Nutrition in numbers

The recommendations made are based on body weight. For young athletes who are training, still growing and in school it would be suggested to have 5-7g/kg of body weight of carbohydrates. E.g. for a female of 55kg this is around 92g of Carbohydrates per meal. Protein would be around 1.2-1.6g/kg of body weight which is around 22-25g of protein per meal.
When looking for carbohydrates aim for low GI foods for a slow release of energy, whilst enjoying everything in moderation. Protein becomes more necessary with increasing intensity and can contribute to 1-6% of energy availability as well repairing muscles after use.
The timing of our nutritional intake is very important. 30 mins post exercise we should be having a recovery snack that is 3:1 on carbohydrates to protein. We should also be eating every three hours throughout the day, too much of a gap between meals increases cortisol levels which affects recovery as well as menstrual cycles and bone turnover.
Sleep can also affect our bone health and recovery, when sleeping and resting we allow our bodies to produce growth hormone that is able to repair damaged muscles. Recent studies have shown athletes having a greater amount of sleep are also associated with having stronger, denser bones.

The monthly cycles

The menstrual cycle is a natural process for females, occurring monthly, and is essential to maintain bone health and fertility. It can start from the age of 12 and continues until the onset of menopause around the age of 49-52. The cycle occurs over a period of 28 days. The first 14 days are known as the follicular phase. During this phase, around day 10, the hormones oestrogen, LH (luteinizing hormone) and FSH (follicular stimulating hormone) rise, reaching their peak around day 14. LH reaches a level double that of both oestrogen and FSH. After day 14 LH levels rapidly drop off while oestrogen and FSH fall off more slowly, over a 5 day period. The second 14 days are known as the luteal phase and there is a gradual increase in another hormone, progesterone, which reaches a peak around day 22 and returns to base levels at day 28.

The cycle then repeats and continues into the next 28 day cycle. Body temperature also fluctuates during the cycle and rises by around 1-1.5 degrees Celsius during the luteal phase. LH is also linked with appetite and so the rise and fall can cause the female to feel hungrier during this time period. Oestrogen is a key regulator of bone resorption, without oestrogen there would be an excess of bone being broken down over new bone being formed, making the menstrual cycle an essential tool in maintaining bone structure.

Bone stability and structure

Bone remains in a state of constant turnover by two types of bone cells; osteoblasts and osteoclasts. (Fig 1). Osteoblasts are involved in bone formation, whereas osteoclasts are involved in bone resorption. The balance between these two types of cells is vital to maintain a steady state of bone health. Bone resorption occurs at a much higher rate than formation; bone resorption takes just 30 days whereas the bone remodelling cycle takes 4 months. Therefore, a slight imbalance can lead to a bone fracture very quickly.

Bone also responds to physical activity and impact. The mechanostat theory describes how the mechanical strain on the bone, caused by muscle forces during contraction, activates the surface osteoblasts which begin the process of forming new bone. Continued activity causes an increase in bone mass, size, and strength, while reduced mechanical deformation causes a decrease. During puberty, bone is most responsive to physical activity so this period of life is 'the window of opportunity' to increase bone cross-sectional area and density. There is evidence to show that the bone mineral content of people who were active during childhood is around 8-10% greater than those that were not, even if they are both active later on in life.

More is not always better..

Elite athletes, particularly those involved in sports that usually adopt a leaner physique with low body fat, are at a greater risk of disordered eating; they are more likely to disturb the balance between optimal health and recovery by reducing energy intake. Some population studies of high level female athletes have shown up to 50% of the athletes demonstrate one or more disordered eating behaviours. The reasons for this disordered eating could be external pressures from teams, coaches and sponsors, or the athletes themselves having the belief that the leaner and lighter they are, the quicker they will be. These pressures may also cause the athlete to push their body to further extremes. By making it difficult to match energy expenditure with energy intake, they unintentionally end up with an energy deficit. Once the athlete reaches a level of negative energy balance, detrimental effects begin to take place.

