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Sports Dietitians Australia Position Statement: Sports Nutrition for the Adolescent Athlete

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Abstract

It is the position of Sports Dietitians Australia (SDA) that adolescent athletes have unique nutritional requirements as a consequence of undertaking daily training and competition in addition to the demands of growth and development. As such, SDA established an expert multidisciplinary panel to undertake an independent review of the relevant scientific evidence and consulted with its professional members to develop sports nutrition recommendations for active and competitive adolescent athletes. The position of SDA is that dietary education and recommendations for these adolescent athletes should reinforce eating for long term health. More specifically, the adolescent athlete should be encouraged to moderate eating patterns to reflect daily exercise demands and provide a regular spread of high quality carbohydrate and protein sources over the day, especially in the period immediately after training. SDA recommends that consideration also be given to the dietary calcium, Vitamin D and iron intake of adolescent athletes due to the elevated risk of deficiency of these nutrients. In order to maintain optimal hydration, adolescent athletes should have access to fluids that are clean, cool and supplied in sufficient quantities before, during and after participation in sport. Finally, it is the position of SDA that use of nutrient needs should be met by core foods rather than supplements, as the recommendation of dietary supplements to developing athletes over-emphasises their ability to manipulate performance in comparison to other training and dietary strategies.

Keywords: Exercise; Sport; Performance; Diet; Youth; Puberty; Health; Growth

Introduction

Organised sport provides many benefits to young people including regular physical activity, social interaction, and the development of self-identity and self-esteem. Indeed, a commitment to regular physical activity is promoted within general dietary guidelines, regardless of age. While community-based guidelines and general nutrient reference values (NRVs)(NHMRC & NZMH, 2006; NHMRC 2013) are suitable for addressing the nutritional needs associated with general sporting or physical activity, some adolescents are involved in sport at a level of commitment and achievement in which special issues of sports nutrition can emerge. There is a reciprocal relationship between nutrition and intense sports participation: high level participation in sport can create unique nutritional requirements, while attention to the unique nutritional goals of sport can enhance training and promote optimal competition performances.

The prospect of sporting success is appealing to many adolescent athletes, their families and the institutions they represent. However, adolescence is also a period of significant growth and physical development that includes altered body composition, metabolic and hormonal fluctuations, maturation of organ systems and establishment of nutrient deposits which may all affect future health(Sawyer et al., 2012). Adolescence is also a time of social, emotional and sexual development, which has implications for how adolescents view themselves and their sporting achievements. In terms of nutrition, adolescence is also an important time in establishing an individual’s lifelong relationship with food, which is particularly important in terms of the connection between diet, exercise and body image. New practices, beliefs and meanings associated with food may be acquired during this time, such as the adoption of vegetarianism, fad diets and supplement use. To ensure that the adolescent athlete fulfils his or her potential, eating patterns should be supported that integrate the unique needs for sporting success with the nutritional considerations for healthy growth and development.

While broad principles of sports nutrition have been published (ADA 2009; IOC, 2010), leading sporting organisations have also highlighted the need for ongoing education of coaches and parents to specifically address issues related to the adolescent athlete (Mountjoy et al., 2008). A number of challenges exist in relation to the development of robust guidelines for the special needs of adolescent athletes:

1. the practical and ethical obstacles associated with conducting research on young people result in fewer sports nutrition studies being undertaken on adolescent athletes compared to adult athletes;
2. rather than age, it is the variable timing and dimorphic nature of pubertal changes (i.e. earlier onset in girls, longer duration in boys) which has the greatest influence on adolescent nutrient demands;
3. many adolescent athletes participate in a number of concurrent sporting pursuits with the performance levels ranging from social sport to elite international competition; and
4. sports food, beverage and supplement companies continue to target adolescent audiences with a large number of commercially driven nutrition messages.

Nevertheless, SDA feels that there is both sufficient need and adequate information for it to formulate sports nutrition guidelines for adolescent athletes. Accordingly, the aim of this statement is to provide health professionals, coaches, teachers, trainers, parents and athletes with recommendations for nutrition as it relates to health and sports performance within the context of adolescence. These recommendations are based on a contemporary and independent review of the scientific evidence which was then considered by an expert multidisciplinary panel. Draft recommendations from this review were then critiqued by the SDA membership at a national conference workshop prior to the final ratification of the position statement.

This statement utilizes the Athlete Development Pathway model developed by the Australian Sports Commission (Gulbin, Croser, Morley, & Weissensteiner, 2013) to focus on two groups of adolescent athletes defined as follows:

Active Adolescent Athlete – an adolescent aged between 12 and 18 years, who applies foundational movement skills in a sports specific context, and may be associated with commitment to training, skill development, and/or formal engagement in competition. (ASC F3 Classification).

Competitive Adolescent Athlete – an adolescent aged between 12 and 18 years, who demonstrates gifts/talents in the physical, physiological, or movement domains which may indicate future potential in high performance sport. This athlete may be engaged in sustained practice through high training volumes which may lead to the achievement of a high performance benchmark (ASC T1-4 Classification).

This statement is not intended to address the needs of elite adolescent athletes (ASC E1 and beyond Classification) competing against adults in national or international competition as it is considered that these athletes should receive individualised support from sports dietitians within existing high performance sporting agencies.

Energy recommendations for adolescent athletes

During adolescence, adequate energy is required to meet both the growth and development needs of the individual, as well as the substrate demands associated with general physical activity, training and competition (Aerenhouts, Deriemaeker, Hebbelinck, & Clarys, 2011; Petrie, Stover, & Horswill, 2004; Unnithan & Goulopoulou, 2004). It is difficult to define the energy needs of an adolescent athlete with precision due to metabolic variability within and between individuals (Petrie et al., 2004), and methodological difficulties in estimating both energy intake and energy expenditure (Burke, Cox, Cummings, & Desbrow, 2001). Furthermore, the energy expenditure associated with the exercise commitments of active and competitive adolescent athletes may vary substantially due to factors such as total training and competition load, seasonal variation, participation in more than one competitive sport and concurrent compensatory sedentary behaviours (Petrie et al., 2004).

