In 2008, Willis et al. published a review paper entitled "Should we be concerned about the Vitamin D status of athletes?" As practicing sports nutrition consultants as well as University Lecturers and researchers, this excellent review made us sit up and take notice of the emerging literature on vitamin D and athletes. In fact, the more we read, the more we actually did get "concerned". Since this review, there has been much discussion on the effects of vitamin D status on the health and performance of athletes however, definitive studies on athletic populations are unfortunately still lacking. This article will look at the theory behind why vitamin D status may be important to athletes and attempt to draw some conclusions and recommendations for the strength and conditioning/sports nutrition professional.

What is Vitamin D?

The term Vitamin D refers to a group of fat-soluble pro-hormones. The discovery of vitamin D can be largely credited to the observation that supplementation with cod liver oil prevented rickets (osteomalacia). One of the components of cod liver oil credited with preventing rickets was identified and termed vitamin D as it followed the earlier discovery of vitamins A, B and C. There are 2 major precursors to vitamin D known as vitamin D3 (cholecalciferol) and vitamin D2 (ergocalciferol). Due to these biological precursors, vitamin D could be described as a unique vitamin since under optimum conditions, physiological sufficiency could be met through endogenous synthesis (Willis et al., 2008).
Vitamin D3 is synthesised when the skin is exposed to UVB radiation, i.e. sunlight. UVB radiation converts 7-dehydrocholesterol (found in the skin) to pre-vitamin D3, which is then converted to Vitamin D3. There are many factors that can impair the conversion of 7-dehydrocholesterol to pre-vitamin D3 including aging, skin pigmentation, clothing, cloud cover, sunscreen use, and perhaps most importantly the time of the year. During the winter months when the sun is low in the sky it has been reported that it is very difficult for UVB rays to pass through the atmosphere and consequently there may not be sufficient UVB radiation to synthesise vitamin D. It has recently been reported that in the UK between October and March, synthesis of vitamin D may be almost impossible and therefore, the majority of the UK population may be vitamin D deficient during the winter months.

Vitamin D2 in contrast, is mainly derived from the diet although it must be stated that very few foods naturally contain vitamin D and therefore, many foods are fortified with it including some milk and orange juices (see Table 1). Vitamin D2 and D3 are converted to 25-hydroxyvitamin D (25-OHD) in the liver and therefore, measurement of circulating 25-OHD is perhaps the best, (and most widely cited), measure of total vitamin D status. The RDA for vitamin D in the UK is 400IU although many authors suggest that this value is too low and there is certainly no consensus on the optimum daily vitamin D intake for athletic performance. The USA has recently increased their RDA of vitamin D to 600IU per day up the age of 70 and 800IU for those aged 70+

### Are athletes deficient in Vitamin D?

For many years the vitamin D status of athletes has been largely ignored. At no point in our education as undergraduate or post graduate students was vitamin D ever discussed and during the first author’s career as a rugby league player, not once did anyone measure or even try to estimate vitamin D levels. The reason for this apathy in relation to vitamin D may be a consequence of the general assumption that vitamin D levels were adequate in the general population, combined with a lack of knowledge as to the importance of vitamin D in many aspects of health. There are also equivocal suggestions from vitamin D experts as to what constitutes a vitamin D deficiency. Zittermann defined sufficiency as between 100-250nmol/L and described a range of sub-optimal levels based on the effects on physiological function (Figure 1). It is important to note that this figure shows that sufficiency is between 100-250nmol/L and as yet there is no evidence that being at the top end of this scale is optimum compared with being at the lower end of the sufficient scale.

It should also be highlighted that excessively high vitamin D levels (greater than 250nmol/L) can be toxic and may result in hypercalcemia and hyperphosphatemia. Vitamin D intoxication can present itself as nausea, fatigue, constipation, back pain and memory loss whereas prolonged hypercalcemia from excessively high vitamin D intake can cause soft tissue damage.

### Table 1. Example of foods containing vitamin D including the absolute amount in International Units and the % RDA. Data adapted from the US department of agriculture.

<table>
<thead>
<tr>
<th>Food</th>
<th>IU per serving (% RDA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cod Liver Oil</td>
<td>1,360 (340)</td>
</tr>
<tr>
<td>Wild cooked Salmon</td>
<td>800 (200)</td>
</tr>
<tr>
<td>Mackerel (cooked)</td>
<td>400 (100)</td>
</tr>
<tr>
<td>Fortified orange juice</td>
<td>100 (25)</td>
</tr>
<tr>
<td>Beef Liver (cooked)</td>
<td>46 (12)</td>
</tr>
<tr>
<td>Egg (whole)</td>
<td>20 (5)</td>
</tr>
<tr>
<td>Fortified Milk</td>
<td>120 (30)</td>
</tr>
</tbody>
</table>

### Figure 1. Classification of vitamin D status based on serum 25-OHD levels (taken from Zittermann.)
 calcification and elevated blood pressure. To our knowledge, no study has ever reported vitamin D levels in the toxic range from a normal diet high in vitamin D or through sunlight exposure, only through the intake of mega dose supplementation. Moreover, even with supplementation, vitamin D intoxication is reported to be extremely rare.16 Data on intoxication have reported doses as high as 50,000IU per day, whereas doses traditionally classed as very high (10,000IU per day for 5 months) have shown no signs of toxicity.17 However, the possibility of toxification should not be ignored, especially in athletes, due to the high prevalence of uncontrolled supplement intakes in athletic populations.

