How to Utilize Visceral Fat Evaluation:

A case analysis for the practicing sports dietitian

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Introduction

Sport participation is often a significant component of one's life and many individuals are involved in a variety of sports from a young age through their collegiate years, few advance to professional levels. The National Collegiate Athletic Association reported 2017-18 participation levels at an all-time high for both male and female student-athletes, with total participation of 494,992 student-athletes.[1] Similarly the 2017-18 High School Athletics Participation Survey conducted by the National Federation of State High School Associations reported nearly 8 million high school students participating in sports [2]

Despite the prevalence of play, athletic participation does not seem to carry forward a protective effect for the amount of physical activity post sport participation or cardiopulmonary health later in life.[3] Thus, it can be important for sports medicine practitioners and sports dietitians to expand beyond providing care and information for sport performance and keep the total health of athletes in focus. Physical activity and nutrition are two key variables of long-term health outcomes. However, despite athletic participation, the Trojan Lifetime Champions Health Survey reported that being a former collegiate athlete had little correlation with being a healthy exerciser. Both student-athletes and non-athletes reported an average of 5hrs/wk of exercise.[4] And one recent survey of Division I student-athletes revealed a score of less than 57% on a nutrition knowledge questionnaire.[5]
A tremendous opportunity exists to educate and teach; thus, significantly impact the athlete in dividend ways.

The 'Holistic Life Span Health Outcomes Among Elite Intercollegiate Athletes' study looked at athletes ages 17-84 and reported that student-athletes had cardiopulmonary health status comparable to non-athletes. Churchill et al. evaluated weight gain during periods of active football participation of former NFL players. Their data suggest that football-associated weight gain occurring in early-adulthood has important health implications that manifest in the post-career years. They concluded that weight gain from high school to college, and college to professional career periods was independently associated with increased prevalence during middle-age of multiple health afflictions including cardiovascular disease, cardiometabolic disease, sleep apnea, neurocognitive impairment, and chronic pain.[6] This post career risk assessment is further examined by Weir, et al. who compared rate and causes of death among nearly 3500 retired NFL players, playing at least 5 years, to what would be expected in the general population. The defensive line players had an increased risk of dying from heart disease and offensive lineman had an even higher risk.[7] Further, rates of type 2 diabetes over the past decade have skyrocketed. According to the CDC's 2015 report, more than 9% of the US population has diabetes. Another 84.1 million have pre- diabetes, which often leads to type 2 diabetes within 5 years if left untreated. One in 4 living with diabetes didn't know they had it and only 11.6% of adults with pre-diabetes were aware of their condition.[8] The distribution and type of body fat may be important indicators for cardiometabolic disease risk.

Specifically, the visceral adipose fat area is associated with metabolic risk factors (Figure 1). Due to their metabolic activity, these fat cells are considered to impact risk factors such as fasting glucose levels, serum triglycerides, and cholesterol.[9] Because the subcutaneous fat component, inner abdominal muscle wall, and visceral cavity can all be identified on a Dual-Energy X-ray Absorptiometry (DXA) whole body scan, the visceral fat or visceral adipose tissue (VAT) (fat tissue located deep in the abdominal cavity and around the internal organs considered hormonally active) area can be quantified. An estimate of the visceral fat can be derived by subtracting the subcutaneous fat from the total abdominal fat in the abdominal region. This measurement method is highly correlated and linearly related to visceral fat area measured by computed tomography (CT).[10] Once estimated, studies have suggested that VAT area levels exceeding 100cm^2 can adversely affect metabolic profiles.[11] Therefore, the VAT area measurement from DXA whole body scans may be an important tool in today's sports medicine practice to help identify those athletes at high risk for metabolic disease or those with existing, underlying pathology that could be otherwise missed.

