The role of swim coaches must of necessity take on a number of responsibilities which requires that their areas of expertise span a great deal of material. One of the most important aspects of the job is dealing effectively and practically with competitive swimming injuries. In an effort to help coaches through the myriad of problems they might encounter in dealing with the common disabilities of the shoulder, knee and back, answers must be sought for the questions: What are the problems? Why do they exist? What causes the problem in swimming? Are the characteristics identifiable? What means are available for prevention?

The three most common maladies of the swimmer's shoulder include the multi-axial dysfunction syndrome, tendonitis and impingement syndromes. All three problems are similar in that their cause may encompass one or more of the following: Repetitive errors in stroke mechanics, leading to joint structure injury; inadequacies in dry-land exercise programs, causing muscular imbalances; overuse of intrinsic structures, due to training at competitive levels.

The shoulder joint is a complex array of muscles, tendons, ligaments and bones, all of which are designed to function in a specific manner at a specific time. The failure of any of these components to perform the designated action, for whatever reason, be it hereditary, structural or muscular adaptation of the sport, jeopardizes the structural integrity of the whole.

The shoulder is a musculo-skeletal array which features a small ball and socket joint suspended at the side of the chest by overhanging muscles, in a lateral position maintained by strut support in front from the collarbone, or clavicle, and fixator muscles attached to the shoulder blade, or scapula, in the back. The arrangement features smaller muscles known as the rotator, or musculotendinous cuff, surrounding the ball and socket joint for stability, with larger overlying girdle muscles, which, in combination, provide for an enormously powerful lever within a great range of motion.

The rotator cuff muscles, supraspinatus, infraspinatus, teres minor and subscapularis, all originate on the scapula and insert around the head of the humerus in a broad tendinous expansion known as the shoulder capsule (figure 1). The large suspensory muscle of the shoulder, the trapezius, is located on the back (figure 2) in opposition to the clavicular strut in the front (figure 3) and the overlying girdle muscles are attached below these structures.

On the anterior chest wall are the clavicular and sternal portions of the pectoralis major (figure 4), pectoralis minor (figure 5) and serratus anterior (figure 6) and posteriorly are the latissimus dorsi and teres major (figure 6A). Overlying the shoulder is the deltoid muscle which is delineated into three heads, anterior, middle and posterior (figures 5 and 7).
Fig. 1 Rotator cuff muscles which form shoulder capsule.

Fig. 2 Trapezius muscle, the suspensory shoulder muscle.

Fig. 3 Collarbone (clavicle) serves as strut to hold the shoulder blade in place.

Fig. 5 Pectoralis minor muscle in relation to the anterior chest wall.
The multi-axial Dysfunction Syndrome relates directly to the functional ability of the muscles to control normal and competitive swimming movements in the joint. In considering the shallowness of the shoulder socket, the strength of the rotator muscles becomes a critical factor in compensating for this bony arrangement, as this syndrome is demonstrated by extreme laxity in the enveloping capsule (figure 9A). The syndrome is characterized by abnormal laxity of the capsule, which permits either passive or active separation of the joint, causing abnormal stress on the surrounding and supporting structures (figures 1 and 3).

In general this syndrome exists as an entity because of the shallowness of the shoulder joint and its dependence on enveloping muscular strength for stability.

The confounding factors are the tendinous expansions of the rotator muscles which demonstrate a fair degree of natural laxity and
the variability in scapular position due to postural and competitive adaptation of longer girdle muscles to a forward position (figure 9).

Fig. 8 Passive shoulder stretching technique.

Figure 9A Hyperlaxity of the shoulder capsule permits the humerus to be passively subluxed. A shoulder with this much laxity needs to be protected by strong deltoids and good postural alignment.

Fig. 9 Forward shoulder posture in swimmers.

