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Understanding "sports hernia" (athletic pubalgia) - The anatomic and pathophysiologic basis for abdominal and groin pain in athletes

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Contents

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Abstract –

Recent publicity and some scientific reports suggest increasing success in treating an entity called "sports hernia" - more accurately named *athletic pubalgia*. The primary purpose of this article is to portray what we believe to be *the key concept* for understanding this wide variety of abdominal and groin injuries that afflict high performance athletes. These injuries have been plaguing athletes for a long time, and past treatments, based on concepts of occult hernia or simple strains, have generally failed. The former concepts do not take into account the likely mechanisms of injury or various patterns of pain that these athletes exhibit. The authors believe that the concept of a "pubic joint" or "pubic dynamic complex" is fundamental to understanding the anatomy and pertinent pathophysiology in these patients. Many injuries can now be treated successfully. Some of the injuries require surgery and others do not. In most cases, decisions regarding treatment and timing for return to full play require proper identification of the problems and consideration of a wide variety of medical, social, and business factors.

Introduction -

Over the past several years, there has been increasing public wonderment about the entity called "sports hernia." What is it? How long has the problem been around? Why haven't we heard much about this before? The purpose of this article is to try to shed some light on the subject. Since the past literature and terminology are so confusing, it seems important to first make a number of general comments and then provide our perspectives on historical, anatomical, and clinical aspects of these problems. Finally, we shall make some additional comments about optimal treatments that take into account traditionally non-medical considerations, such as contracts, owners, and agents. These perspectives and comments are based on an experience of over 8000 examinations and over 5000 surgeries on patients with these problems. Success rates and other clinical follow-up have been reported in other articles [1,2,3,4].

General Comments –

Let us first make some general comments on what we are talking about. We are talking about a wide variety of injuries to the anterior pelvis outside of the hip joint. The locations of the symptoms and signs involve the lower abdomen, the pubic symphysis, thigh adductors and hip flexors, as well as many other structures such as the gracilis, sartorius, and obturator externus muscles. Therefore, from an anatomic basis alone the term "sports hernia" seems much too simplistic and just doesn't fit with the fact that numerous anatomic structures are involved.

Plus, the primary mechanism for most of these injuries involves hyper-extension of the abdomen and/or hyper-abduction of the thigh, and the pain occurs primarily with exertion, often in multiple locations, rarely involving the internal ring. Therefore, thinking along the lines of occult, garden-variety inguinal hernias seems intuitively wrong. Instead, we should be thinking in terms of some sort of imbalance that affects multiple soft tissue structures, often symmetrically,

around the pubic bone. So, to understand the many abdominal and groin injuries that afflict athletes, it is likely appropriate to first throw out of one's head all assumptions associated with the pathophysiology of inguinal hernias. Instead, it is better to think more "orthopedically", i.e. in terms of attachment disruption and instability of a "joint."

The term *athletic pubalgia* seems a much better fit than "sports hernia" since the former term captures the idea of multiple possible afflictions around the pubis and does not connote a likely misleading cause of pain. Unfortunately, as poor a term as "sports hernia" may be, we may be stuck with it since the sports news media has recently so popularized it. The press has popularized the term for three presumptive reasons: a demand for stories since several prominent athletes have gotten injuries, an apparent need to connote understanding, plus easier pronunciation.

The Past Literature **-** When one looks at the large number of articles on such injuries in the sports medicine, physiatry, physical therapy, and other literatures, one comes away very confused. Two recent reviews document well this confusion [5,6]. A huge number of other terms and diagnoses are introduced – *osteitis pubis*, *hockey groin*, *"Gilmore's" groin*, *gracilis syndrome*, *pectineus syndrome*, to name a few [7-12]. There seems a tremendous amount of overlap among both the diagnoses and terms used, and it is often difficult to distinguish the objectivity of the various observations. To confuse things more, terms such as "athletic hernia," "sports hernia" or "sportsman's hernia" were actually around since at least the 1970's and then at some time came into disrepute. Apparently, the poor results from surgical hernia repairs for such problems led to the well-incorporated dogma in surgery residency teaching that one should not operate on the groin unless one palpates a distinct hernia-type bulge [13].

In parallel with the confusing terminology, the past literature also seems devoid of any consistency with respect to how to think about the pertinent pelvic

anatomy or pathophysiology of the injuries. There may be two main reasons for this inconsistency. First, the musculo-skeletal anatomy of the anterior pelvis ***is*** very complicated. Plus, no real surgical specialty has had to deal very much in this region of the body, except for severe blunt trauma when treatment often involves non-operative measures such as mass trousers or prolonged bed rest.

One might even describe the pelvic anatomy involved in these athletic injuries as a "no-man's land" for the various specialties. Orthopedists classically take care of problems up to the hip except for the rare resections of large pelvic cancers. General surgeons take care of problems of the colo-rectum, internal inguinal ring/Hasselback triangle areas, and large blood vessels. Urologists think of the pelvis according to the genito-urinary anatomy, and gynecologists define the pelvis according to the reproductive organs that reside in this space. For these specialists, the musculo-skeletal attachments of the pelvis may once have been studied in medical school but later had little pertinence to their current practices.