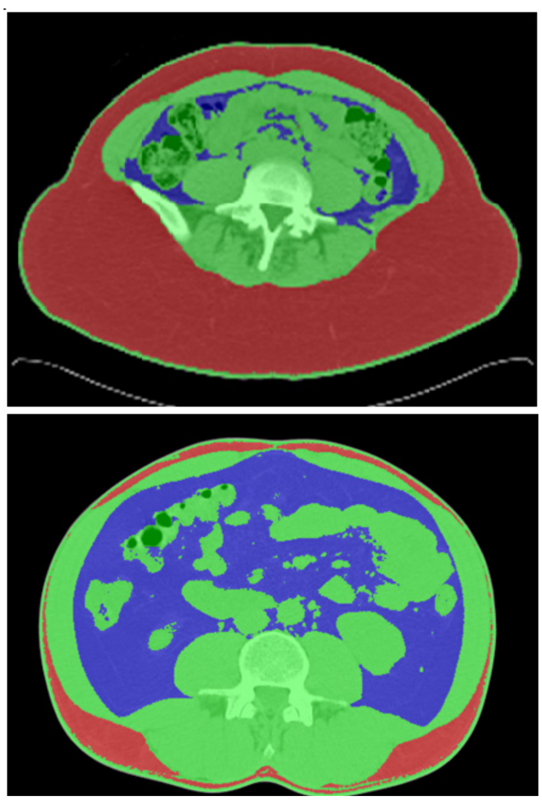

Figure 1: Abdominal CT images courtesy of M. Puyanitya, Image Reading Center, New York, NY showing two individuals with similar waist circumference but different levels of visceral adipose tissue. Red area on image = subcutaneous fat, blue area on image = visceral adipose tissue.

The following case study presentation demonstrates how VAT data helped guide the treatment of an individual athlete struggling with weight loss as well as increasing lost game and practice time over the course of 3 years.

Case Review

Athlete Profile

The player was a white, female varsity athlete who arrived at campus as a freshman and highly touted prospect. During her senior year of high school (HS) she was diagnosed with spondylolysis (a stress fracture of the vertebra most commonly in the lumbar region) and reduced both her daily and sport related physical activity in an effort to heal and recover. The team's head coach alerted the university's sports medicine and nutrition staffs that she had gained some weight during her senior year and requested support in this area when she arrived on campus. At the Pre-participation Physical Exam (PPE) the summer before her freshman year of college she was 5'9" and weighed 264lb. No food allergies or intolerances, or prescription medications were reported. Her menstrual cycle was regular without prior or current oral contraceptive use and was 13 y/o at time of menses. She described her eating habits as "fair", typically ate 3 meals and 2 snacks/day, and consumed two of those meals per week at restaurants or retail food chains. She avoided fish and alcohol, did not drink milk but did eat yogurt and cheese, and was registered for an unlimited, 7-day campus dining hall meal plan. She noted sleeping 8-10hrs/night. She also expressed a desire to lose weight as she was not happy with her current weight and wanted additional follow up with the team's sports dietitian for weight loss and fitness information.

Her initial nutrition assessment visit occurred towards the end of August where an in-depth food and weight history were taken. Through the conversation, it was discovered that in her hometown, she lived across the street from 4 fast food restaurants. Her best friend worked at one of the establishments and she used to eat fast food 1-3 times/day. She had low exposure to a variety of foods resulting in limited food related knowledge and experiences. During her senior year of high school, she played basketball on a team with an up-tempo style of play and lost 15lbs over the course of 3 months due to the running and following a 2800 kcal diet. She recalled feeling very tired and fatigued during that time and reported that the weight came back on quickly once the season was over and was diagnosed with spondylolysis. Her highest adult body weight reported was 270 lbs. and lowest adult body weight was 250 lbs. During her 24-hr recall she reported having foods such as sports bars or nothing for breakfast; grilled chicken sandwich, banana, tator tots, and soda at lunch; pasta and soups at dinner; and cookies or fruit for an evening snack. An appropriate assessment of 5.5 g/kg carbohydrate and 1.5 g/kg protein were calculated, and an initial intervention and monitoring plan was formulated which included discussion on healthy weight loss goals, strategies to decrease or alter night time snacking, general healthy plate and portion education, and regular follow up visits. By early September she had lost 5 lbs. from her PPE weight, had reported eating a consistent breakfast meal, but was still drinking soda, beginning to tire of dining hall foods, had returned to eating out at fast food restaurants and was choosing high calorie, high fat foods in the dining halls. A refocus of her nutritional priorities and goal setting was done through continued education and motivation interviewing techniques.