Australian recommendations for energy are based on predictive estimates of resting energy expenditure (Schofield equation) multiplied by an activity factor (NHMRC & NZMH, 2006). The equation is based on the weight and height within the 10-17 year age category and does not allow for further differentiation by pubertal maturation (Schofield, 1985). Additionally, the broad and subjective nature of the activity factors means that the predictive equations should only be used as a guide (Meyer, O'Connor, & Shirreffs, 2007). Indeed, adolescent athletes often report energy intakes lower than those suggested via predictive equations (Aerenhouts et al., 2011; Gibson, Stuart-Hill, Martin, & Gaul, 2011).

The energy needs for growth must be considered when assessing the energy requirements of adolescent athletes. The energy needs for growth consist of two parts: the energy deposited in growing tissues and, the energy expended to synthesize those tissues (Torun, 2005). The energy deposited in growing tissues is small and has been commonly estimated as 8.6 kJ/gram of daily weight gain (e.g. for a 15yo male gaining 6 kg/year = ~140kJ/day) (WHO, 1983). The energy expended to synthesize new tissues is incorporated in measures of total energy expenditure such as doubly labelled water. Measurements of total energy expenditure in adolescents indicate that the energy changes associated with physical activity and/or training are likely to have a much greater influence on energy demands than the increases associated with growth (Torun, 2005). Suggested energy requirements (incorporating total energy expenditure plus energy deposited in growing tissues) for adolescent populations with different levels of habitual physical activity have been published (Torun, 2005).

The concept of “energy availability” is useful in understanding the importance of adequate energy consumption, particularly as it is expected that, consistent with normal growth, adolescent athletes will typically gain weight during the period of maturation (Loucks, Kiens, & Wright, 2011), suggesting positive energy balance (intake > expenditure). Energy availability differs from the traditional energy balance approach to energy needs by taking the following definition:

$$\text{Energy Availability} = \text{Energy Intake} - \text{Exercise Energy Expenditure}$$

The concept focuses on the amount of the individual’s energy intake that is “available” for other body processes and functions, once the energy cost of sporting activity has been subtracted. It acknowledges that concurrent reductions in physiological processes occur when energy intakes are reduced and/or energy expenditure is increased beyond the level at which the energy remaining for body health and function is compromised(Nattiv et al., 2007; Stubbs et al., 2004).

Prolonged periods of low energy availability in adolescent athletes may have a number of health consequences including delayed puberty, menstrual irregularities, poor bone health, short stature, the development of disordered eating behaviours and increased risk of injury(Bass & Inge, 2010; Meyer et al., 2007; Nattiv et al., 2007). Alternatively, a chronic consumption of energy in excess of requirements may result in several well documented health issues such as an increased risk of overweight/obesity, metabolic disorders such as type II diabetes, hyperlipidemia, atherosclerosis and hypertension, and again an increased risk of injury(AIHW, 2012; NHMRC, 2013).

The most practical objective method to assess the adequacy of energy availability is to assess energy intake and compare this with concurrent serial measures of exercise energy expenditure and markers indicating the adequacy of energy supply. Energy intake can be assessed using a variety of methods with known limitations(Burke et al., 2001; Heaney, O’Connor, Gifford, & Naughton, 2010) and is usually compared to dietary reference standards(Heaney et al., 2010). Exercise energy expenditure can also be determined using a variety of methods(Sirard & Pate, 2001).

The resultant value of energy availability is then matched against serial measures of growth, development and physiological function to determine if this intake is meeting the needs of the adolescent. Such objective measures include height, weight, height velocity, weight velocity relative to reference standards (e.g. CDC) or skinfold and/or circumference measures. Other indicators of the adequacy of energy availability may include measures of self-reported fatigue, timing and progression

through puberty, menstrual dysfunction and bone mineral density. The assessments of planned energy expenditure and energy availability are then used to plan the ongoing recommended energy intake.

Managing energy issues in adolescent athletes is complex. While long periods of restricted energy supply have the potential to compromise the long term health of the adolescent (Meyer et al., 2007; Nattiv et al., 2007) some evidence exists that an acceleration in growth can occur immediately following retirement in former elite adolescent athletes such as gymnasts (Caine, Lewis, O'Connor, Howe, & Bass, 2001). This may indicate adolescent athletes have the potential to “catch up” following periods of compromised growth, although an alternative explanation is that the data describe “normal” growth for a unique population that is subject to selection practices favouring late maturers. Conversely, about 25% of children and adolescents in Australia are overweight or obese (AIHW, 2012) indicating that many young people are unable to habitually self regulate energy consumption to match energy output. While there is no evidence on the numbers of adolescent athletes in Australia having problems with body weight management, it is prudent to suggest that many adolescent athletes will also require knowledge, skills and support to develop a healthy lifelong relationship with food. Additionally, while weight loss may be desirable in an overweight adolescent athlete, severe and prolonged restrictions to available energy are not recommended for overweight young athletes (Bass & Inge, 2010).

The position of SDA is that no predictive equations currently exist to accurately determine the energy needs of adolescent athletes. The difference between an athlete's energy intake and the energy expenditure associated with his or her sporting activities provides an indication of the energy that is available for optimal function and growth. Markers of growth and development should be compared against reference standards throughout the life of an adolescent athlete to determine if total energy intake is appropriate.

Body image, dieting behaviours and the adolescent athlete

Participation in sport can play an important role in supporting the psychological well-being of adolescents and developing a healthy physical self-image. Indeed, a meta-analysis suggests a positive relationship between sports participation and self-esteem for most adolescents (Ekeland, Heian, & Hagen, 2005). However, it is also important to recognise that increased rates of disturbed eating attitudes and behaviours have been observed in sports emphasizing leanness by requiring very low body fat levels for optimal performance and/or aesthetics (Ferrand, Magnan, & Philippe, 2005; Monthuy-Blanc, Maiano, Morin, & Stephan, 2012; Rouveix, Bouget, Pannafieux, Champely, & Filaire, 2007).