Swimmers are prone to this type of problem because of acquired hyperlaxity in the joint capsule, poor deltoid and rotator cuff strength, errors in stroke mechanics and muscular imbalances between the anterior-posterior and right-left structures. The hyperlaxity in the tendinous expansion of the cuff is partially attributable to the predominate passive stretching techniques which are traditional in swimming (figures 8, 11).
As in all stretching techniques the goal is to stretch the large power-strength muscles of the shoulder girdle to improve flexibility and enhance performance. However, this commonly used technique usually results in placing the humeral head in a position where stress is placed on the anterior fibers of the capsule and enveloping ligaments of the shoulder socket rather than the large muscles (figures 1 and 4). Often this can cause irreversible intrinsic damage to the structural integrity of the capsule and ligaments causing the hyperlaxity that is a precursor to other joint problems. Poor deltoid and rotator cuff strength are equal contributors to the cause of this problem and are due to a failure of exercise programs to include these muscles or failure to place an isolated emphasis on the strength requirements these muscles need to provide joint integrity.

Errors in stroke mechanics are also precursors to the problem in that incorrect arm position under load after multiple repetitions, can weaken structural integrity and cause poor muscular development. The straight-arm pull, unilateral breathing, poor body roll, late breathing and dropped elbow are all contributors to added shoulder stress as swimmers develop either the customary forward shoulder posture (figure 9) or uneven deltoid profile (figure 10), that is indicative of muscular imbalance and dysfunction.

Fig. 10 Uneven shoulder and deltoid profile. His right shoulder is definitely more developed.

Fig. 11 Traditional shoulder stretch. Note stress on anterior deltoid muscle by the head of the humerus.
There are preventive exercises which are effective in decreasing the chance that this injury will occur. Initiation of an appropriate stretching program is a first step in accomplishing the reduction of this problem. The three depicted exercises stretch the girdle muscles front and back using the contract-relax method (figures 14, 15, 16), or an active method (figure 13), where the swimmer helps to control the limits of the stretch.

Fig. 13 Active shoulder stretching. The partner holds elbows as swimmer leans forward. Notice stretch on two major shoulder muscles latissimus and pectoralis.

Fig. 14 Contract-relax stretch. Elbows are bent and palms face ground to remove all stress on biceps tendon. Swimmer pulls forward against resistance then arms move back.

Fig. 15 Contract-relax stretch. Swimmer pulls down against resistance then arms move up.

Fig. 16 Contract-relax stretch. Arms are pulled down and forward against resistance then the arms are moved back overhead.
The second part of the exercise program is an active strengthening program for the deltoid muscles, both anterior and middle parts, as well as the scapular retractors. These can be done using manual resistance or machine resistance (figures 17, 18, 19).

Fig. 17 Anterior deltoid exercise. Hands pull together in front of chest.

Fig. 18 Middle deltoid exercise showing hands pulling above chest at nose level.

Fig. 19 Contraction of the anterior and middle deltoid muscles. Strength in these muscles will avoid shoulder problems.

Fig. 20 Long head biceps tendon as it passes over humeral head under transverse humeral ligament.
The term tendonitis has been applied almost universally to a multitude of shoulder problems that have plagued swimmers in both acute and chronic conditions. It is a process essentially resulting from repetitive irritations of the long head biceps tendon (figure 20) as it passes over the humeral head under the transverse humeral ligament. Many theories and controversies exist concerning this problem due to the location of the overlying supraspinatus tendon which, as an expansion in the shoulder capsule, interfaces with the biceps tendon and is often involved individually or in combination with it.

The existence of tendonitis in these shoulder structures stems from the naturally shallow socket that depends on the rotator cuff and overlying muscles for its structural integrity. A loose capsular structure, which permits abnormal motion under load and goes unchecked by the supporting structures, is apt to be subjected to added stress when a swimmer fatigues and begins to demonstrate poor technique such as dropped elbow.