By early October she was managing a shoulder injury in addition to her lingering back pain. She had also become overwhelmed and stressed with academic responsibility and rigor. She was spending an increasing amount of time with academic support personnel. Frustration was also mounting with her injury status and the need to spend additional time in rehabilitation sessions. The increasing time demands led to her missing lunch meals and eating fewer and fewer meals at the dining halls. By the end of the fall semester she had very little capacity to address her nutrition needs and had begun snacking, eating out, and even binging at times. Over the course of the semester break, she was not able to exercise and was not able to adhere to many of her nutrition goals or behaviors. She returned to campus that January having gained 10 lbs. Towards the end of January, the start of the spring semester, she felt ready to refocus on her nutrition again and restarted some small shifts. She built some confidence with small successes over the course of the next ~6wks.

As of early March, she had developed a stress fracture in her foot and contracted strep throat. Weight maintenance became her goal. At the beginning of April, she had begun looking forward to going home for the summer break and felt that she would be better motivated for a lifestyle change at that time. This pattern of initial high motivation, followed by buildup of academic stress, physical and mental fatigue, injury, rehabilitation, and limited capacity to address her nutrition needs continued going into her third year with limited and slow recovery from injuries and periodic short-term weight loss success. See Figure 2. for weight history data over time.

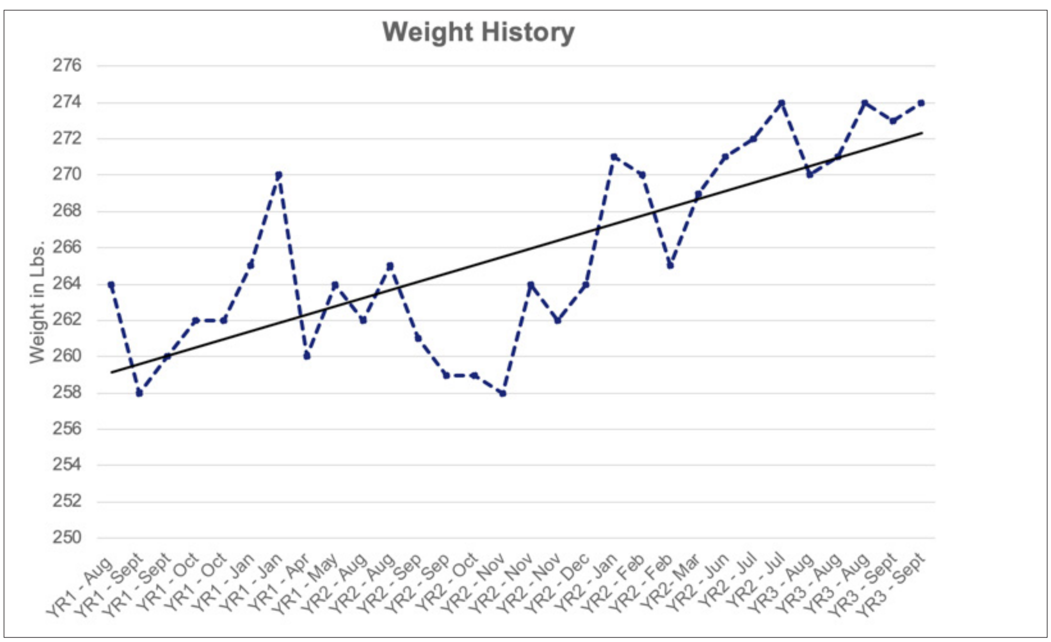

Figure 2: Weight History

Athlete Management

Performance Team Assessment

In the summer before her 3rd year the performance team met to consider new approaches. With the aim of continuing to support weight loss and improve nutrition knowledge and behaviors, the team took a step back to look at the big picture and reviewed the athlete's history in depth. A full scope and timeline of the medical and nutritional problems were outlined. Medicine, athletic training, nutrition, strength & conditioning and academic staffs all contributed to the comprehensive analysis. It was clear that the pattern of academic stress load and the athlete's injury history routinely slowed momentum of her weight loss efforts due to increased academic and rehabilitation time demands as well as limitation of higher intensity activities. These variables affected the athlete's available time and mental capacities to focus and progress on her nutrition goals. Therefore, in an effort to rule out low bone mineral density as a possible