The reduced intake will not only cause weight loss but, with a lack of energy, the liver will begin to release more ketone bodies. Ketone bodies are water soluble molecules that ae released from the break-down of fatty acids, which are used as the main energy source when there is a low energy availability. A build-up of these ketones can cause the blood pH to reduce to dangerously acidic levels, a process known as ketoacidosis. Muscles will become weaker as the body starts to preserve the small amount of energy it has been given, heightening risk of injury. Without the necessary energy intake, the menstrual cycle will most likely become irregular and eventually cease, which is known as amenorrhea. Amenorrhea is as prevalent as 65% in distance runners and 69% in professional ballet dancers. Without a regular menstrual cycle the levels of oestrogen are significantly reduced, which causes a disproportionate level of osteoblasts and osteoclasts, leaving a higher rate of

bone resorption than formation. This may ultimately lead to bone injuries, osteopenia, or even osteoporosis at a very young age, making any further career achievements even more difficult.

These three symptoms (disordered eating, amenorrhea and osteoporosis) became more prevalent in the 1990s and were termed 'The Female Athlete Triad' in 1997 by the American College of Sports Medicine. Athletes may only present with one or two of the components but this does not mean they cannot be diagnosed with the triad. It has been estimated that only 50% of trained physicians are knowledgeable about the female athlete triad and are comfortable diagnosing and treating the condition. More recently the triad has been encompassed within a new term; RED-S (Relative energy deficiency sport). This was defined by the international Olympic committee in 2014. This new title is due to an increased number of patients presenting with various other physiological symptoms (chronic fatigue, irritability, depression, long-term fertility issues, reduced immunity and reduced metabolic rate). RED-S is deemed to result from a prolonged low energy availability disrupting numerous physiological systems, such as, but not limited to, cardiovascular, gastrointestinal, endocrine and renal systems. Redefining the RED-S also allows male athletes who present with similar issues to be included. The IOC developed a return to play model to be used by all physios/coaches and team leaders when dealing with RED-S issues. See table 1 and Figure 2.

The oral contraceptive pill will cause a 'withdrawal bleed' however, this is not the same as a natural menstrual cycle. The pill may give a perception that everything is 'okay' and functioning, however it prevents natural oestrogen and therefore the ability to build new bone is lost. Menstrual cycles are a natural process and they need to be maintained as much as possible. If you are not having menstrual cycles and have been recommended the pill I would suggest working on increasing your energy availability before taking any medication.

More research is being conducted to better understand the issues, and accurate diagnosis will hopefully become more frequent. But what we really need is education at a young age, as most athletes become familiar with the triad only once they have been diagnosed with a bone injury. Prior to this, they may have never known why their menstrual cycle stopped, or why they were frequently injured/ill as it can be seen as a 'normal' thing to some when training at such a high level. If athletes are made aware of the symptoms and issues around the triad and poor nutrition before they occur, then nutrition and menstrual cycles can be more closely monitored as they progress through their athletic careers. Whilst we may still have new findings that need to be discovered within research, what we can do now is use the information we have to educate athletes (males and females) and their support networks.

I hope this article and presentation has provided a sense of awareness and understanding about this topic. I can be contact for further enquiries on runscienceltd@gmail.com, www.runscience.co.uk, twitter: @runscienceltd.