Stroke changes to correct the technique of a young swimmer will also cause muscle ache in the front of the shoulder, which is often mistaken for the onset of tendonitis. Actually this type of tenderness is associated with an increased internal rotation of the shoulder as the hand enters the water and is affected by the anterior deltoid contracting with increased effort. However, this position of the hand in entering the water places the shoulder in a fully flexed and internally rotated position where there is the greatest movement of the humerus against the biceps tendon. So a proper diagnosis of the cause of this pain is important.

Most often the onset of tendonitis in swimmers is preceded by poor symmetry in stroke mechanics, causing one side of the body to develop in a disproportionate manner (figures 21 and 22) because the swimmer has failed to finish long with strength from both arms. Those swimmers who pull only to their chest and not through to their legs tend to add more stress to the anterior shoulder structures, due to their greater stroke numbers.

Figs. 21, 22 Disproportionate upper body development due to poor stroke mechanics. Pectoral, latissimus, deltoid and trapezius muscles are all imbalanced on a right to left comparison.
Breathing only to one side or breathing extremely late are also stroke errors which can be contributors to the muscular development problem that may be a precursor to tendonitis or other shoulder problems. The confounding factor in this problem is a dry-land exercise program which does not compensate for or supplement the intrinsic strength of the rotator cuff and improve the strength of the underdeveloped limb, chest and back muscles.

Generally, the coach should be cognizant of incomparable right to left muscular development, as demonstrated by uneven shoulder height, uneven pectoralis size and shape and uneven deltoid size.

In determining the true existence of tendonitis, be aware of the various stages of symptoms that swimmers will describe. Initially, there will be pain during the warm-up, no pain during the majority of practice, then extreme pain which will subside several hours after practice. In the secondary stages, the swimmer experiences pain in warm-up which continues through the initial stages of practice then becomes a subdued ache that can be tolerated through practice if no quality work is imposed. At the end of practice, or after the initial onset of quality work, the pain is again extreme. This pain may last many hours after practice in the later stages, then there is pain all the time that is partially subdued in the early part of a practice but ends up being too severe. The swimmer will generally try to use a kickboard, but just holding the board out at arm's length is too uncomfortable. Finally, they experience "night" pain, where the dull aching pain hinders their ability to carry on normal activities, such as sleeping or carrying books.

Prevention of this problem is possible through an exercise program which strengthens the anterior and middle deltoid muscles (figures 17, 18, 19) as well as the posterior deltoids and scapular abductors, which draw the shoulder blades together (figures 23, 24).

![Figs. 23, 24 The scapular retraction/abduction and posterior deltoid exercise to increase shoulder position and flexibility. The picture on the right shows the muscles strengthened. These include the posterior and middle deltoid, middle and lower trapezius and rhomboid major and minor which are the major retractors of the shoulder blade.](image)
The last shoulder problem we will cover is the Impingement Syndrome. This is closely associated with the incidence of tendonitis in the biceps long head and supraspinatus tendons and is often considered to be one and the same.

To fully comprehend this injury, the coach must appreciate the fact that the structure positioned over the head of the humerus is known as the coraco-acromial arch (figure 25). This structure is formed by the suspensory ligaments attached to the bones of the shoulder blade which overhang the head of the humerus (figure 26). The term "impingement" refers to the action that affects the supraspinatus tendon (the anterior part of the shoulder capsule) and the long head tendon (directly under the supraspinatus) when an abnormal shoulder motion allows the humerus into the ligamentous arch.

![Fig. 25 Top and side view of coraco-acromial arch which overhangs the humeral head.](image1)

![Fig. 26 Coraco-acromial arch in relation to the shoulder capsule.](image2)

The function of the shoulder in abduction is an extremely important concept for the swim coach, because it is the underlying mechanism for all overarm components of the freestyle, backstroke and butterfly. In understanding this motion, consider the fact that there are less than four joints which must function synchronously to allow the arm to assume an overhead position. These joints include: The scapulo-thoracic, or shoulder blade sliding over the ribs; The gleno-humeral, or ball and socket of the shoulder; The sterno-clavicular, or collarbone rotating on the breastbone; The acromic-clavicular, or shoulder blade rotating on the collar bone (figures 27, 28).

