Nutrition and Hydration Biomarkers

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Article written for Professional Baseball Athletic Trainers Society

Introduction

A typical sports performance team is comprised of a variety of professionals, and communication between the medical and sports science teams is important.[1] Fitness, fatigue, recovery, and injury prevention are often the topics of these teams' communication and athlete monitoring schemes. There are many different approaches to athlete monitoring including physical workload, nutrition, sleep, and various recovery technologies. Often the lowest-hanging fruit is dietary intervention.

Nutrition assessment is a critical first step in evaluating need for dietary interventions including micronutrient intake and supplement use.[2] Blood profiling is a beneficial step in the assessment process to understand any deficiencies that may exist. This approach is becoming more prevalent in elite sport, however there are certain external factors that can impact biomarker outcomes, such as posture, exercise, hydration status, fasting status, and psychological stress. A more in-depth review can be found in Pedlar et al.[3]

Similarly, there may be statistical implications that need to be considered. Longitudinal data is often seen as the most impactful form of monitoring, however there are multiple ways to interpret collected data such as utilizing critical difference thresholds, general reference ranges, and even individualized methods using a Bayesian approach.[3] Factors influencing biomarker outcomes and statistical analysis are outside the scope of this article, therefore this brief piece will discuss a few key biomarkers useful in sports medicine and performance, particularly those related to nutrition and hydration for health and recovery.

Vitamin D

Vitamin D's most recognizable role is that of regulation of calcium homeostasis. Low vitamin D status has often been linked to poor immune function and compromised muscle health and bone composition. Specifically, manifestations such as unexplained muscle weakness and pain, and potential bone implications have been reported.[2] Vitamin D deficiency has also been associated with decreased immune capacity and increased upper respiratory tract infections (UTRI).[4]

In most clinical trials serum 25[OH]D concentration is measured. However, recent work has highlighted its limitations, particularly in the context of bone health in black individuals.[5] Therefore, if bone health is the interest, it is likely that an assay for vitamin-D binding protein (or potentially bioavailable/ free 25[OH]D) should be used.[6]

There is little to no evidence for ergogenic effects at levels above 75 nmol/L.[6] In fact, while case reports of vitamin D toxicity are limited there is evidence that levels >180 nmol/L may be toxic.[6] Although these direct cut-offs may not be definitive for all outcomes, there does seem to be widespread agreement that 75 nmol/L is the optimal circulation of serum 25[OH]D to prevent UTRI and maintain immunity.[4]

REFERENCE	VALUE (nmol/L)
Deficient	< 50
Insufficient	< 75
Sufficient	< 75

Iron

Appropriate iron levels are crucial and underpin many important functions for athletic performance. Namely, iron supports red blood cell (RBC) production, delivering oxygen to the muscle, helps to produce energy at a mitochondrial level, and aids in immune function.[7] While the incidence rates for iron deficiency do seem to be higher in females than males,[7] it can occur in males. Assessing iron status is critical due to the important role of iron. The symptoms of iron deficiency may manifest as lethargy, lightheadedness, fatigue, and negative mood states along with the more severe cases inducing anemia.[2,7]

Presently there is still debate as to what are the appropriate cut-off values in blood profiling for iron deficiency due to the large number of biomarkers (see table), however it is agreed that there are three stages of iron deficiency.[2,7,8] Hepcidin has also emerged as a potential new marker of iron metabolism.[3,7,9] Although not yet broadly available or measured, hepcidin seems to impair iron absorption and/or metabolism. Therefore its measurement might be critical to get the most out of

iron supplementation planning.[10,11] To date a plethora of information on iron as a biomarker exists so ensuring the most appropriate measures are collected is critical as some of them may overlap in various stages.

MEASURE	STAGE OF SEVERITY		
	I ↓	II ↓	III ↓
Ferritin (ug/mL)	< 35 ( )	< 20 ( )	< 12 ( )
[Hb]	> 115	> 115	< 115
Transferrin Saturation (%)	> 16	< 16	< 16
Serum Iron		↓	↓
Soluable Transferrin Receptor		↑	↑
[ZnPP]			↓
HGB			↓
HCT			↓
MCV			

Omega 3

Omega 3 polyunsaturated fatty acids (PUFA) are essential fatty acids, meaning they must be consumed either through dietary sources (i.e., fish oils, salmon, tuna) or supplemented. The most bioactive of the Omega 3 PUFA are eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) [12]. The assessment of Omega 3 has received increased attention with athlete monitoring at the collegiate and professional level, specifically the Omega 3-Index. The Omega 3 Index is a percentage of EPA and DHA in total erythrocyte fatty acids. Although the Omega 3 Index is based on CVD risk (see table) this has been primarily used as a reflection of athletes' Omega 3 PUFA consumption over the past 2 months.[13]

CARDIOVASCULAR DISEASE RISK	OMEGA 3 INDEX
High Risk	< 4%
Intermediate Risk	4-8%
Low Risk	> 8%

The scientific rationale for monitoring Omega 3 blood levels stems from Omega 3 PUFA's role in promoting muscle remodeling, muscle repair, improving immune status, decreasing muscle soreness, and helping to maintain explosive power.[14,15] Recent work has shown the majority of athletes to have a low to moderate Omega 3 Index.[16,17] These studies have also used Omega 3 dietary and supplement questionnaires to examine intake of Omega 3 PUFA, which have shown low dietary and supplemental intake.[16,17] If teams do consider measuring Omega 3 Index this should be combined with an Omega 3 PUFA questionnaire examining dietary and supplement intake.[17] Education can then be provided by the team dietitian for players that need to increase their dietary intake of Omega 3 PUFA. Further, Omega 3 Index should then be periodically monitored among players especially if supplementing Omega 3 PUFA as individual blood concentrations can vary to a given dose.[18]

Hydration Biomarkers

The reference method for determining day to day hydration status involves first-morning urinary measures (color, specific gravity, osmolality), plasma osmolality, nude body mass, and thirst.[19] However, obtaining such measurements daily can be challenging, time-consuming, and cumbersome for athletes and coaches. Studies have also examined various hydration biomarkers through saliva and tear osmolality.[20] Exploring these methods is beyond the scope of this article however the reader is referred to Barley et al.[20] for further information.

Recent work on hydration biomarkers has focused on technology providing real-time urine-specific gravity measurements.[21] A paper published in 2022 showed an automated urinalysis device that attaches to a urinal showed a strong correlation to optical refractometry for measuring urine-specific gravity.[21] Technology that addresses both convenience for the athlete, as well as accuracy in measurement, will help practitioners understand athlete behavior.

Work out of Arizona State University showed using a three-panel urine color chart provided similar results to those of traditional urine color charts.[22,23] However, the key application here is the assessment can be done directly from the toilet. This could help make the method more applicable to the athlete. As technology miniaturizes and becomes more accessible to athletes and the general population this could help allow for a more practical understanding of athletes' day-to-day hydration status.

Conclusion

There are a number of biomarkers the sports medicine staff could potentially monitor. The key question for the athletic trainer is to think through what specific biomarkers they want to track for athlete's long-term health and to help promote behavior change with nutrition and hydration. Further, understanding what biomarkers have been validated against gold

standard measurements that can also be easily implemented during annual medical screenings or daily implementation in the field.

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