Adolescent athletes may engage in inappropriate dietary and training strategies in the belief that these efforts will control their body shape and weight, lean body mass or fat mass to levels required to reach optimal performance or a physical self-perception of ideal (Bonci et al., 2008). These behaviours commonly manifest in the pursuit of leanness in female adolescents and of muscularity in male adolescents (Botta, 2003). This highlights the difficulty experienced by many adolescent athletes in dissociating the relationship between eating appropriately to change body composition for performance improvement and inappropriate dietary patterns aimed solely at achieving societal “ideals” of physique. Whilst dieting is common in adolescence (Boutelle, Neumark-Sztainer, Story, & Resnick, 2002; Huon, 1994; Martinsen, Bratland-Sanda, Eriksson, & Sundgot-Borgen, 2010; Neumark-Sztainer, Wall, Eisenberg, Story, & Hannan, 2006), adolescent athletes with high energy requirements are more vulnerable to the physical and psychological consequences of this behaviour.

The female athlete triad consisting of disordered eating, menstrual dysfunction and low bone mineral density has been well described in the literature (Currie, 2009; Nattiv et al., 2007; Waldrop, 2005); and is often related to recurring restrictive eating disorders. Risk factors for developing the female athlete triad include being pressured by coaches or parents to lose weight in order to improve performance. Early warning signs include overtraining even when unwell, lack of recreational activities

outside sport, low self-esteem, perfectionism, dieting behaviours and misconceptions about nutrition(Waldrop, 2005).

The position of SDA is that dietary education and recommendations for adolescent athletes should reinforce eating for long term health. Parents, guardians and coaches of adolescent athletes should be aware that body composition is only one contributor to adolescent athlete performance. Their role is to act as advocates for the development of a positive body image within adolescent sporting environments. They should not tolerate divisive weight related comments or bullying. Dietary and training strategies exclusively designed to manipulate an adolescent athlete’s physique independent of performance should be avoided. The delivery of team-based education programs about disordered eating symptoms is not desirable and may lead to harm(NEDC, 2010). Those responsible for the care of adolescent athletes should seek professional advice if they become concerned about sustained, obsessive or irrational body image issues associated with athletes under their supervision.

Protein recommendations for adolescent athletes

In the adult athletic population, additional attention to protein intake is recommended in the form of a meal plan providing a regular spread of moderate amounts of high quality protein across the day and in the recovery period after strenuous exercise(ADA 2009; Phillips & Van Loon, 2011; Tarnopolsky, 2004). Such a pattern promotes activation of the protein synthesis pathway and provides substrate for lean tissue accretion. While these considerations focus on maximizing the response to the stimulus of exercise training, adolescents have additional protein requirements to support general growth and development(Aerenhouts et al., 2011; Meyer et al., 2007). Total energy intake is also important to consider in the assessment of protein requirements since inadequate energy intake will cause protein to be used as a substrate for energy, potentially reducing its availability for its primary functions(Campbell et al., 2007; Petrie et al., 2004).

Australian daily protein requirements for adolescents are set as a function of body weight (NHMRC & NZMH, 2006). The values are based on a factorial method which uses estimates of whole body protein turnover with an additional estimate provided for growth and maintenance on a fat-free mass basis (NHMRC & NZMH, 2006). The adolescent Recommended Dietary Intake (RDI) for protein (Table 1) is only slightly higher than for adults (Adult RDI ~0.8 g/kg/d) (NHMRC & NZMH, 2006). Notably, the recommendations acknowledge a lack of evidence on which to determine the RDI values and do not account for any extra requirement needed for adolescents participating in heavy exercise.

Nitrogen balance studies, a method used to assess whole body protein turnover, has been conducted on adolescent athletes including sprinters and soccer players. These studies indicate that positive nitrogen balance is achieved with reported daily protein intakes between 1.35 and 1.6 g/kg/d (Aerenhouts et al., 2013, Boisseau et al., 2007; Boisseau et al., 2002). In addition, recent longitudinal evidence suggests that a dietary protein intake within this range will lead to a positive nitrogen balance, irrespective of the adolescent's growth rate or increase in fat free mass (Aerenhouts et al., 2013).

Over the past two decades significant methodological developments have improved our understanding of the skeletal muscle response to food, exercise and their interaction (Phillips, Hill, & Atherton, 2012). Methods of measuring protein synthesis rates typically track the incorporation of amino acids into muscle protein or its sub-fractions using ingestion/infusion of tracer-labelled amino acid solutions. To date, no investigations of this type have been conducted on adolescents. Therefore, data from adult studies provide our only evidence to estimate the protein demands of skeletal muscle in young athletes.

It has been suggested that competitive and elite adult athletes should aim for protein intakes between 1.3-1.8g/kg/d, consumed in meals spread across the day, with higher intakes (up to 2.5 g/kg/d) during periods of intensified training or when reducing energy intakes (Phillips & Van Loon, 2011). As such, these recommendations represent an effective doubling of protein intakes relative to the

requirements for non-exercising individuals. Additionally, there is evidence that the timing of intake of protein, rather than the total daily intake *per se*, is important for maximising the skeletal muscle response to resistance training. Indeed, the consumption of modest amounts (~20g) of high quality protein throughout or immediately after strength training enhances the acute protein synthetic response to the training stimulus(Hawley, Burke, Phillips, & Spriet, 2011; Phillips & Van Loon, 2011). Consumption of protein beyond requirements will result in elevated levels of amino acid oxidation(Kurpad & Thomas, 2011) but does not appear to cause deleterious effects for otherwise healthy active adults(Bedford & Barr, 2005; Blum, Averbuch, Wolman, & Aviram, 1989; Knight, Stampfer, Hankinson, Spiegelman, & Curhan, 2003).

Adolescent athletes often report protein intakes within the range of ~1.2-1.6 g/kg/d(Aerenhouts et al., 2013; Aerenhouts et al., 2011; Gibson, Mitchell, Harries, & Reeve, 2004; Heaney et al., 2010; Petrie et al., 2004). Thus, the typical dietary patterns of adolescent athletes appear consistent with the recommendations for adults. These dietary intake data also indicate that adolescent athletes are unlikely to require special protein supplements to meet elevated protein needs(Aerenhouts et al., 2011; Gibson et al., 2004; Heaney et al., 2010; Petrie et al., 2004) since dietary protein is found in many foods that are consumed within their current food selection. Thus, if protein-containing supplements and sports foods are to be recommended to adolescent athletes, the only justifiable reason is that they provide a convenient source of protein within the athlete’s lifestyle rather than being additionally required as a dietary supplement.