In assuming the overhead position, through the side lifting or abducting motion, the importance of the rotator cuff, deltoid and scapular muscles becomes apparent. A coordinated and rhythmical action, involving the external rotator muscles, infraspinatus, teres minor and posterior deltoid, causes the humeral head to turn so that the large part of the cam turns out from under the coraco-acromial arch (figure 25). This is accompanied by rotation of the collarbone, or clavicle (figure 27), and forward rotation of the shoulder blade,
or scapular, on the thoracic rib cage (figure 28), thus placing the socket of the shoulder in a new position that faces at a higher angle than when the arm is at the side of the body.

Fig. 27 Actions of the gleno-humeral and accessory joints during abduction include:
(1) external rotation of the humerus, (2) external rotation of the clavicle, (3) elevation of the sternoclavicular joint, (4) rotation at the acromio-clavicular joint.

The muscular contraction which facilitates the new shoulder position requires that the supraspinatus and deltoid synchronously raise the arm laterally, or abduct it, as the rotator muscles depress, rotate and stabilize the humeral head, thus allowing the arm to pass safely overhead (figures 29, 30, 30A, 30B).

Fig. 29 In abduction the head of the humerus is rolled downward by the supraspinatus so the humerus will not ride up into the coraco-acromial arch.

Fig. 30 In abduction muscles contract so that: (1) tension is applied by the supraspinatus, (2) the infraspinatus depresses the humeral head, (3) with help from the subscapularis. These cuff muscles help steady the humerus for the deltoid to act.
failure of interrelated shoulder parts to act correctly, due either to uneven development of certain muscles which oppose each other, poor postural factors, inherited bone development irregularities, poor stroke mechanics, or a combination thereof.

Forward shoulder posture is caused by very strong anterior pectoral muscles imbalanced by weaker posterior muscles. Forward shoulder posture elongates scapular retractors and brings the shoulder socket forward and facing down. This makes it difficult to effectively roll the humerus overhead.

The cause of this syndrome is a resultant combination of the failure of interrelated shoulder parts to act correctly, due either to uneven development of certain muscles which oppose each other, poor postural factors, inherited bone development irregularities, poor stroke mechanics, or a combination thereof.

Fig. 30A The humerus must rotate backwards, externally, to allow the larger part of the humerus to pass under the arch and acrion.

Fig. 30B The four rotators of the shoulder must work to position the humerus so the larger deltoid can act.

Figs. 31, 32 Forward shoulder posture is caused by very strong anterior pectoral muscles imbalanced by weaker posterior muscles. Forward shoulder posture elongates scapular retractors and brings the shoulder socket forward and facing down. This makes it difficult to effectively roll the humerus overhead.
Swimmers have a greater tendency toward this problem because of the multiple repetitions of overarm strokes necessary in training. A direct result of this training is the forward shoulder, or slumped posture, which is called "swimmer's posture." This condition develops as a result of muscular accommodation of the front shoulder girdle muscles, especially the pectoralis major. The shortened muscles draw the shoulders forward, using the collarbone as a lever arm, with the back shoulder girdle muscles, trapezius, rhomboids and levator scapulae, elongating to accommodate this position (figures 31, 32).

This shoulder position presents two confounding problems. The first is of mechanical origin due to the realignment of the shoulder socket in a downward angulation, which inhibits the normal upward rotation of the shoulder blade and external rotation of the collar bone, that is required in abduction of the arm, which makes it more difficult for the swimmer to achieve the good overarm recovery. The second problem is a precursor to the previous discussion on multi-axial dysfunction, in that swimmers with forward shoulder posture are apt to have less flexibility in attempting to place their hands together behind their backs (figures 33, 33A). This will cause them to use the passive stretch technique and thus create a potentially hyper lax shoulder capsule (figure 9A).