In a comprehensive review of the field, Zitterman17 suggested that during the winter months both children and older adults in the UK are reported to have levels <50nmol/L (insufficiency), and that these levels are only marginally better in the summer with values approximately 60-80-nmol/L (hypovitaminosis). It is also important to consider that dark skinned children living in the UK have very low vitamin D status.17 This is because dark skin has high levels of melanin, which competes with 7-dehydrocholesterol for the absorption of UVB. Clemens et al.,4 have suggested that dark skinned individuals may need up to 50 times the sunlight exposure of an individual with pale skin complexion.

There is a lack of published studies on the vitamin D status of athletes and even less on UK based athletes, however the extant data does suggest that like the general public, athletes do appear to be deficient. In a collaboration between Liverpool John Moores University and Professor Bill Fraser at The University of Liverpool, we have recently tested the vitamin D status, (using the highly sensitive technique of tandem mass spectrometry), of several groups of elite athletes including professional soccer players, rugby players and jockeys. Data generated in the months between December-February suggest that athletes may be particularly susceptible to low vitamin D status observed in the wintertime suggesting that athletes may be particularly susceptible to bone problems during hard training in the winter. It should however be noted, that this study was in older non-athletes and this study is yet to be repeated on athletic populations.

**Muscle function** – The sudden and marked increase in muscle function is related to vitamin D and associated to immune system function.7 Gleseson explained the effects that exercise has on the immune system, suggesting that athletes may be especially susceptible to infection. In our experience working with elite athletes, it is important that nutritional plans are not only devised to improve performance, but also to maintain (or even enhance) immune function during times of intense training. There is now significant evidence that vitamin D plays a key role in the immune system, and this may be related to their association with monocytes.

**Immune Function** – A third important role of vitamin D with respect to athletes is in relation to immune function. Gleseson explained the effects that exercise has on the immune system, suggesting that athletes may be especially susceptible to infection. In our experience working with elite athletes, it is important that nutritional plans are not only devised to improve performance, but also to maintain (or even enhance) immune function during times of intense training. There is now significant evidence that vitamin D plays a key role in the immune system, and this may be related to their association with monocytes.

**Do your UK based athletes require vitamin D supplementation?**

Much more research is needed in athletic populations before a definitive answer could be given. However, it is interesting to note that in the Harvard Universities version of the food pyramid (http://www.hsph.harvard.edu/nutritionsource/what-should-you-eat/pyramid/),

**Recommendations include 10-30 minutes twice per week of sun exposure between the hours of 10am-3pm without sunscreen.**
daily vitamin D supplementation is advised for most people. Given the key role that vitamin D plays in health, and potentially athletic performance, it would appear wise to ensure that athletes are not deficient, and data would suggest that this is highly likely especially during the winter months. Therefore, it may be wise to get your athletes tested for vitamin D to allow sports nutritionists/dietitians/medics to make informed decisions on the need to supplement or not. One of the major problems with supplementation is prescribing a dose, as there are no definitive recommendations to correct marginal deficiencies. If there are clinical deficiencies present, Professor Bill Fraser, in a personal communication, suggests that supplements can be prescribed from a medic and this often involves 20,000IU (Dekristol) being given once per week for 6 months, followed by once per month for 6 months. However this must be prescribed and monitored by a doctor.

Another option is for athletes to obtain sensible skin exposure to sunlight. Recommendations include 10-30 minutes twice per week of sun exposure between the hours of 10am-3pm without sunscreen. However, this again should be only be advised after consultation with a doctor, ensuring that skin type is suitable for this level of exposure and sunburn does not occur with the associated increase in the risk of skin cancers. Perhaps the safest option is to attempt to consume a vitamin D rich diet utilising some of the foods outlined in Table 1 and during the winter months, consider a daily 1000-5000 IU supplement for 8-12 weeks depending on the magnitude of deficiency and in consultation with a qualified individual (Close et al., Unpublished Observations). It has been argued that the common dose of 400IU found in multivitamins is not sufficient to increase vitamin D levels and therefore a separate supplement is required.

Conclusion

We hope this brief commentary has provided a useful insight into a contemporary area in sports nutrition, but furthermore, we hope that it has stimulated interest amongst readers to conduct further research in this area. Moreover, we would encourage practitioners to monitor the vitamin D status of their athletes throughout the year looking for seasonal variations. Through our collective efforts we may be able to improve the health, wellbeing and performance of our athletes.

References