On the other hand, the anatomy and the pathophysiological considerations of the pelvis are indeed complicated, and in a way, it is appropriate for there to be some confusion. For example, each of the above-mentioned specialties does treat a variety of conditions that cause pelvic pain, and it is particularly important to consider this wide differential diagnosis in athletes and non-athletes with pelvic pain. We have seen many cases of inflammatory bowel disease, endometriosis, cancer, as well as many other non-musculoskeletal problems in this generally young group of patients referred for abdominal and groin pain.

Let us mention one additional point about the past literature. In that literature, there are many claims with respect to the best way to treat the many injuries. We must be extremely careful in interpreting these results. There is a misleading tendency to lump all the injuries into one category when the patients clearly have multiple different problems [2,3,14,15]. Follow-up parameters in

such series must be carefully defined, measured, and sufficiently detailed to permit critical interpretation. In addition, it is easy to become biased upon some initial success. For example, the zeal [16] of the "laparoscopic revolution" [17-20] over the past 15 years may have carried over to the treatment of these injuries.

To be more specific, we have been re-operating on a large number of patients who have had open or laparoscopic mesh repairs unsuccessful in solving the pains. Over a 16-month period, we re-operated on 153 such athlete-patients treated unsuccessfully by laparoscopic or open mesh hernia repairs. Fortunately, the two-year success rate with the re-repairs in these patients approaches the same rate as for first-time repairs [1]. We have also treated several disastrous complications from the laparoscopic attempts at treatment of otherwise very healthy patients. For the above reasons and the wide range of reported results [21-27,77], we are skeptical of laparoscopic hernia repair as a primary treatment for most, but not all, of these patients. Plus, we worry about the increasingly large number of athletes for whom we are taking out the mesh from their prior open or laparoscopic repairs.

The "Pubic Joint" **-** In this article, we shall make numerous references to what we call *the pubic joint.* This is because we believe this to be the most important concept for understanding and treating these injuries. Multiple injuries occur around this joint and the operations vary depending on the specific musculo-skeletal anatomy that is involved. With current techniques of MRI, we can image each of these injuries and correlate the images precisely with the clinical diagnoses [28-33] [Figures 1 and 2].

The pubic joint is *not* the same as the pubic symphyseal joint, i.e. the space between the two sides of the pubic symphysis. Instead, we are talking about a large, complex rotational joint that involves both pubic symphyseal bones and the entire anterior pelvic musculo-skeleton around these bones. The joint involves all the non-hollow organ, soft-tissue attachments on either side of the

pubis, specifically **excluding** the ball-in-socket hip joint. According to the U.S. National Library of Medicine and the National Institutes of Health, a joint is defined by "the point of contact between elements of an animal skeleton whether movable or rigidly fixed together with the surrounding and supporting parts" [34]. Considering the rotational activity around the pubic bone, we see no reason that the "pubic joint" does not satisfy this definition. Most of the abdominal and groin injuries that afflict athletes are due to disruptions of this joint, and can be managed effectively after identifying the precise anatomy that has been disrupted. We shall go into this anatomic concept in more detail later.

Another way to think of this anatomy is to liken the anatomy and function to the inferior glenohumeral ligament complex in its role of providing stability, function, and the prevention of over-extension and over-rotation. So, alternatively, we might call the "pubic joint" the "dynamic pubic complex." "Pubic joint" is easier to say so we shall use this term mostly in this article.

A Historical Perspective –

Early History **-** These injuries are not just a recent phenomenon. Let us begin this history with Richie Szaro [35]. Richie was a college classmate of one of the authors in the late 1960's/early 1970's. In his senior year in high school, Richie was considered the top recruited high school football player in the country. A running back, Richie's first love was actually soccer. An immigrant from Hungary, Richie actually played both sports at the same time.

Throughout Richie's years at Harvard, Richie had a nagging lower abdominal or groin injury that kept him from playing full-time American football. This author remembers well first-hand the disappointment that this caused, both to Richie and the Harvard alumni. It was obvious at the time that Richie had a real injury that was not understood and that injury functionally ended his running-back career.

While playing soccer at amateur and professional levels in the U.S. and South America [36], the author saw multiple other soccer players who probably had similar injuries that ended their careers. It is clear, therefore, that such injuries are not just a recent problem. It is not just a condition caused by recent training methods or changes in turf conditions. A large number of such injuries have occurred for many years.

In the mid-1980's, the author had the good fortune of assisting Drs. Frank Basset and William Garrett [37] with the care of the Duke University athletic teams. It seemed that on each team there were one or two players who prematurely ended their careers because of abdominal or groin injuries. At the time we did not know how to take care of such injuries. As we looked around, no one else seemed to have the answer either. Partially as a result of listening to a Yugoslavian physician named Nesovic [38], we developed the concept of the pubic joint.

At the time we were following three players with similar injuries – a college soccer player, one of our basketball players, and a minor league centerfielder. We decided to apply to these athletes a surgical procedure that made sense in the light of our new concept. To our delight, the patients did well and returned to their previous performance levels.

Then by word of mouth and the result of an early publication [15], other patients came to us for treatment. This experience allowed us early on to amass a very large series and to collect detailed long term follow-up initially on about three hundred patients [1].

The 1990's **-** During this time, we recognized several things. There were multiple types of injuries that required tailoring of the operations to those specific injuries [1,2]. Also, we initially had excluded patients who had similar problems but also carried the bone scan or MRI diagnosis "osteitis pubis." Based on some

verbal communications with European surgeons who had reproduced some of our results, we called back some of the latter patients and did surgery on them. The results from surgery on the osteitis patients were similar to the group as a whole [4,39].