Figs. 33, 33A Forward shoulder posture, as seen on the right, indicates an adaptation of the anterior chest muscles which can prevent the posterior movements of the arms, as seen on the left.

The impingement syndrome is seen a great deal in swimmers due to poor body roll in backstroke and freestyle. Adaptive muscular shortening of the pectoralis causes poor shoulder retraction in the recovery phase (figure 34). The characteristics of the problem are forward shoulders, widely separated shoulder blades (figure 22), poor posterior deltoid development (figure 22), poor shoulder retraction range of motion (figure 33) and a "clicking" sound when the arm is brought overhead in the recovery phase of freestyle. Preventative exercise measures include posture exercises (figures 35, 36, 37, 38), manually resisted posterior deltoid exercise and external rotation exercise (figures 39, 40).
Fig. 34 The recovery phase of freestyle and all other overhead motions become limited in the full flexion, abduction position, due to the loss of clavicular rotation that occurs because of the tight pectoralis.

Figs. 35, 36 The posterior deltoid and scapular retraction exercise, which is manually resisted at the elbows, encourages postural improvement and correct alignment of the shoulder blade.
Figs. 37, 38 The shoulder flexion exercise helps the swimmer improve posture and aids in the overarm freestyle and backstroke recoveries.

Figs. 39, 40 The external rotation exercise improves muscular balance between strong anterior chest muscles and the small rotator muscles. This helps prevent tendonitis by improving shoulder rotation in overhead movements.

The knee is another area that is frequently afflicted with one of the overuse syndromes known as "swimmer's knee." These are conditions which are seen all too often in competitive swimmers, especially in the age group. As in the shoulder, the knee has a joint component with a shallow socket, called the tibial plateau, which is ringed by cartilage to make the surface a deeper cup shape. The upper part of the joint, the femoral surface, is a cam shape that sits on this
shallow cup and forms a very efficient hinge joint that allows the knee to bend and straighten. Because the femur has two cams of different sizes resting on the tibial surface, a limited rotational motion is also possible in the joint. The movement of the bones and any excess joint play is controlled by the ligaments attached on both sides of the joint and in key positions, between the joint surfaces.

The powerful thigh muscles, quadriceps and hamstrings, which provide a major propulsive force in kicking, transmit their power pulling motion to the lower leg via the tendons. The hamstring tendons pass over and around the sides of the joint in a particular pattern, while quadriceps incorporate the patella for strength. The bursa spaces are at critical stress points for lubrication.

Swimmer's knee is a condition which primarily affects the medial, or inside, aspect of the knee and the structures that connect the two bones, the femur and tibia. The hamstring tendons, medial collateral ligaments and associated bursa spaces constitute the areas of soft tissue irritation which comprise the majority of swimmer's knee problems caused by repetitive stress due to mechanical irregularities in knee function.

Fig. 41 Hyperextension is a factor in patellar tracking because of the free space created by the femoral-tibial alignment.

Fig. 42 The incidence of medial lean of the joint, especially in females, creates an angle of pull causing irregular patellar tracking in the appropriate groove.
The problem known as "patellar tracking disorder" is partially presented as a result of irregular patellar (kneecap) movement through the femoral intercondylar groove. Swimmers have a tendency for hyperextended knees because the stress of kicking tends to stretch the posterior cruciate knee ligament (figure 41). This, therefore, allows the patella more free space between it and the femoral groove, in which it is supposed to rest, which gives the patella more movement in a side-to-side motion, as well as up and down.

For female swimmers there are two compounding factors. The first is their tendency for a smaller patella (figure 43), which allows more side-to-side motion. Second, they usually have a slight angle in their knee (figure 42) due to female predisposed skeletal configuration. Both of these factors add stress as the patella moves up and down with the contracting quadriceps.

Because of a combination of several training factors, swimmers generally experience this type of medial knee pain as a unilateral entity. The first of these is the fact that a high percentage of competitive swimmers have tight hamstrings, which places an added stress on the tendon as it crosses the joint (figure 44). This muscular shortening is an adaptation of the muscle to the functional position required during propulsive kicking and turning.

