Athlete Triad: a case example. *International Journal of Eating Disorders*, 39(3), 193-201.

Smathers, A M., Bemben, M G., Bemben, D A. (2009. Bone density comparisons in male competitive road cyclists and untrained controls. *Medicine and Science in Sports and Exercise*, 41(2), 290-296.

Steinfeldt, J A., Zakraisek, R A., Bodey, K J., Middendorf, K G., Martin, S B. (2013). Role of uniforms in the body image of female college volleyball players. *Counseling Psychologist*, 41, 791-819.

Stubbs, R J., Hughes, D A., Johnstone, A M., Whybrow, S., Horgan, G W., King, N., Blundell, J. (2004). Rate and extent of compensatory changes in energy intake and expenditure in response to altered exercise and diet composition in humans. *American Journal of Physiology-Regulatory Integrative and Comparative Physiology*, 286(2), 350-358.

Sundgot-Borgen, J. and Garthe, I. (2011). Elite athletes in aesthetic and Olympic weight-class sports and the challenge of body weight and body compositions. *Journal of Sports Sciences,* 29. Suppl 1, 101-114.

Sundgot-Borgen, J., Meyer, N L., Lohman, T G., Ackland, T R., Maughan, R J., Stewart, A D., Muller, W. (2013). How to minimise the health risks to athletes who compete in weight-sensitive sports review and position statement on behalf of the Ad Hoc Research Working Group on Body Composition, Health and Performance, under the auspices of the IOC Medical Commission. *British Journal of Sports Medicine*, 47(16), 1012-1022.

Sundgot-Borgen, J. and Torstveit, M K. (2004). Prevalence of eating disorders in elite athletes is higher than in the general population. *Clinical Journal of Sport Medicine,* 14(1), 25-32.

Sundgot-Borgen, J. and Torstveit, M K. (2010a). Aspects of disordered eating continuum in elite high-intensity sports. *Scandinavian Journal of Medicine and Science in Sports*, 20, Supplement, 112-121.

Sundgot-Borgen J. (1994). Risk and Trigger Factors for the Development of Eating Disorders in Female Elite Athletes. *Medicine and Science in Sports and Exercise,* 26(4), 414-419.

Sutton, L. and Stewart, A D. (2012). A professional discipline and inter-disciplinary toolkit. In: *Body composition in sport, exercise and health*. (Eds. Stewart AD, Sutton L). Routledge, Abingdon,UK,187-208.

Swanson, S A., Crow, S J., Le, G D., Swendsen, J., Merikangas, K R. (2011). Prevalence and correlates of eating disorders in adolescents. Results from the national comorbidity survey replication adolescent supplement. *Archives of General Psychiatry*, 68(7), 714-723.

Thein-Nissenbaum, J M., Rauh, M J., Carr, K E., Loud, K J., McGuine, T A. (2011). Associations between disordered eating, menstrual dysfunction, and musculoskeletal injury among high school athletes. *Journal of Orthopaedic & Sports Physical Therapy*, 41(2), 60-69.

Thompson, R A. and Sherman, R T. (2010). *Eating disorders in sport*. Routledge

Torstveit, M K. and Sundgot-Borgen, J. (2005). Low bone mineral density is two to three times more prevalent in non-athletic premenopausal women than in elite athletes: a comprehensive controlled study. *British Journal of Sports Medicine*, 39(5): 282-287.

Torstveit, M K. and Sundgot-Borgen, J. (2005). The female athlete triad exists in both elite athletes and controls. *Medicine and Science in Sports and Exercise*, 37(9), 1449-1459.

Torstveit, M K., Sundgot-Borgen, J. (2011). Are Under- and Overweight Female Elite Athletes Thin and Fat? A controlled study. *Medicine and Science in Sports and Exercise*, 44(5), 949-957.

Torstveit, M K. and Sundgot-Borgen J. (2013). Eating disorders in male and female athletes. In: *Clinical Encyclopaedia of Sports Nutrition*. Ed. International Olympic Committee.

Van Heest, J L., Rodgers, C D., Mahoney, C E., De Souza, M J. (2014). Ovarian Suppression Impairs Sport Performance in Junior Elite Female Swimmers. *Medicine and Science in Sports and Exercise*, 46(1):156-66

Warren, M P. (2011). Endocrine manifestations of eating disorders. *Journal of Clinical Endocrinology and Metabolism*, 96(2), 333-343.