During the early 1990"s, we also spent considerable time in the fresh cadaver laboratory. With these fresh specimens that had not undergone the distortions of *rigor mortis*, we sought to understand better the anatomy and the mechanics of the conceptual joint. None of these studies had enough numbers to meet statistical standards, nor were they done with rigorous scientific calibrations, so they remain unpublished. Nonetheless, they formed the basis of our devising several new operations. Therefore, we feel it important to mention one study on eight fresh cadavers.

In these specimens, varying degrees of cutting the insertion of the rectus abdominis attachment to the pubis with the cadaver in a supine position resulted in 30-100 cm (water) increases in pressure within the adductor longus muscle compartments. In fact, when observers inserted their fingers behind the adductors while the rectus was being cut, bony projections from the anterior edge of the inferior pubic ramus caused dramatic pain in the observers.

Such observations led us to understand better the anatomy. The abdominal attachments to the pubis and hips interrelated profoundly in a mechanical way with the adductors, flexors, and rotators of the hip; thus providing additional evidence that the pubic joint concept was applicable to severe injuries.

During the same time period, we also recognized empirically that there were a variety of musculo-skeletal syndromes to consider as well as many diagnoses involving the gastrointestinal, genitourinary, and other body systems [1]. At that time, MRI's, in fact, revealed the specific musculo-skeletal problem in

only 10 to 15 per cent of patients [40], it often provided evidence of the non-pubalgia diagnoses. Therefore, even though the magnetic resonance imaging (MRI) usually did not identify precisely the problems, it was nonetheless still important to perform.

This imaging test was helpful in interesting other ways. In about 90% of cases, the imaging tests revealed multiple "soft" musculo-skeletal findings, such as tiny avulsion fractures or peculiar edema patterns, on the side(s) of the injury. Considering the National Library definition of a joint cited above, "multiple points of contact" would provide multiple potential sites for injury if the joint were unstable. Therefore, the latter constellation of observed MRI findings fit well with the concept of joint instability [40,41].

Intrinsic hip pathology often surfaced as an important consideration particularly when the clinical findings were equivocal. And in fact, several problems in nearby locations were sometimes seen in the same patient – such as the co-existence of rectus abdominis tears with a psoas bursitis or a labral tear. MRI also revealed multiple other hip and other musculo-skeletal problems, as well as other problems that had nothing to do with the musculo-skeleton [40,1].

Surprisingly, Crohn's disease was one of the more common non-musculoskeletal problems the MRI's initially revealed. We also picked up several cancers of various types plus some benign tumors. The test also revealed a number of urologic and other problems. In women, endometriosis, ovarian, and other gynecologic and obstetric pathology emerged as relatively frequent considerations.

To test the veracity of the concept of joint instability, we did what we believed was an important study using the MRI images. Our hypothesis was this: Although the "soft" findings did not always correlate specifically with the clinical

findings on the patients, the radiologists would be able to predict the side(s) of the injury without their knowing any of the clinical findings.

So we gave 40 sets of images – 30 on injured patients and 10 on normal, uninjured patients – to three MRI experts and asked them to tell us, in a blinded fashion, whether they suspected an injury; and if so, on which side(s) they believed the injury to be. Interestingly, the radiologists were correct in identifying the injuries in 29 of the 30 patients with injuries, and also in naming the correct side or sides of injury (or absence of injury) in 36 of the 40 patients. Therefore, the "soft" findings on MRI may not have identified the primary site of injury; nevertheless, the findings were useful in identifying general disturbances on the side of injury, perhaps via compensatory musculo-skeletal effects and fitting with the concept of joint instability.

Some of the above results were subsequently published [40], but at the time we already knew that often the injury would begin on one side of the abdomen and groin and then involve the other. We subsequently learned that when the patient initially presented with unilateral pain, we should suspect that the other side might also be at risk even if the MRI showed no findings on the contralateral side. The incidence of a new problem on the side opposite a successful repair turned out to be about 4 per cent. Therefore, we now use "soft" findings on the side opposite a unilaterally symptomatic abdomen/groin as a potential indication to do bilateral repairs.

It is interesting that a recent paper [42] from Europe reported objective findings very similar to ours mentioned above. In this recent paper, 52 MRI examinations were given to two radiologists "masked to the clinical details." Through similar "soft" findings, both radiologists identified the side(s) of injury with a high degree of accuracy. Assessment of imaging side severity using post-gadolinium sequences correlated significantly with the clinical findings ($p=0.048$ and $p=0.023$ for the two radiologists).

Several other events are noteworthy from the 1990's. About the same time as we were studying the problems, Gilmore in England was making observations similar to our own initial observations. He was caring mostly for European soccer players [43,44]. He also seemed to be performing similar operations to our own, and was reporting similar success rates. While some of Gilmore's observations were different than ours, we believed that Gilmore was more or less independently confirming many of our concepts and surgical results.

Also at about the same time, Nesovic from Yugoslavia also appeared to be independently coming up with observations similar to ours and Gilmore's. We have in our possession an apparently unpublished paper written by Nesovic about the year 2000. The paper, entitled *Painful Symphysis Syndrome in Athletes and Possibilities of its Treatment,* describes many observations and successful management of an unspecified number of athletes. Nesovic's observations go into some detail concerning the anatomy of the muscular attachments to the pubic symphysis, a "kynesiological analysis" of 63 patients, and a long list of operations that are similar to our own [2].