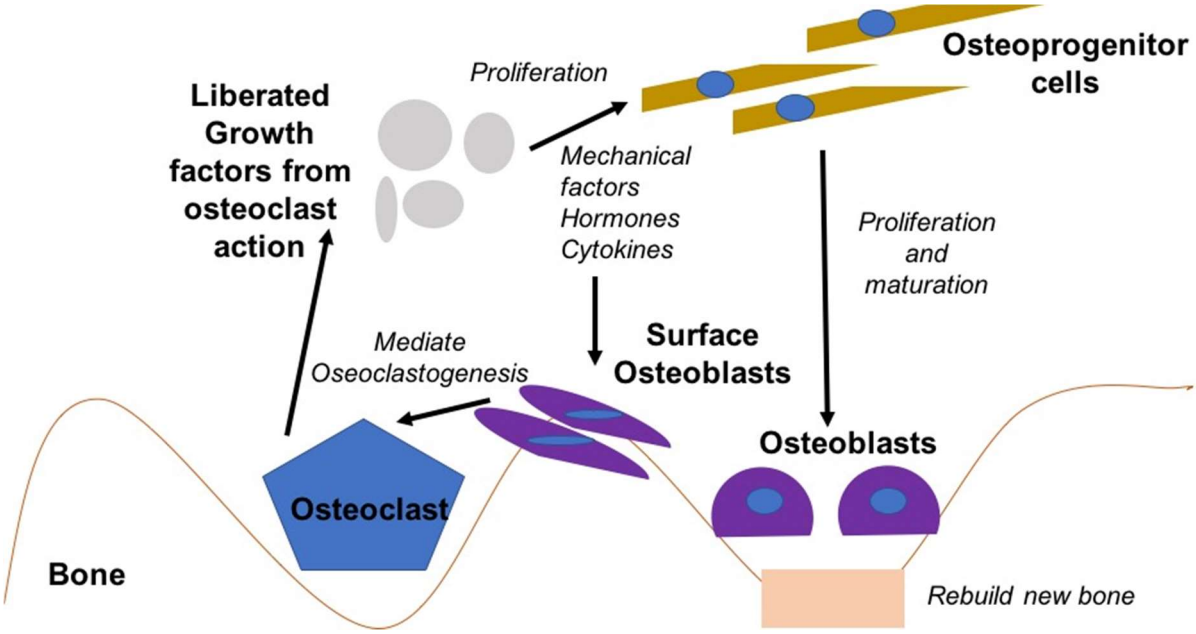

Figure 1: An adaption to show the balance between osteoblasts and osteoclasts to maintain bone health

High Risk; no start	Moderate Risk; caution	Low risk; go
Serious eating disorders other serious Psychological and physiological conditions associated with low EA Extreme weight loss techniques	Prolonged low % body fat Substantial weight loss within short time frame Attenuation of expected growth and development Abnormal menstrual cycle Menarche after age 16 Abnormal hormone profile in males Reduced BMD History of stress fractures Lack of progress Energy deficiency	Healthy eating habits with appropriate energy availability Normal hormonal and metabolic function Healthy BMD Healthy musculoskeletal system

Table 2: Return to play guidelines; as suggested by the IOC consensus statement (Mountjoy et al., 2014).