Ideally, adolescent athletes should consume lean protein sources whenever possible to promote their long term health(NHF, 2009). Vegetarian and vegan adolescent athletes should ensure they consume adequate amounts of protein from a wide variety of sources(Fuhrman & Ferreri, 2010). They may benefit from specific dietary advice to support the achievement of this.

The position of SDA is that in the absence of specific evidence from studies on adolescent athletes, the most prudent approach for competitive adolescent athletes is to follow the guidelines for adult athletic populations regarding protein consumption. In this regard, the adolescent should adopt eating patterns that provide a regular spread of high quality protein sources across the day, including a plan for the period immediately after a training session, where the consumption of protein containing choices appears to convey the greatest benefits.

Carbohydrate recommendations for adolescent athletes

A key focus of an athlete’s daily diet is to provide adequate levels of substrates to fuel daily exercise (Burke et al., 2001; Burke, Kiens, & Ivy, 2004). Replenishing stored carbohydrate (glycogen) between bouts of exercise is important as carbohydrate is an important fuel for exercise and brain function (Burke & Deakin, 2010). Additionally, the body’s carbohydrate stores (liver and muscle glycogen and blood glucose) are limited in relation to the fuel costs of the training and competition programs undertaken by many athletes (Burke et al., 2004). The replenishment of glycogen stores is regulated by total daily intake of carbohydrate and the timing of consumption, with intake as soon as practical after exercise helping to initiate an efficient refueling process.

Although earlier sports nutrition guidelines recommended a “high carbohydrate diet” for all athletes, recent updates to such guidelines have redefined this concept, at least for adult athletes. Rather than a “one size fits all” approach to carbohydrate needs, amended guidelines propose that each athlete should consume enough carbohydrate to meet the fuel costs of his or her training load, with general guidelines also being scaled to body size (Burke, Hawley, Wong, & Jeukendrup, 2011). New carbohydrate intake guidelines account for daily and seasonal fluctuations in the periodised training/competition calendar and are fine-tuned according to feedback from the individual athlete:

- For immediate recovery after exercise:
(0-4hrs): 1-1.2g/kg/h, then resume daily fuel needs

- For daily recovery:
 - low intensity or skill based activity: 3-5 g/kg/d
 - moderate exercise program (e.g. training 1 h/d): 5-7g/kg/d
 - endurance program (e.g. training 1-3 h/d): 6-10g/kg/d
 - extreme exercise program (e.g. training 4-5 h/d) 8-12g/kg/d
- During sport:
 - short duration (0-75 min): not required or very small amount
 - medium/long duration (75min-2.5h): 30-60g/h(Burke et al., 2011)

Since these adult guidelines are based on research on adult participants, it is important to consider potential differences between adult and adolescent athletes that may influence the need for dietary carbohydrate. Such differences may occur either as a consequence of altered substrate storage, altered substrate utilization during exercise or as a result of specific modifications in training loads and sporting competitions designed for adolescent athletes.

During the mid 1970s a series of Scandinavian studies used muscle biopsy techniques to investigate adaptations to exercise training in young males in comparison to older athletes(Eriksson, Gollnick, & Saltin, 1973, 1974; Eriksson & Saltin, 1974). The initial findings indicated that young athletes adapt to training similarly to adults; training results in greater storage of muscle glycogen, increased glycogen utilisation during maximal tests, and increases in oxidative and anaerobic enzyme capacity. However, the magnitude of increase in anaerobic enzyme activity appears to be small in adolescents, raising the possibility that younger athletes may have less or limited capacity for adaptation of their anaerobic capacity(Eriksson et al., 1973, 1974; Eriksson & Saltin, 1974). Similarly, other researchers, have demonstrated that at the same relative intensity of exercise, children rely more on oxidative metabolism to meet energy demands(Taylor, Kemp, Thompson, & Radda, 1997) and that when carbohydrate is being utilized the relative oxidation of ingested (exogenous) carbohydrate is higher in pre and early pubescent boys (Timmons, Bar-Or, & Riddell, 2003; Timmons, Bar-Or, & Riddell, 2007).

However, not all researchers agree that this indicates that glycolytic metabolism in humans is maturity dependent (Haralambie, 1982; Petersen, Gaul, Stanton, & Hanstock, 1999). Researchers have

also demonstrated the importance of expressing results relative to a participant’s fat-free mass (which can vary considerably during adolescence)(Kaczor, Ziolkowski, Popinigis, Tarnopolsky, 2005, Brandou, Savy-Pacaux, Marie, Brun, & Mercier, 2006). An investigation into the activity of 22 enzymes related to energy metabolism, glycolytic enzymes, including fructose-6-phosphate kinase, showed no significant differences in their activity in adults compared to adolescents(Haralambie, 1982). Additionally, in a study comparing trained pre-pubertal and pubertal female swimmers, Petersen et al (1991) demonstrated no differences in in-vivo glycolytic metabolism in response to a high intensity exercise task, particularly when muscle cross-sectional area was considered(Petersen et al., 1999). Taken collectively, the existing evidence of the impact of maturation on energy metabolism suggests little to warrant deviation from the current adult recommendations for dietary carbohydrate.

The duration and intensity of an exercise session determines carbohydrate utilisation patterns and refueling requirements. Therefore, dietary carbohydrate needs should be considered in light of the training loads and competition characteristics that are typically undertaken by adolescent athletes. These can differ from those undertaken by adults in a number of ways; some sports feature different rules, game durations or race lengths for younger competitors while others have different competition formats (e.g. sports carnivals, representative competitions and trials). While the training commitments involved in adolescent sport may be lower in comparison to adult sport (e.g. fewer sessions in a week, shorter duration sessions), it is also possible that the adolescent is participating in a number of different sports. These different energy demands and subsequent carbohydrate requirements must be either added or adjusted depending on whether the participation is concurrent (e.g. netball and rowing) or seasonal (e.g. cricket in summer and football in winter).