During the decade of the 1990's, team trainers, physical therapists and physicians became much more skilled at recognizing these injuries [1]. In the first half of the decade, most patients had had their symptoms well over a year. In the latter half, the diagnosis was made, for the most part, within months after the injury.

In general, the trainers and physical therapists became convinced that these injuries were real before many team physicians did. Most of the proliferation of papers on the subject was printed in the orthopedic literature. Good reviews also appear in multiple trainers' manuals and in the physiatry literature [45-56]. These reviews point out both the multiplicity of problems and the difficulty sorting out the underlying pathology and treatment.

Also during the 1990's, we came to recognize that a variety of tightening and loosening operations [2] have major applicability in the care of these patients. As mentioned, the set of injuries involve multiple different areas in the abdomen and pelvis. Therefore, performing applicable operations requires a detailed understanding of the applicable anatomy. Pains often result from not only the primary injury but also from compensatory attempts to restore joint stability. We will review some of these syndromes and procedures later in this review.

The 2000's **-** During the latter half of the 1990's, we came to recognize that the pathology associated with these injuries can be obvious or subtle. The group with the most dramatic pathology has been bull-riders, many of whom have been under the care of Dr Tandy Freeman in Dallas. Riding their animals, these athletes routinely exhibit postures that highlight the classic mechanism of injury – a combination of *hyperextension of the abdominal muscles* and *hyperabduction of the adductors* of the thigh. Complete avulsions of the rectus abdominis muscles and/or multiple adductor muscles from the pubic symphysis occur frequently in these rodeo performers.

The 2000's have brought additional advances in the understanding and management of these injuries as well as a few steps backwards. Recent MRI studies exemplify this increased understanding [28-33]. With the advent of high-definition MRI and other MRI techniques, we are now imaging more pathology. As noted, in a recent presentation at the Radiologic Society of North America [28], we found in a large series that 98% of patients had findings on MRI deemed likely to be related to the abdomen and/or groin pain. When compared with surgical findings, MRI had sensitivity and specificity of 68% and 100% for rectus abdominis pathology and 86% and 89% for adductor tendon pathology. Only two patients had inguinal hernias. Interpretation of the MRI findings still is very tricky from the standpoint of identifying primary versus compensatory pathology, but

MRI was overall 91% effective in identifying the precise pathology correlating with clinical findings. Compared to MRI, ultrasonography [57,58] or herniography [5,6] remain more subjective and less helpful. Like the knee, the most important problem with respect to stability of the pubic joint may be obscured by other identifiable pathology.

Overall, the existence and fixable nature of many of the severe injuries has become more recognized. More syndromes have become established [2]. Some injuries are more reparable than others and some injuries do not require surgery.

The 2000's have brought with it not only an increased recognition of the problem, but also some likely advances in both rehabilitation and prevention. During the season, we now return most athletes to full performance within several weeks after the repairs. The observations of a German surgeon [59] who tried to return players within 2-3 days of her procedure, rather than the 2-3 week protocol now commonly employed for simple tears, challenges us to return players to full activity even sooner than we have doing as well as to consider the roles of nerves in the causation of pain. The notion of such early return challenges us that sensory denervation may play a role in treatment [60]. The problem here, of course, is that many patients who had denervation approaches alone actually persisted with symptoms, had early recurrences, and in some instances developed more serious injuries, presumptively because the primary injury was never fixed.

Various factors affect optimal timing for return to full activity such as: specific type of injury(ies), severity of the injury, type of sport, the playing season, pre-operative fitness, strength re-building, and contract negotiations. Often, injury repair can be postponed until the end of the season. For most but not all injuries, continued physical activity prior to repair is unlikely to change the

success rates of surgery. After surgery, the incidence of persistence or recurrence for most injuries is very low.

We have learned that this multi-factorial nature of the decision-making can profoundly affect timing for return to play. For example, consider the multiple variables involved in a baseball pitcher having a great season in his contract year and suddenly avulses his adductor longus and part of his rectus abdominis. Say, for the purposes of discussion, that his team is on the bubble for the playoffs. Does one do surgery right away or wait? After surgery, how quickly should he come back, taking into account the danger to his arm of poor pitching mechanics? The answers also have to take into account the player, agent, manager, and owner, and in addition, how long will it take for him to re-build his arm strength after being free of pain? Other factors include the signability of the player after the season as well as the contract risk related to performance if he comes back too soon. Clearly, these answers are not simple.

Prevention of injury has also become now become a special focus in the 2000's. Alex McKechnie, now working for the Lakers, has now applied a certain combination of core stabilization and flexibility training to the prevention of such injuries [61]. He bases his exercises on the anatomically neutral position. In the past, attempts at preventing injuries had been conducted prospectively within individual teams from various professional sports. The previous attempts at prevention focused more purely on strengthening of certain abdominal muscles, and may even have led to some injuries. Trials are underway with McKechnie type protocols in Major League Soccer and several other venues to see if such training can prevent such injuries [62].

Interestingly, a similar protocol may have, in one study, decreased the incidence of anterior cruciate knee injuries in women college soccer players [62]. The latter observation suggests the same core training may have applicability for a variety of sports and injuries.

In a recent study of NFL players, it appeared that injury occurrence was influenced by specific player positions and the timing of pre- and off-season workout sessions [63]. Efforts are underway to optimize in-season and off-season protocols with respect to prevention of these injuries.