factor in her spondylolysis and stress fracture diagnoses, a DXA measurement was scheduled. The resulting body composition measure would also potentially increase the accuracy of the nutrition assessment. After review of almost 40 office visits over 2 years with different sports dietitians offering different approaches, it was clear that there had been improvement in the athlete's knowledge, interest in evolving food choices, and some successful behavior modification albeit at a slow pace. A variety of nutrition intervention strategies had been tried with varying degrees of success mostly correlated with time of year and academic and sport load trends. Total body weight and body composition shifts were also slow to follow.

In the meantime, sport coaches and performance staff were frustrated at this stage with the lack of weight loss progress, and limited availability to make progress in training, conditioning, and game day contributions. As an alternative approach, the performance team staff came together with a new plan to prioritize the athlete's weight loss and fitness during the summer before her 3rd year and capitalize on her somewhat injury free state at that time. The academic staff adjusted her summer class load. The strength and conditioning coaches designed high intensity interval workouts to maximize expenditures and minimize time. The athletic training group incorporated rehab exercises into her workouts while the nutrition team updated the athlete's meal prescription, timing, and choices, provided regular onsite meal guidance, increased the frequency of nutrition mentoring opportunities including tele-support. Her sport coaches gave her flexibility in her practice schedules to make additional room for her workouts and nutrition plan. The structure and accountability was a positive aspect of the plan and success was quickly realized. The athlete felt confident and positive about her plan's momentum and was able to play an active role in her own success. The fall semester began with her best start to date. Despite not having lost scale weight, the athlete passed the team conditioning test for the first time, was pain free, eating regular meals with improved food choices, and felt strong and confident for the first time in a long time. Through these efforts her body composition had begun to change. Figure 3. shows changes in DXA measured body weight, lean mass, and fat mass changes over time. Additional measures of body fat data that same year showed a 14 lbs. decrease in fat mass from August through November and an increase of 8 lbs. of lean mass.

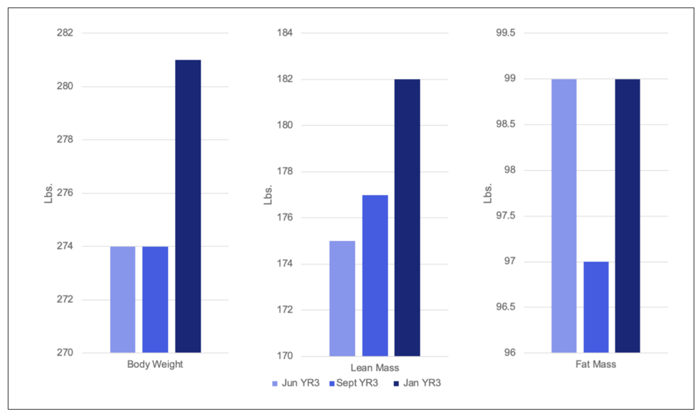

Figure 3: DXA Body Composition measurements during 3rd academic year showing the change in body weight vs change in lean mass and fat mass.