The position of SDA is that the carbohydrate requirements of training and competition are well established in adults. There is little evidence to suggest that the carbohydrate requirements of adolescents differ substantially from those of adults. Adolescent athletes should be encouraged to adjust

carbohydrate intake to match actual daily energy demands and adopt strategies to include nutrient rich carbohydrate foods and fluids where possible.

Dietary fats recommendations for adolescent athletes

Adequate dietary fat is important to ensure an appropriate supply of fat soluble vitamins and essential fatty acids, as well as to provide adequate energy to support the growth and maturation of an adolescent athlete (Petrie et al., 2004). Body fat, in the form of adipose tissue and triacylglycerol stored within muscle, is the main endogenous energy store for both adults and adolescents, with the primary metabolic adaptation to endurance training being an increased capacity for oxidation of fatty acids and a reduced reliance on carbohydrate stores (Shaw, Clark, & Wagenmakers, 2010). Typically, the need for pro-active replenishment of fat stores after exercise has not been considered due to the relatively large (adipose) stores which can be found in even the leanest athletes (Burke et al., 2004). Recently, there has been an increased interest in the role of the intramuscular triacylglycerols on exercise performance (Bergman et al., 2010; Shaw et al., 2010) and the impact of training in a carbohydrate depleted-state to further promote adaptations to enhance the capacity to use fat as an exercise fuel (Hawley, 2011). However, the effect of strategies which promote “fat adaptation” on endurance exercise performance in adolescent athletes remains unstudied.

Since excessive intakes of fat can contribute to obesity and various long term health consequences (NHMRC, 2013), the consumption of fat by adolescent athletes should be in accordance with public health guidelines. While no formal nutrient reference values exist for total fat intake, the Acceptable Macronutrient Distribution Range (AMDR) to reduce chronic disease risk has been set at 20-35% of total energy, with saturated and trans fats together providing no more than 10% of total energy (NHMRC & NZMH, 2006). These recommendations support the avoidance of foods containing saturated fats and provide a range for the consumption of unsaturated fats. Dietary surveys of

adolescent athletes suggest that current dietary practices typically provide a fat intake of at least 30% of total energy intake (Croll et al., 2006; Juzwiak, Amancio, Vitalle, Pinheiro, & Szejnfeld, 2008).

Certain female adolescent athletes with very high training demands are at risk of impaired menstrual function if energy expenditure from training and other stressors greatly exceeds energy intake (Nattiv et al., 2007). Given that fat is the most energy dense macronutrient, an increase in fat intake by some individuals may contribute to the dietary changes needed to address sub-optimal energy intakes. However, the causes of low energy availability are often complex and multifactorial and a full dietary review is warranted in such cases.

The position of SDA is that the consumption of fat should be in accordance with public health guidelines. Adolescent athletes should be encouraged to consume unsaturated fats including plant based sources and fish. Furthermore, they should limit their intake of food containing high concentrations of saturated fats such as fried foods and baked products and use practices that reduce the fat content from animal sources (e.g. choose lean meats). Due to its energy density, manipulating dietary fat intake has the capacity to rapidly influence an adolescent athlete's total energy intake.

Iron recommendations for adolescent athletes

Iron deficiency anemia is the most common and widespread nutrient deficiency in the world (WHO, 2012). Among athletes, the prevalence of iron deficiency anemia lies in the range of ~3% and is comparable to the general population (Shaskey & Green, 2000). In the diagnosis of iron status disorders, it is important to recognise the progression from depleted iron stores (defined by changes in serum ferritin), early functional iron deficiency (defined by changes in transferrin saturation or serum transferrin receptor), and iron deficiency anemia (defined by changes in haemoglobin and mean cell volume) (Burke & Deakin, 2010).

Depleted iron stores, without clinical symptoms, are observed frequently in studies conducted on adolescent and young adult athlete populations (particularly endurance athletes) (Gropper, Blessing,

Dunham, & Barksdale, 2006; Rodenberg & Gustafson, 2007; Sandström, Börjesson, & Rödger, 2012).

However, the impact of athletic training on increasing the risk of depleted iron stores is less apparent as these observations are also observed in nonathletic counterparts (Sandström, Börjesson, & Rödger, 2012). Interpreting studies in this area requires caution as cut-off values used to determine depleted iron stores can vary considerably. For example, a recent study of 193 elite young athletes from 24 different sports suggesting depleted iron stores was present in 31% of male and 57% of female athletes used a serum ferritin <35 µg/L as the cut-off (Koehler et al., 2012). However, when a more stringent criteria (serum ferritin <12 µg/L) was applied to the same group of athletes, only 4% of male and 7% of females were deemed to have depleted iron stores (Koehler et al., 2012). Regardless of etiology, high rates of depleted iron stores, with and without anemia, is of concern to athletes as recent reviews of the literature concluded that suboptimal iron status leads to adverse athletic performance (Rodenberg & Gustafson, 2007) as well as negatively effecting training adaptation. These adverse effects are most likely due to reductions in oxygen transport, ATP production and DNA synthesis.

In female endurance athletes, suboptimal iron status can result from low iron intake as well as the loss of iron in menstrual blood (Gropper et al., 2006; Koehler et al., 2012). The large increase in RDI for developing girls is to account for iron lost via the menstrual cycle. In setting the recommendation, the NHMRC assumed that those younger than 14 years do not menstruate and that all girls who are 14 years and older do menstruate (NHMRC & NZMH, 2006). It should be noted that the majority of young women experience menarche before this age (average ~12½ years). In both genders, further iron losses are also possible via sweat, gastrointestinal blood loss and the cumulative effect of “heel-strike” haemolysis when an athlete undertakes multiple training sessions per day (Koehler et al., 2012; Peeling et al., 2009). Despite the potential for exercise-induced iron loss, there is no evidence that adolescent athletes have requirements beyond the RDI values set for the general population. The RDIs for iron are based on a mixed western diet in which iron absorption is ~18%. Iron absorption from a

vegetarian diet may be lower due to bioavailability issues, which consequently would suggest that adolescent athletes who are vegetarian eaters may require intakes in excess of the RDI(NHMRC & NZMH, 2006).