Anatomic Perspective –

The anatomy pertinent to the understanding of athletic pubalgia syndromes appears in the latest edition of Byrd's Operative Techniques in Sports Medicine [2]. Basically, one thinks of the anterior pelvis not only as a large number of complex joints, but also as one joint that we call the "pubic joint." Let us consider a brief summary of this anatomy.

It is probably easiest to consider this joint in three ways: 1) by its bony anatomy and the forces the joint creates [Figure 3], 2) by the three compartments of muscles or other attachments that provide ligamentous type support [Figure 4], and 3) by the net effect of the forces – a slight anterior tilt [Figure 5] that helps define the normal anatomical position and forms the basis for the newer preventive protocols.

Bony Anatomy **-** The bony pelvis has two principal functions: to transfer weight and to withstand compression forces resulting from its support of the weight. There are four major pelvic bones joined anteriorly at the pubic symphysis. The four pelvic bones are, of course, the two hip bones, the sacrum, and the coccyx.

The Forces **-** A key part of the anterior pelvic anatomy that forms the fulcrum for many of the forces is the pubic symphysis. Coordinated contraction of the muscles that directly attach to this fulcrum produces a slight anterior tilt consistent with the combined nature of the anterior tension that results.

The muscles that attach to the fulcrum probably play more of a role in stability than the fibrocartilaginous disc that connects the two sides of the symphysis. Note that the latter statement represents a difference in the thinking compared to older concepts about "osteitis pubis." Most athletic patients with osteitis pubis actually have some degree of inflammation that relates to the disruption and compensation of the muscles that attach to the pubis rather than an intrinsic inflammatory condition that relates to the fibrocartilaginous disc that connects to two parts of that bone.

Therefore, for most athletes, use of the term *osteitis pubis* in athletes simply describes an empiric sign or a radiologic finding rather than an actual diagnosis. Another way to think about this is to use the term *primary osteitis pubis* to describe the patient with unexplained severe pain and inflammation of the pubic symphysis mostly at rest. One then calls the exertional pain or tenderness in athletes that relates to secondary inflammation of the pubic symphysis - *secondary osteitis pubis.*

One can then think in terms of there being three sets of forces and counter-forces that point to and from the symphysis fulcrum. For convenience, we think of these forces as residing in three different compartments.

The anterior compartment consists mainly of the abdominal muscles plus some complex interdigitations with fibers from the thighs and medial and posterior pelvis. The posterior compartment then consists primarily of the hamstrings, a portion of the adductor magnus, and several key nerves, and an artery. The medial compartment consists of the most important thigh components, which include the gracilis, the three adductors, and the obturator externus.

The Ligaments **-** The anterior compartment is particularly important with respect to many of the relatively uncommon, but nonetheless extremely

important, variants of the athletic pubalgia syndrome. Together, these variants comprise about 50% of the patients that we see.

The anterior aspect of the thigh accounts for a number of these variants. For these particular variants, we are talking about the: sartorius, iliacus, psoas, pectineus, vastus lateralis, vastus medialis, vastus, intermedius, and the rectus femoris muscles and tendons. One can think of the attachments as providing different types of either *central* or *strap* support – depending on their medial or lateral locations, insertions, or origins. For example, a combination of the rectus femoris and the obturator externus are particularly important in place-kicking, the adductor longus and magnus are particularly important as push-off muscles in pitching.

We also can think in terms of four groups of muscles: adductors, abdominal flexors, thigh flexors, and internal or external rotators. The adductors that are most important are the adductor longus, brevis, and magnus, the gracilis, and the pectineus. The rectus abdominis and to a much lesser degree the obliques and transverses comprise the more superior flexors, and the psoas major and minor combines with the other thigh flexors as the key inferior flexors of the pubic joint. The rotators consist primarily of the obturator externus and internus and the quadrator femoris.

Other Important Anatomic Considerations that Relate to the Pathophysiology – It is important to recognize that there used to be two rather different traditional definitions of the *pelvis or pelvis floor,* and now there are three. Traditionally, there is the gynecologic definition that includes primarily the gynecologic organs the bladder and urethra [64]. Second, there is a laparoscopic definition that describes both the anterior and posterior aspects of the entire pelvis (or "abdominal floor" as seen through the laparoscope) [65]. The second definition describes only the deep aspects of the pelvis that faces the peritoneal cavity*.

From that viewpoint of the laparoscopic surgeon, the floor is made up of several muscles that include the pubococcygeus, puborectalis, and iliococcygeus muscles that are commonly called the levator ani. The floor also represents the entire inferior, saccular muscle-organ complex that holds the intra-abdominal viscera inside the peritoneal cavity. The floor also includes the organs in the gynecologic definition and the rectum.

Now we have a third definition. In the present definition, the “pelvis” or “pelvic floor” portrays just the anterior half of the pelvis. This floor includes the rectus abdominis muscles and tendons, the thigh muscles, and the other stabilizers in the three compartments mentioned above and also the semimembranosus, the sartorius, and the biceps femoris muscle insertions. We think of the latter three muscles as having various functions including strap, flexion, abduction, and lateral rotation functions.