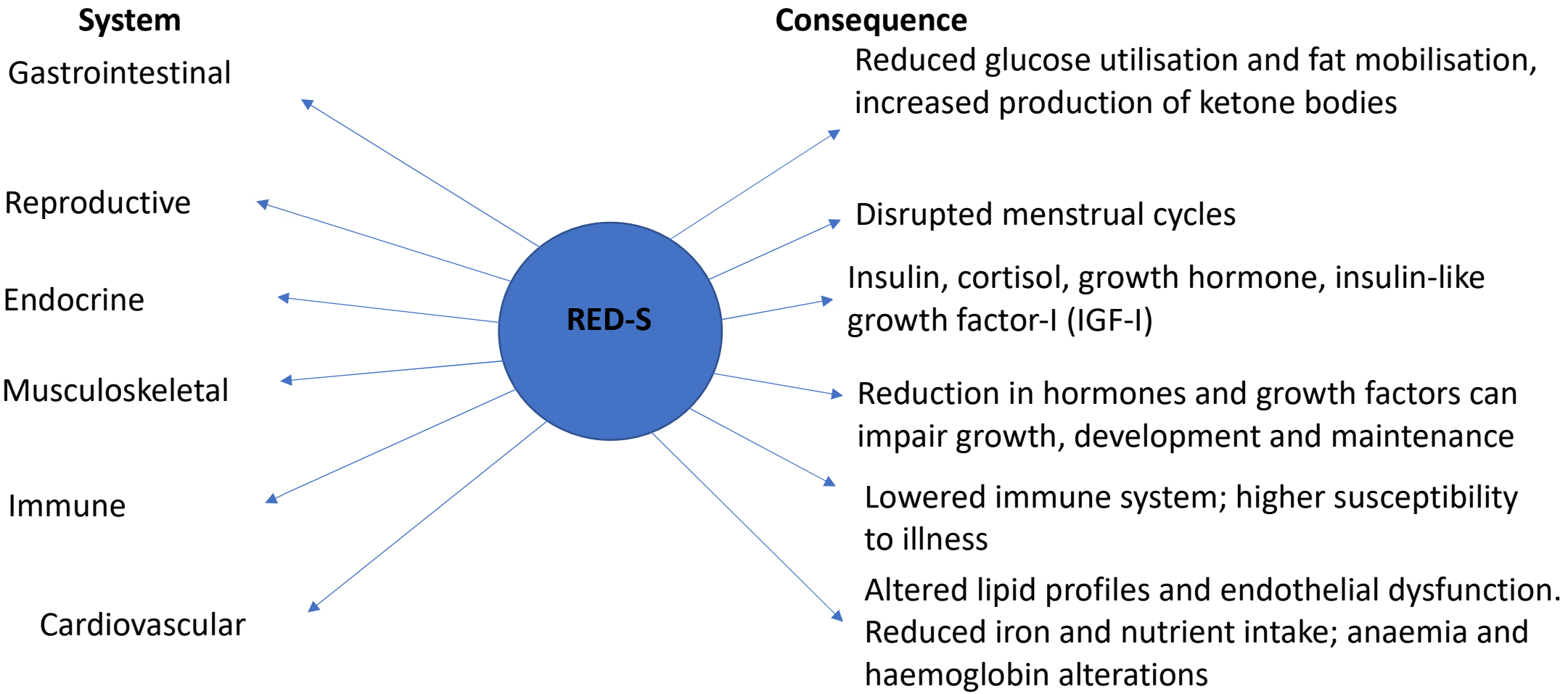

Figure 2: Physiological impairments associated with RED-S (Mountjoy et al., 2014)

References

1. Barnett, A (2006). Using recovery modalities between training sessions in elite athletes does it help? *Sports Med* (36), 781-96
2. Agerbaek, M. O., Eriksen, E. F., Kragstrup, J., Mosekilde, L. and Melsen, F. (1991) A reconstruction of the remodelling cycle in normal human cortical iliac bone. *Bone Miner*, 12 (2), pp. 101-12.
3. Frost, H. M. (1987) 'Bone "mass" and the "mechanostat": a proposal', *Anat Rec,* 219(1), pp.1-9
4. Baxter-Jones ADG, Kontulainen SA, Faulkner RA, Bailey DA (2008) A longitudinal study of the relationship of physical activity to bone mineral accrual from adolescence to young adulthood. *Bone*. 43(6):1101–1107
5. Mountjoy, M., Sundgot-Borgen, J., Burke, L., Carter, S., Constantini, N., Lebrun, C., Meyer, N., Sherman, R., Steffen, K., Budgett, R., Ljunggvist, A. (2014). The IOC Consensus statement: beyond the female athlete triad- Relative energy deficiency in Sport (RED-S). *Br J Sports Med*. 48 (7): 491-7.
6. Curry, E, Logan, C, Ackerman, K, McInnia K, Matzkin, E (2015) Female athlete triad awareness among multispecialty Physicians. *Sports Med Open*. 1:38.
7. Tenforde, AS, Parziale, A, Popp, K, Ackerman, K. (2017) Low Bone mineral density in male athletes is associated with bone stress injuries at anatomic sites with greater trabecular composition. *Am J Sports Med*. DOI: 10.1177/0363546517730584
8. Piasecki J, Ireland A, Piasecki M, Cameron J, McPhee JS, Degens H (2018) The Strength of weight-bearing bones is similar in amenorrheic and eumenorrheic elite long-distance runners. *SJMSS*. (30).