Results from dietary intake studies in adolescent athletes indicate male athletes typically exceed dietary iron recommendations. In contrast, while average female adolescent dietary intakes remain close to recommended levels, individual intakes vary considerably(Gibson et al., 2011; Heaney et al., 2010; Juzwiak et al., 2008; Martínez et al., 2011). The use of iron supplements should be guided by an appropriately qualified health professional (e.g. medical practitioner) with regular follow-up.

The position of SDA is that depleted iron stores without clinical symptoms occur more frequently in female athletes. Despite the potential for increased iron turnover in adolescent athletes there is little evidence that adolescent athletes have requirements beyond the RDI values. Adolescent athletes (particularly females) should ensure dietary iron intake is consistent with the RDI and iron supplementation should be considered only if medically warranted.

Calcium and Vitamin D recommendations for adolescent athletes

Calcium and vitamin D are key nutrients that play important roles in the development and maintenance of the skeleton. Vitamin D enhances calcium absorption in the gut and is essential for normal calcium metabolism. Adolescence is the period in which the level of bone remodeling is highest(MacKelvie, Khan, & McKay, 2002). Evidence suggests that optimal bone mineral accrual during adolescence and early adulthood is critical to ensure sufficiently high peak bone mass is achieved to help reduce the subsequent risk of osteoporosis later in life(Rizzoli, Bianchi, Garabédian, McKay, & Moreno, 2010).

Calcium requirements in adolescence are increased due to significant bone growth during this period in both boys and girls. It is estimated that the rate of skeletal calcium accretion during adolescence is approximately 300mg per day(Matkovic, 1991). After accounting for urinary and

insensible losses and assuming a net calcium absorption from food of approximately 25-35%, the recommended intake of calcium for adolescents is 1300mg per day(NHMRC & NZMH, 2006).

Exercise interventions of up to 15 months have been shown to increase bone mineral content in adolescents(Nichols, Sanborn, & Love, 2001; Stear, Prentice, Jones, & Cole, 2003; Weeks, Young, & Beck, 2008). However, interpretation of these studies is often difficult because bone mineral content also increases in the control groups as a result of normal growth. The magnitude of the increase in total bone mineral content in the intervention groups over control groups is quite small (<6%) in these studies(Nichols et al., 2001; Stear et al., 2003; Weeks et al., 2008). Therefore, this relatively small additional bone mineral accretion as a result of weight bearing exercise is unlikely to substantially increase calcium requirements in exercising adolescents. Nevertheless, accumulation of small increases in bone mineral content is likely to result in significantly greater bone density in active compared with inactive individuals by the end of adolescence(Bailey, McKay, Mirwald, Crocker, & Faulkner, 1999).

Determining vitamin D requirements for optimal health is a complex process and there is conjecture concerning the ideal amounts of vitamin D required for athletes of any age (Nowson et al., 2012). Vitamin D is available in the diet, but most individuals obtain the majority of their vitamin D from exposure to sunlight when ultraviolet B radiation converts 7-dehydrocholesterol to cholecalciferol. Therefore, dietary recommendations for vitamin D are problematic due to variations in sun exposure among different populations. The current Adequate Intake (AI) for vitamin D intake for adolescents is 5µg per day. Vitamin D deficiency is indicated by serum vitamin D levels below 50 nmol·L⁻¹, however, the threshold for deficiency may be higher if measured in summer (in order to account for seasonal losses)(Nowson et al., 2012).

Some populations of adolescent athletes appear to be at higher risk of vitamin D deficiency. The major risk factor is inadequate exposure to the UVB radiation from sunlight, which can occur in athletes who live at latitudes >35 degrees where UVB radiation is absent during winter, or in athletes who spend

long periods training indoors or aggressively follow “sun smart” behaviours when outdoors. For example, a study of the vitamin D status of adolescent female gymnasts found a high prevalence of sub-optimal vitamin D status; six out of 18 athletes recording serum vitamin D levels below 50 nmol L^{-1} (Lovell, 2008). Heaney et al(2010) have also shown that over 90% of female athletes (including many adolescents) from a variety of sports have vitamin D intakes below current recommendations. The literature examining the effect of supplementation with vitamin D on sports performance is limited(Powers, Nelson, & Larson-meyer, 2011). However, low serum vitamin D has been associated with impaired performance on measures of physical fitness in 12-14 year old girls(Ward et al., 2009) and 8 weeks of Vitamin D and calcium supplementation reduced the risk of stress fractures in physically active women(Lappe et al., 2008). It appears that low vitamin D status in adolescent athletes has the potential to impair performance, and increase the risk of injury which could have long term consequences for bone health. It is prudent for adolescent athletes who are at high risk of vitamin D deficiency and insufficiency to undertake regular monitoring of vitamin D status. Correction of any vitamin D deficiency through increased sun exposure or supplementation may be necessary to ensure optimal performance and the maintenance of bone health in adolescent athletes.

Adolescent female athletes involved in vigorous exercise training are at risk of suppressed bone mineral accrual(Barrack, Rauh, & Nichols, 2010). This is potentially a result of irregular menstrual function and/or low energy availability that is common in female athletes(Gibson et al., 2004) and which, in severe cases, may manifest clinically as osteoporosis(Nattiv et al., 2007). The American College of Sports Medicine recommends that restoring energy availability by increasing energy intake, reducing energy expenditure or both is the most important factor in improving reproductive and skeletal health in female athletes(Nattiv et al., 2007). In addition, it is of concern that the calcium intakes of both adolescent males and females are reported to be well below the recommended daily amount of 1300mg(Gibson et al., 2011; Juzwiak et al., 2008; Martínez et al., 2011). Despite the difficulties

associated with estimating and interpreting dietary adequacy from food intake data in athletes(Heaney et al., 2010), it is concerning that the consumption of calcium by adolescent athletes may be as low as half of the recommended amount(Gibson et al., 2011, Juzwiak et al., 2008), with low intakes being much more likely to occur in females than males(Martínez et al., 2011). As amenorrheic adolescent athletes have significantly impaired bone microarchitecture compared with eumenorrheic athletes and nonathletic controls(Ackerman et al., 2011), it is important that adolescent female athletes with irregular menstrual function have adequate calcium and vitamin D intakes.