In athletes, tremendous torque occurs at the level of the pelvis. The anterior compartment often, but not always, takes the brunt of the forces resulting from this torque. Contraction of many of the above muscles, especially the rectus abdominis, adductor longus, and psoas major, creates tremendous force and counts as a major factor in this torque. The net normal anatomic effect of this torque is a net anterior or antero-medial tilt [66-69] of the pubic joint [Figure 5]. When one muscle weakens, the result is an unequal distribution of pelvic forces compared to normal. This is basically what happens in the athletic pubalgia syndromes.

Another key consideration here is to consider the hip joint itself. The hip joint sits rather passively within these huge body forces. Therefore, the hip joint is particularly vulnerable to the large forces that commonly apply themselves here. The softest part of the hip joint may be the anterior labrum. So, that feature is particularly vulnerable to these forces.

In athletes that we see, we commonly try to separate out the diagnoses of athletic pubalgia from labral tears or other intrinsic hip pathology. One needs to recognize clearly that these injuries often *do occur together.* Plus, even when multiple injuries are recognized, one or more of the injuries may be asymptomatic. Therefore, the precise diagnosis that relates to the pain problem may not be immediately apparent. Important judgments then need to be made with respect to which injury to attack first in the treatment of the athlete's pain. To complicate things further, the afferent sensory nerve distribution overlaps greatly among the above anatomic structures.

We should also consider that if one thinks of these attachments as ligaments, the injuries then often occur in the most physically fit of athletes. The latter observation suggests that inadequate fitness *per se* is *not* a pathophysiologic factor in the development of most injuries. Like anterior cruciate injuries, anterior pelvic injuries often occur in the most fit of athletes. Acute pelvic injuries, like anterior cruciate injuries, probably result from an exertional imbalance and temporary loss of core body control.

The latter concepts also possibly explain why the pelvic injuries are more common in males than females [1] and why when women do get these injuries, they are often slightly different [2]. We once attributed the relatively fewer abdominal and groin injuries in females to less participation in major sports. The latter explanation is obviously not the case today.

The differences are undoubtedly a result of differences in female versus male anatomy [Figure 6]. These anatomical differences include: 1) a more slender and lighter female pelvis with fewer shifts in forces, 2) a relatively wider subpubic angle leading to a different distribution of forces, and 3) a relatively wider, more stable pelvis of the female resulting in transference of dangerous, destabilizing forces to the more narrowly based lower extremities, particularly the

knees. The latter, of course, also probably explains the increased incidence of anterior cruciate injuries in females.

Clinical Perspective –

Understanding the anatomic principles outlined sketchily above leads to the recognition of a number of different syndromes. In the recent chapter in Byrd mentioned above [2], we described 17 different syndromes or variants of the same athletic pubalgia syndrome.

The way to think about each of these syndromes is to identify which muscles or group of muscles have been weakened and which are over-compensating. Like the knee, the basic injury may be of one particular ligament, but the resultant instability causes pain in other locations represented by failed attempts by attachments to restore stability.

General Considerations About the More Common Syndromes **-** The syndromes include some of the more classic athletic pubalgia abdominal problems with or without adductor or iliopsoas components, as well as a number of relatively uncommon syndromes. The most common mechanism of injury is a tear or a series of micro-tears of the rectus abdominis muscle or tendon as it inserts onto the pubis.

The tears are most obvious in its anterior and lateral aspects, but also may be seen posteriorly or intramuscularly. Since the torque that causes most injuries results from hyper-extension of the abdomen and hyper-abduction of the thighs, the anterior and lateral pathology are the most important.

One way to think about the pathology associated with the more common injuries is to imagine pulling on two ends of a rope. The pathology that becomes most evident immediately is the fraying that occurs on the superficial aspects of the rope. The sides that get most torn depend on the direction of forces

associated with the torque. And although we see the pathology on the outside of the rope (or muscular sheath), this is because this is the only aspect of the rope that we can see. We must assume that the inside of the rope is also injured.

This is precisely what we see in patients. There are multiple areas of fraying on the lateral and anterior aspects of the fascia of the muscles. Sometimes the tears are deep and sometimes they are only superficial. It is a mistake to think that what we are seeing is the only site of injury. These tears occur both in the abdominal muscles as well as the adductors and other attachments.

It is also logical to think, based on the directions of forces and torque, that the more anterior and lateral aspects of the abdominal attachments will be most affected, and this is usually the case. On the other hand, the posterior and medial aspects may also be affected, but to a more minor degree.

There is actually no posterior sheath on the lower third of the rectus abdominis muscle so descriptions of tears of the posterior sheath in this region are simply not accurate. Instead, minor injuries to the posterior muscle fibers are sometimes seen, but again these are not, generally, as important as the anterior and lateral pathology. Over the course of the past 17 years, we have performed multiple laparoscopic examinations of the pelvis in these and other patients. We can not usually tell a difference in pathology in the male athletes with groin pain compared to non-athletes undergoing laparoscopy for other reasons. However, we do occasionally see small tears of the transversalis and internal oblique, consistent with observations of others [70] and consistent with the multi-focal nature of the injury depicted by the above “rope” analogy.

In the extreme, such as what has been seen often in the bull-riders, partial or complete avulsions from the pubic symphysis of the rectus abdominis or

adductor muscles occur. In the worst cases, there are multiple avulsions at the same time.

Therefore, we classify the pathology seen at surgery for the common syndromes as: *Grade 1* – single or multiple small tears; *Grade 2* – partial avulsion or avulsions; or *Grade 3* – complete avulsion or avulsions or a complete avulsion associated with another partial avulsion.