Table 1. *DSM-V diagnostic criteria for anorexia nervosa.*

DIAGNOSTIC CRITERIA FOR ANOREXIA NERVOSA
A. Restriction of energy intake relative to requirements leading to a significantly low body weight in the context of age, sex, developmental trajectory, and physical health
B. Intense fear of gaining weight or becoming fat, even though underweight
C. Disturbance in the way in which one's body weight or shape is experienced, undue influence of body weight or shape on self-evaluation, or denial of the seriousness of the current low body weight

Table 2. *DSM-V diagnostic criteria for bulimia nervosa.*

DIAGNOSTIC CRITERIA FOR BULIMIA NERVOSA
A. Recurrent episodes of binge eating characterized by <u>both</u> of the following: 1. Eating in a discrete amount of time (within a 2 hour period) large amounts of food 2. Sense of lack of control over eating during an episode
B. Recurrent inappropriate compensatory behaviour in order to prevent weight gain (purging)
C. The binge eating and compensatory behaviours both occur, on average, at least once a week for three months
D. Self-evaluation is unduly influenced by body shape and weight
E. The disturbance does not occur exclusively during episodes of anorexia nervosa

Table 3. *DSM-V diagnostic criteria for binge-eating disorder.*

DIAGNOSTIC CRITERIA FOR BINGE-EATING DISORDER
A. Recurrent episodes of binge eating. An episode of binge eating is characterized by both of the following: 1. Eating, in a discrete period of time (for example, within any 2-hour period), an amount of food that is definitely larger than most people would eat in a similar period of time under similar circumstances 2. A sense of lack of control over eating during the episode (for example, a feeling that one cannot stop eating or control what or how much one is eating)
B. The binge-eating episodes are associated with three (or more) of the following: 1. Eating much more rapidly than normal 2. Eating until feeling uncomfortably full 3. Eating large amounts of food when not feeling physically hungry 4. Eating alone because of feeling embarrassed by how much one is eating 5. Feeling disgusted with oneself, depressed, or very guilty afterwards
C. Marked distress regarding binge eating is present
D. The binge eating occurs, on average, at least once a week for three months
E. The binge eating is not associated with the recurrent use of inappropriate compensatory behavior (for example, purging) and does not occur exclusively during the course Anorexia Nervosa, Bulimia Nervosa, or Avoidant/Restrictive Food Intake Disorder

Table 4. *Examples of presentations that can be specified using the "other specified" designation for the DSM-V Other Specified Feeding or Eating Disorder (OSFED)*

DIAGNOSTIC CRITERIA FOR OSFED; EXAMPLES
1. *Atypical anorexia nervosa*: All of the criteria for anorexia nervosa are met, except that despite significant weight loss, the individual's weight is within or above the normal range
2. *Bulimia nervosa (of low frequency and/or limited duration):* All of the criteria for bulimia nervosa are met, except that the binge eating and inappropriate compensatory behaviors occur, on average, less than once a week and/or for less than 3 months.
3. *Binge-eating disorder (of low frequency and/or limited duration):* All of the criteria for binge-eating disorder are met, except the binge eating occurs, on average, less than once a week and/or for less than 3 months.
4. *Purging Disorder:* Recurrent purging behavior to influence weight or shape (e.g., self-induced vomiting, misuse of laxatives, diuretics, or other medications) in the absence of binge eating
5. *Night eating syndrome:* Recurrent episodes of night eating, as manifested by eating after awakening from sleep or by excessive food consumption after the evening meal. There is awareness and recall of the eating. The night eating is not better explained by external influences such as changes in the individual's sleep-wake cycle or by local social norms. The night eating causes significant distress and/or impairment in functioning. The disordered pattern of eating is not better explained by binge-eating disorder or another mental disorder, including substance use, and is not attributable to another medical disorder or to an effect of medication.

Reference; The American Psychiatric Association, 2013

Table 5: *Prevalence of disordered eating and eating disorders in studies including aquatic athletes*

Reference	**Subjects and sport**	**Assessment**	**Main findings**
(Schtscherbyna et al., 2009)	Adolescent female elite swimmers (N=78)	3 questionnaires (Eating Attitudes Test, Bulimic Investigatory Test Edinburgh, and Body Shape Questionnaire)	45 % of the athletes met the criteria for DE behaviour
(Beals and Hill, 2006)	Female athletes (N=112) from non-lean (n=47) and lean built sports (n=65) including diving and swimming	Health, weight, dieting, and menstrual history questionnaire	25 % of the athletes met the criteria for DE with no differences between non-lean and lean built sports
(Anderson and Petrie, 2012)	Female swimmers and divers (n=134) and gymnasts (n=280) National Collegiate Athletic Association, Div. I	2 questionnaires (the Questionnaire for ED Diagnoses and 7 items from the Bulimia Test-Revised)	21 % of the swimmers/divers were classified as subclinical, and 7 % met the criteria for EDs
(Benson et al., 1990)	Female adolescent elite swimmers (n=18), gymnasts	1 questionnaire(the Eating disorder inventory)	38 % of the swimmers scored high on body dissatisfaction

	(n=12) and non-athletic control (n=34)		subscale compared to 9% of the gymnasts and 1% of the controls
(Ferrand et al., 2005b)	Female elite synchronized swimmers (n=42), team ball sports (n=40) and non-athletic control (n=50)	2 questionnaires (the Body-esteem Scale and the Eating Attitudes Test)	No differences between the groups in ED score. Synchronized swimmers reported greater negative feelings about their appearance and low perceptions of how others evaluate their physical appearance compared to the other groups.