Intervention strategies that aim to increase calcium intake in adolescent athletes, especially girls, are needed. A sample of elite athletes, comprised mostly of adolescents, was recently shown to score poorly on the ‘sources of nutrients’ section of a nutrition knowledge questionnaire compared with non-athlete controls(Spendlove et al., 2012). Enhancing the nutrition knowledge of adolescent athletes may therefore be a potential strategy to improve calcium intake. Clearly further research is required to better inform intervention strategies for this population.

The position of SDA is that both calcium and vitamin D are important nutrients for bone health in adolescent athletes. The recommendation for calcium intake for adolescent athletes is not likely to be different from levels recommended for all adolescents, 1300 mg/d. However, there is evidence that, as with adolescents in general, the actual calcium intake by adolescent athletes is well below this recommendation which suggests a need for strategies to be implemented to assist adolescent athletes, especially girls, to achieve an adequate intake of calcium. Many adolescent athletes are at risk of low vitamin D status and regular monitoring of vitamin D status is recommended. Correction of any vitamin D deficiency or insufficiency through supplementation may be necessary to ensure optimal performance and bone health in adolescent athletes.

Fluid recommendations for adolescent athletes

Researchers and expert working groups have previously concluded that in comparison to adults, children and adolescents are less effective in regulating body temperature and have lower exercise tolerance in the heat(Bar-or, Dotan, Inbar, Rotshtein, & Zonder, 1980; "Council On Sports Medicine and Fitness. Climatic heat stress and exercising child and adolescent," 2000; Drinkwater, Kupprat, Denton, Crist, & Horvath, 1977; SMA, 2008). The reasons for these differences include:

1. Children have a greater surface area-to-body mass ratio than adults which causes a greater heat gain from the environment on a hot day and a greater heat loss to the environment on a cold day(Drinkwater et al., 1977);,
2. Children produce more metabolic heat per unit mass than adults during physical activities that include walking or running(Astrand, 1952); and
3. Sweating capacity is considerably lower in children than in adults, which reduces the ability of children to dissipate heat by evaporation(Shibasaki, Inoue, Kondo, & Iwata, 1997).

However, more recent studies, in which tighter controls have been employed to match relative exercise intensities, fitness levels, environmental conditions and hydration status, indicate that children and adults have similar capacity to deal with thermal loads and exercise-tolerance time during exercise in the heat(Inbar, Morris, Epstein, & Gass, 2004; Rowland, Hagenbuch, Pober, & Garrison, 2008; Shibasaki et al., 1997). What is evident is that the mechanisms by which young individuals dissipate heat loads during exercise differ from those of adults(Falk & Dotan, 2008; Rowland, 2008). Children and adolescents rely more on peripheral blood redistribution (radiative and conductive cooling) rather than sweating (evaporative cooling) to maintain thermal equilibrium. There is also evidence that adolescents who undertake regular training adapt by enhanced peripheral vasodilation(Roche, Rowland, Garrard, Marwood, & Unnithan, 2010) which is likely to improve non-evaporative cooling. While the timing of the transition from child-like to adult-like thermoregulatory mechanism is likely to be related to pubertal development, it appears that these changes do not become physiologically evident until puberty has been completed(Falk, Bar-Or, & MacDougall, 1992).

Despite developments in our understanding of thermoregulation in children and adolescents, fluid intake remains an important aspect of adolescent sports nutrition. One reason for this is the increased prevalence of heat-illness associated with sport and activity in younger athletes (CDC, 2011). Heat-illness may be influenced by poor hydration status along with other factors such as undue physical exertion, insufficient cooling between exercise bouts and inappropriate choices of clothing, including uniforms and equipment ("Council On Sports Medicine and Fitness and Council on School Health. Climatic heat stress and exercising children and adolescents," 2011). Unfortunately, there is no evidence to determine the extent to which (if at all) fluid intake may modulate the risk of heat illness in adolescent athletes. This is because fluid monitoring studies on children and adolescents at risk of heat-illness are scarce and often fail to report participants who actually experience heat-illnesses (Somboonwong, Sanguanrungrasirikul, & Pitayanon, 2012). In contrast, field studies indicate that adolescent athletes can experience significant deficits in fluid ($\leq 4\%$ body weight) during training and competition in the heat (Aragon-Vargas, Wilk, Timmons, & Bar-Or, 2013; Silva et al., 2011). Fluid shifts of this magnitude have the potential to effect exercise performance (Walsh, Noakes, Hawley, & Dennis, 1994), providing further rationale to monitor fluid consumption in adolescent athletes. It appears prudent then to apply the published fluid intake guidelines for adults which suggest that during exercise athletes should drink to avoid weight changes $>2\%$ of their pre-exercise body mass (Sawka et al., 2007).

Sports drinks are regularly consumed by adolescents for a wide variety of reasons (O'Dea, 2003). However, for the active adolescent engaged in routine physical activity, the use of sports drinks in place of water on the sports field or as a general beverage is unnecessary. This is because sweat sodium losses are generally lower in young athletes compared to adults (Meyer, Volterman, Timmons & Wilk 2012) and the consumption of sports drinks may also lead to excessive caloric consumption and increased risk of overweight and obesity ("Committee on Nutrition and the Council on Sports Medicine and Fitness. Sports drinks and energy drinks for children and adolescents: Are they appropriate?," 2011). For

competitive adolescent athletes the use of carbohydrate/electrolyte based sports drinks may offer benefits mediated by the supply of additional carbohydrate and fluid during periods of prolonged, vigorous sports participation. In recovery between events which occur in close proximity the use of carbohydrate/electrolyte based sports drinks or milk may offer benefits mediated by the supply of additional carbohydrate, fluid, sodium and protein (in the case of milk)(Volterman, Obeid, Wilk & Timmons 2011). It is concerning that many adolescents do not appear to understand the differences between sports drinks and caffeinated energy drinks as indicated by similarities in the reasons they cite to explain their consumption of these different types of beverages(O'Dea, 2003).