Body Composition, DXA, and Lab Analyses

In collaboration with a research lab on campus with a DXA machine, the VAT measurement capability was identified and discussed as a potential measurement that could help prove success of her summer nutrition and training program. This could continue to motivate the athlete and ultimately advocate for necessary academic and sport load adjustments if weight loss was to continue to be a priority. The VAT estimates were retro-actively applied at the end

	June	September	January
DXA Scan - 3rd Yr			
Whole Body Z-score	2.1	2.2	2.2
Lumbar Z-score	1.0		
L Hip Z-score	2.8		
%Body Fat	36.2	35.3	35.1
VAT Estimates – 3rd Yr			
Estimated VAT Mass (g)	469.0	356.0	383.0
change from previous	-	(-113)	(+27)
Estimated VAT Volume (cm3)	507.0	385.0	414.0
change from previous	-	(-122)	(+29)
Estimated VAT Area (cm2)	97.4	73.8	79.5
change from previous	-	(-23.6)	(+5.7)

**A Z-score above 2.0 is normal according to the International Society for Clinical Densitometry. See Appendix for more information.*

Table 1: DXA and VAT measurements 3rd year

of October to her summer (June) and fall (September) DXA whole body scans and a third DXA and VAT estimate was planned for the beginning of spring semester. See Table 1. for DXA measurement and VAT estimate data. The initial June DXA scan resulted in a VAT area estimate of 97.4 cm^2. Based on the difference between the June and September scans, the analysis demonstrated that the summer nutrition and training program specifically produced a ~0.5 lbs. visceral fat loss. A review of past and pertinent labs along with the current findings triggered a discussion with the team physician on recommendations for exploratory lab work since the June VAT estimate was so close to the threshold for increased risk (>100 cm^2) of an adverse metabolic profile. Shortly after, during the month of November a soft tissue injury followed by a lower body stress fracture again slowed progress in the middle of that 3rd year.

Diagnosis

Lab orders examining the athlete's metabolic status were drawn and reported in January after she returned from semester break. Table 2. summarizes key lab findings. Glucose levels were indicative of impaired fasting glucose and her insulin levels indicated some degree of insulin resistance. The results also showed a vitamin D blood level classified as insufficient, and a stage 2 iron deficiency.

Care Plan

Based on her lab results the athlete was prescribed metformin to improve blood glucose management, an over the counter vitamin D3 supplement, and given a refill of her iron supplement. Her nutrition goals were focused on meal patterning, meal timing, as well as dinner meal planning and prepping in an effort to improve her food choice strategies. Labs were repeated in April and showed a significant, positive change. At the mid-point of the spring semester, the athlete and the performance team members were looking forward to another productive summer given the success she had with the previous year's structure and support. Additional referrals to rule out other medical related conditions, such as polycystic ovarian syndrome were made, and her nutrition and training plan designs would both focus on further reduction of the visceral fat.

Conclusion

Case Summary

In summary, the athlete struggled with her body weight and ability to lose body fat despite being a multisport athlete in HS and participating as a Division I athlete. Both the rates and types of injury coupled with poor nutrition knowledge

Laboratory Results	Aug-1st Yr	Jan 2nd Yr	Feb 2nd Yr	Jun 2nd Yr	Jan 3rd Yr	Apr- 3rd Yr
Glucose (mg/dL)	95	96	99	94	**115**	89
Insulin (ulu/mL)	-	-	-	-	**56.3**	9.9
Hgb A1C (%)	-	-	-	5.1	5.0	5.2
Total Cholesterol (mg/dL)	129	-	-	136	-	-
Hgb (g/dL)	12.8	12.6	12.6	12.5	-	-
Hct (%)	37.6	37.0	38.0	38.0		
Ferritin (ng/mL)	**20**	-	-	**13**	-	-
25-OH vitamin D (ng/mL)	-	-	-	-	**25**	-

**red highlight indicates value outside the normal range*

Table 2: Laboratory results

and habits combined as challenges to achieving an appropriate weight. However, as a result of working through the process and gathering additional data from DXA technologies, we now know that her metabolic status was likely a primary contributor to the slowed response. The DXA whole body, hip, and spine measurements were initially ordered to rule out low bone mineral density and to gather additional body composition data. However, the VAT analysis from the whole-body scan added another dimension of information. That data ultimately provided a critical layer of information which helped identify the problem and guide the clinical decision making. The athlete had likely been insulin resistant for some time and was likely beginning to enter the early stages of prediabetes that would most likely progress to full diabetes if not otherwise detected.