Another source of pathology that we are appreciating with increasing frequency in these athletes is labral and/or other hip pathology. An upcoming publication will illustrate this overlap of athletic pubalgia and hip pathology, which we have seen in as high as 27% of hockey players referred to us. This co-occurrence of pathology probably should not be too surprising considering the proximity of the hip and pubic joints as well as the interplay of the musculo-skeletal structures that probably serve both joints [66-69].

Less Common Variants - A number of different variants of the above syndromes populate our database. The more common of the "less common variants" consist of injuries to the same or similar attachments.

We'll mention several interesting examples. The principal pathology of soccer players with particularly strong kicks from the ground may be in the more *superior aspects of the rectus abdominis* muscles. The *Spigelian* areas seem particularly vulnerable to shearing forces. Women are much more likely to have the *sartorius variants*. Basically, the thinking here is that the sartorius is a strap muscle that receives relatively more force. In a relatively wider pelvis, this would be logical and might explain why women relatively commonly have pain in this location when they have athletic pubalgia symptoms.

Similarly, the *gracilis,* the *pectineus,* or the *rectus femoris* may exhibit similar problems, and we have named the syndromes according to the

musculotendinous insertions that are most intimately associated with the pains. We have also seen prominent pain in more unusual areas such as the *quadratus* or the *iliotibial tract*. Pains in these locations have resolved with surgery aimed at these locations.

Other Syndromes **–** Over the duration of our large experience, we have also had the opportunity to see a large number of other problems for which we have identified specific pathology and sometimes devised ways to treat them effectively - either operatively on non-operatively. Others have described some of these problems previously.

One of the more common of these syndromes that has been described by many authors is *coxa saltans* or *internal snapping hip syndrome.* This syndrome can occur in conjunction with the athletic pubalgia syndrome or as an isolated entity and is described as an audible, palpable, or visible snap resulting from the repeated shifting of the iliopsoas tendon laterally over the head of the femur [71]. This syndrome, of course, involves the snapping of the psoas tendon over a number of possible protruding structures between the hip and the tendon. The possible protrusions include two bony eminences, the hip capsule itself, or granulation tissue that has accumulated as a result of injury.

Sometimes, but not always, this syndrome is cured or ameliorated by one or a series of well-placed steroid injections. The snapping hip syndrome that occurs in conjunction with athletic pubalgia responds to a combination of psoas release and pelvic floor repair.

Some other interesting problems include *the Baseball Pitcher/Hockey Goalie Syndrome, Athlete's Rib Syndrome, the Round Ligament Syndrome,* and various *Calcification Syndromes.* The first of the above occurs mostly in players in those positions and consists of a true muscular hernia through the nearby epimesia sometimes in conjunction with a partial or avulsion of the adductor

longus or magnus. The problem often resolves on its own but is fixable through a variety of methods. When surgery is necessary it involves rather extensive focal epimesiotomies and a neurolysis.

We have seen the second of the above syndromes primarily in rowers and tennis players. Basically, the problem involves a subluxation of the lowermost ribs or costo-chondral cartilages. Treatment may mean resection of ribs and replacement by mesh to prevent hernias or re-growth of bone. The round ligament syndrome may be a manifestation of endometriosis. The clinical diagnosis involves a trigger point for the pain associated with manipulation of the round ligament. The pathology consists of considerable acute and chronic inflammation of the round ligament and occasionally true endometriomas.

The calcification syndromes involve pain relating to the calcifications associated with chronic partial or complete avulsions of key attachments such as the rectus adominis muscle or adductor longus. We have also seen the latter syndrome following unusual operations for athletic pubalgia.

For example, an unusual operation actually worked for ten years. The patient was a collegiate tight end, and the operation consisted of a pubic periosteal flap lifted onto the rectus muscle in order to stabilize it and three months of bed rest. We saw the patient initially eleven years after his original operation when he developed severe pain resulting from a massive rectus calcification. Management was surgical and consisted of excision of part of the rectus muscle and mesh replacement.

Additional Comments –

Let us summarize briefly what has been stated above, so that we may add a few more comments about how best to manage or possibly prevent these problems, and also when to best return the athletes to game activities. It should

be clear that these injuries are real and that these are not new problems related to recent training activities or new facilities. The concept of the pubic joint is key to understanding the various injuries. And the diagnosis and management of these injuries can be tricky considering that most of us were not provided very sophisticated courses in the anatomy or biomechanics of the pelvis.

Consistent with the reality that athletes get *a variety of injuries* to the abdomen and groin, proper clinical care requires careful consideration of the specific structures involved and the short and long term consequences of the prescribed treatment. Therefore, no one treatment technique fits most patients. Similarly, proper rehabilitation and timing of return to game activity depends on both the precise diagnosis and the consequent treatment.

Prevention of such injuries, on the other hand, may indeed involve a common protocol. The protocol should be directed at maintaining balance with respect to the pubic joint. The concept of "losing core control" involves losing balance in this joint. Proper use of this joint involves a slightly pronated posture, as might be suggested by in the basic tenet of the normal anatomic position.

Therefore, proper balance involves improving strength and fitness to maintain this slightly anterior bend. Many evolving protocols are now focusing on these points. The relatively easy acceptance of some of the protocols by soccer coaches may be a testimony to the above logic.

It should not be surprising that these new methods of training may not only decrease the incidence of pelvic injuries, but also may also decrease the incidence of other injuries such as to the back, hip, or knee. The results of this new fitness training may be better training in general for athletes.