The position of SDA is that to maintain optimal hydration status, fluids that are cool and appropriate (e.g. water, milk) be supplied in sufficient quantities to adolescent athletes before, during and after participation in sport. Given the potential variability in sweat rates during adolescence, young athletes are encouraged to regularly monitor their fluid needs. Adolescent athletes should be encouraged to ensure they are well hydrated prior to commencing exercise, particularly in hot environments and to adopt drinking practices that limit fluid deficits. Monitoring changes in body mass over the exercise session (i.e. comparing body mass pre- and post-exercise) provides a guide to the net fluid deficit incurred during exercise. If this deficit is deemed to be excessively large or, alternatively, if fluid is over consumed during exercise such that there is a gain in body mass over the session, the athlete should be guided to adjust drinking rates. The goal of post exercise fluid recovery is to restore fluid balance prior to the subsequent exercise session.

Dietary supplements and nutritional ergogenic aids for adolescent athletes*

(* the definition of dietary supplements and ergogenic aids excludes sports foods and drinks)

The judicious use of dietary supplements and nutritional ergogenic aids may improve sporting performance in adults. However, their effectiveness and potential long-term effects have not been rigorously studied in healthy adolescent populations, largely due to the ethical concept of beneficence

(i.e. cost versus benefit). Despite this lack of scientific evidence, supplement use with the intent to improve sports performance amongst young athletes is common (Evans-Jr, Ndetan, Perko, Williams, & Walker, 2012; McDowall, 2007). For example, a recent investigation into the prevalence of supplement use amongst US children indicated that 1.6% of the general population younger than 18 years (or ~1.2 million people) were taking supplements to boost sports performance (Evans-Jr et al., 2012).

Adolescent athletes may take “performance enhancing” dietary supplements for a variety of reasons. Factors influencing supplement use may include pressure to achieve results as they strive towards a career as an elite athlete, the pursuit of physical ideals related to their body image or impulsive behaviours encouraged by the marketing and availability of dietary supplements targeting teenagers. Additionally, while there is some evidence to suggest that young elite athletes do not believe that dietary supplements are required to be successful in their sport, they still consider them important for certain training adaptations such as strength gains (Bloodworth, Petroczi, Bailey, Pearce, & McNamee, 2012).

Philosophically leading sporting organisations and expert groups believe it is inappropriate for active and competitive adolescent athletes to be encouraged to consume dietary supplements for performance enhancement (“Committee on Sports Medicine and Fitness. Use of performance-enhancing substances.” 2005; IOC, 2010; Meyer et al., 2007). This excludes the clinical use of dietary supplements (eg. calcium, iron and vitamin D) when taken under appropriate guidance from suitably qualified health professionals (eg. a medical practitioner or sports dietitian). Aside from issues related to safety, the use of supplements in developing athletes over-emphasises the ability of supplements to manipulate performance. Essentially younger populations have the potential for greater performance enhancement through maturation and experience in their sport, along with adherence to proper training, nutrition and rest regimens. It can also be argued that discouraging the use of dietary supplements downplays the “win at all costs” mentality and sets an important example for young athletes.

In reality, some adolescent athletes use ergogenic supplements to directly enhance training or competition. In this situation, athletes and their guardians should seek credible information on the safety and efficacy of intended dietary supplements from independent sources such as the Australian Sports Anti-Doping Authority (ASADA) (<http://www.asada.gov.au/substances/supplements.html>) ("Australian Sports Anti-Doping Authority. Supplements," 2012) and the Australian Institute of Sport (www.ausport.gov.au/ais/nutrition/supplements) ("Australian Institute of Sport. Sports Supplement Program,"). All athletes should be aware that the content of supplements can vary from batch to batch and may contain prohibited substances. Athletes who take supplements are therefore, even inadvertently, at risk of violating anti-doping rules ("Australian Sports Anti-Doping Authority. Supplements," 2012). The World Anti-Doping Code strict liability principle states that athletes are ultimately responsible for any substance found in the athlete's body, regardless of how it got there (*World Anti-Doping Agency. World Anti-Doping Code* 2009). Athlete support personnel[†] should also be aware that harsher penalties apply for anti-doping rule violations when such individuals are found to be administering or trafficking to a minor (clause 10.3.2 (*World Anti-Doping Agency. World Anti-Doping Code* 2009)).

The development of a local sports supplement policy is a useful strategy that can be recommended to specific schools, clubs or other sporting associations to address the issues around supplement use within their sporting setting. This approach allows support personnel to advocate for appropriate restraint in the use of dietary supplements and encourages the utilisation of expert opinion and advice from professionals including sports medicine practitioners, sports dietitians and sports scientists.

The position of SDA is that it is inappropriate and unnecessary for active and competitive adolescent athletes to consume dietary supplements for the purpose of performance enhancement. The use of supplements in developing athletes over-emphasises their ability to manipulate performance in

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comparison to other training and dietary strategies. Adolescent athletes and their support personnel should be aware of the risks associated with dietary supplementation. Organisations involved with adolescent athletes should develop guidelines to regulate supplement use.

†**Athlete Support Personnel:** Any coach, trainer, manager, agent, team staff, official, medical, paramedical personnel, parent or any other Person working with, treating or assisting an Athlete participating in or preparing for sports competition.

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Table One: Australia and New Zealand Nutrient Reference Values for Protein*

		RDI
Boys:	12-13 yr	0.94g/kg/d
	14-18 yr	0.99g/kg/d
Girls:	12-13 yr	0.87g/kg/d
	14-18 yr	0.77g/kg/d

*intake to support growth and maintenance of fat-free mass and should be used for active adolescents:

Table Two: Australia and New Zealand Nutrient Reference Values for Iron*

		RDI
Boys:	9-13 yr	8mg/d
	14-18 yr	11mg/d
Girls:	9-13 yr	8mg/d
	14-18 yr	15mg/d