> ***"For the athlete to be made aware of her long term metabolic and disease risks at this stage of life was invaluable. The significance of her continued nutrition education, medical management, training and overall preventive efforts will no doubt pay lifelong dividends."***

Applied Benefit

The DXA technologies are well-known for their role in bone mineral density evaluation and body composition assessment. The VAT analysis is an additional capability that can truly assist sports medicine and nutrition practitioners in identifying those athletes most likely to benefit from early, preventative interventions. The measurements of visceral fat more accurately assess health risks than other methods due to the tissue's pathogenic qualities.[12] Anthropometric measures often do not adequately assess obesity related risks. Thus, commonly used clinical measures can misclassify individuals in terms of visceral adipose tissue and disease risk. The added benefit is that the existing whole-body scans can be reanalyzed with the VAT application. In this manner, the VAT estimates can be a useful, time efficient, and practical method for screening and identifying nutrition related risk. Diagnostic thresholds for visceral fat are being more firmly established; in the meantime, available literature supports VAT thresholds of 100cm^2 for increased risk[11, 14] as shown in Figure 4. Once risk categories are assigned, medical and nutritional strategies along with training and workout sessions can be designed to maximize athlete health and performance.

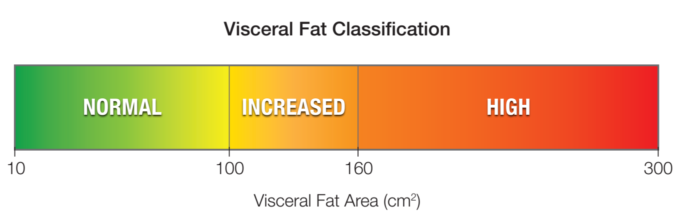

Figure 4: Visceral fat thresholds associated with metabolic risk factors for coronary heart disease[11,14]

Additionally, VAT estimates may also help assess injury risk. Recent evidence has linked an increase in abdominal adiposity with an increased risk of lower body injury.[13] Bosch et al. also showed in 2014 that as body fat increased in males, abdominal accumulation increased exponentially. A measure of 20.1% body fat is described as the threshold at which VAT begins accumulating; before that point, fat is preferentially distributed to subcutaneous regions. Therefore, monitoring the type and region of adipose accumulation can help ensure that weight gain or mass changes are in fact changing in beneficial ways that limit risk of injury, cardiovascular disease, and insulin resistance. Since body composition can be associated with physical performance in many sports and in some sport specific positions, assessing these changes can be advantageous.

Dietitians practicing in sport have a unique opportunity to positively affect and influence the "human" in human performance. The dietitian should be proactive and stay attuned to risk factors of overall health status such as pre-existing or developing conditions that can ultimately affect sport performance and long-term well-being. If an athlete is not healthy and well first, he/she may not be able to reach their full athletic potential. Nutrition care for athletes' health and human performance is complementary.
DXA technology can be a powerful tool to assist the sports dietitian in a variety of ways.

Appendix

Table 1. Bone mineral density (BMD) definitions by various organizations.

	World Health Organization		International Society for Clinical Densitometry		American College of Sports Medicine	
Population	Postmenopausal women		Premenopausal women		Premenopausal female athletes	
Terminology	Osteopenia	Osteoporosis	BMD within expected range for age	BMD below expected range for age	Low BMD	Osteoporosis
Criteria	*T-Score*: −1 to −2.5 (1 to 2.5 SD below the average value for young healthy women)	*T-Score*: ≤ −2.5 (2.5 SD or more below the average value for young healthy women)	*Z-Score*: > −2 (< 2 SD below the average value for age-, sex-, and race-matched controls)	*Z-Score*: ≤ −2 (2 SD or more below the average value for age-, sex-, and race-matched controls)	*Z-Score*: −1 to −2 with secondary clinical risk factors for fracture (eg, chronic malnutrition, eating disorders, hypogonadism, glucocorticoid exposure, previous fractures)	*Z-Score*: ≤ −2 with secondary clinical risk factors for fracture

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