To this effect, we quote the statement of Alex McKechnie at a recent soccer conference [72]: "As trainers and physicians, we are not, and should not

be in the business of training soccer players. We are and should be in the business of training the players to be better athletes."

Let us say a few more words about identification of the injuries, timing of treatment, rehabilitation, and return to sport. We and others have published various algorithms and programs with respect to these important decisions [3,4,73,74]. It is important to understand whether these protocols are designed for the in- or off-season. Those algorithms or programs have value in a general sense but not so much value with respect to a specific patient.

The above decision points depend on a variety of medical and social/business factors. The medical factors include identification of the specific suspected injury, the degree of debility the injury causes, the possible negative consequences of playing with the specific type of injury, and the success rates of operative versus non-operative treatments. The social/business factors include the relative risks of playing on the injury, the timing of the injury i.e. whether or not the injury occurs within or at the end of a season, the importance of the upcoming games such as playoffs, the individual player's contract, the team's interest in the player, and the player's confidence that his/her performance will not affect subsequent interest or contracts.

While most of the injuries to the abdomen or groin may be treated according to the degree of produced debility, several injuries can be made worse by continued playing. Correct decisions, therefore, can be complex and require good doctor/patient/management relationships.

Certain general considerations seem worth mentioning as guidelines to the above decision-making. Most, but not all, operative repairs can get the athletes back to full game activity before six weeks. It makes sense that if the operation involves re-attachment or re-enforcement of a structure, then one must allow a certain amount of time for scarring to take over the function of the

stabilizing sutures. Whether or not such stabilizing scarring takes one week or four or five weeks is arguable. The arguments must involve a discussion of relative risks of return with respect to disruption, etc.

The various loosening operations [75,76] – adductor releases, etc – do not require stabilizing time, and time for return to game activity in general may be shorter. However, the surgical pain resolution may vary and take at least several weeks.

Conclusions –

In this article, we have tried to provide some perspectives on a large set of real injuries that afflict high performance athletes. From a historical basis, the injuries have been around for a long time. Some initial mistakes attributing the cause of the injuries to occult hernias led to many unsuccessful operative repairs and a general surgical dogma against surgery for uncertain abdominal or groin pain. Increased understanding of the basic underlying anatomy and pathophysiology has led to considerable advances in the care of these patients.

The concept of the pubic joint is key to the understanding of the anatomy and pertinent pathophysiology in these patients. These patients develop a large set of injuries. Many of these injuries can now be treated successfully. Some of the injuries require surgery and others do not. In most cases, decisions regarding treatment and timing for return to activity require proper identification of the problem and a consideration of a wide variety of medical and social/business factors.

Fortunately, protocols for prevention of these and other injuries look promising. These protocols utilize the concept of playing under core body control.

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Figure Legends

1. Axial (a) and sagittal (b): T2-weighted fast spin echo fat suppressed (images from a noncontrast MRI dedicated to the pelvis using an athletic pubalgia protocol acquired at 1.5 tesla in a professional football player with refractory right sided groin pain: On the axial image, the left rectus abdominis (RA), pectineus (P) and adductor longus (AL) are intact, and the pubic symphysis is normal (PS). On the right, the rectus abdominis is amputated (arrowheads) and the adductor longus is retracted (arrow). On the sagittal image, the rectus abdominis is disrupted at its anteroinferior pubic attachment (arrow). On this lateral representation of anatomy one cm lateral to the pubic symphysis, “P” denotes the pubic bone and “RA” the rectus abdominis muscle.

2. Coronal short tau inversion recovery (STIR) image of the pelvis acquired at 1.5 tesla using an athletic pubalgia protocol in a professional baseball player with an acute right sided groin injury while firlding a bunt: The brightest signal represents fluid on this fluid sensitive sequence. Note the abnormal fluid signal tracking inferolaterally from the pubic symphysis (arrowhead), sometimes referred to as a secondary cleft sign and often indicating a tear at the rectus abdominis attachment on the pubic bone. The adductor longus tendon has been avulsed and is retracted caudal and lateral (arrow).

3. Bony skeleton and forces of the pubic joint. Note the pubic symphysis is at the center of the forces created by

these muscles. Signs and symptoms distribute around this axis.

For illustrative purposes, we list the location of signs in a recent series of 100 patients: left rectus abdominis – 72; right rectus abdominis – 68; left adductor longus – 43; right adductor longus – 37; left pectineus – 28; right pectineus – 24; pubic symphysis – 23; left adductor brevis – 16; right adductor brevis – 14; left psoas – 11; right psoas – 7; either sartorius – 9; either rectus femoris – 4; obturator externus – 3; adductor magnus – 1; gracilis – 1.

4. (a) Muscles, etc. that comprise the anterior, posterior, and medial compartments of the pubic joint. (b) Anterior view. (c) Lateral view. Note relatively anterior location of insertion of the psoas tendon onto the lesser trochanter.

5. The *anterior tilt*: the anteromedial tilt of the "ready" position of the athlete. Note the importance of the anterior and medial compartments of the pubic joint.

6. Basic differences in male versus the female anatomy that relate to the pubic joint and injury. Note the differences in width between the pelves and knees of the two genders. These differences suggest a different distribution of forces during extremes of exertion; e.g. more lateral forces emanate from the female pelvis and more acutely angled forces are transmitted to female knees during landing.