Fig. 43 Patella size also plays a role in knee problems. The smaller female kneecap on the left contributes to more free space which can cause injury.

Fig. 44 Tight hamstrings, as seen by the tendon protruding at the bottom side of the knee tend to become irritated and aggravate the underlying ligaments.

A second most important factor that affects only one of the swimmer's knees is presented in repeated turning with force. The top leg tends to exert force on the wall for a longer period of time than the bottom leg because the swimmer is in a side-lying crouch before rotating the body, during the push, to resume a horizontal position.
This motion requires the knee to extend and rotate in a hand-locking fashion, with the leg fixed in a foot-stationary position on the wall (figures 45, 46, 47, 48).

Fig. 45 "Swimmer's turning knee" is attributable in part to the hard rotation the top leg makes as the foot pushes from the wall.

Fig. 46 The rotation of the body around the knee axis, with the foot of the top leg fixed on the wall, also contributes to "swimmer's turning knee."

Figs. 47, 48 The swimmer pushes off from the crouch position, as the body rotates around the axis of the knee of the top leg.

The medial rotation of the femur on the tibia, with the foot fixed, exerts a medially-directed force onto the collateral ligaments, which stabilizes at the inside of the knee. This action also requires a very active contraction of the medial hamstring muscles as they assist in hip and knee extension and knee rotation. Due to the intimate contact of the medial hamstring tendons and the medial collateral ligaments the forces exerted on these two structures is shared.
A similar situation exists in football, basketball and other running sports where "cutting" is required. The ligaments, tendons and cartilages have an extreme and traumatic force exerted on them producing a severe insult to these structures and causing the injury known as the "Unhappy Triad of O'Donoghue."

While the turning force in swimming is not quite as severe as that of the terrestrial sports, it will produce a micro-trauma to the finely interwoven fibers of the ligaments, while at the same time causing an irritation and wringing out of the overlying tendons. Repeated turning can produce an accumulated effect on these knee structures causing the "swimmer's turning knee" and the pain associated with it.

Swimmers who are prone to knee problems of this type have tight hamstrings (figure 49), tight lower back muscles (figure 50), a tendency toward increased lordosis, or lumbar curve (figure 51), and a high degree of knee hyperextension (figure 52). Preventative measures include hamstring stretching (figure 53), calf stretching and the use of heel-lift orthotics in the athlete's shoes.

Fig. 49 The swimmer with tight hamstrings is prone to knee injury.

Fig. 50 Athletes with tight hamstrings should also be checked for flexibility in the lower back which is also a factor in knee injury.
Another factor in knee injury is lordotic or increased lumbar curve (left picture). This condition may be due to very strong quadriceps which cause the pelvis to tilt forward. The swimmer with hyperextended knees (center picture) is also prone to knee problems. Hamstring stretching (right picture) can be a big factor in preventing knee injuries. With the leg at waist level and parallel with the floor, the swimmer tries to place the chin on the knee.

The other major knee problem is "breaststroker's knee." This, like "swimmer's knee," is a sprain of the medial collateral ligaments of the knee but can also affect the hamstring tendons, on both sides of the knee, medial and lateral, as well. The problem exists due to the anatomical configuration of the skeletal and ligamentous knee structures which are then placed under load by the kicking mechanisms. The kick requires a continually active contraction of the hamstring muscles for the external rotation of the tibia on the femur (figure 54), a lateral hamstring function, the flexing of the knee in recovery (figure 55) and the extension of the hip in propulsion (figure 56). These muscular contractions performed repetitiously cause the hamstrings to adapt and result in a loss of flexibility. In addition to tightness of the hamstrings, the total lower extremity experiences an adaptation of the musclo-skeletal system which adds to the cause of hamstring tendon irritation.

The quadriceps of breaststrokers become very strong and defined (figure 57) and as such cause the pelvis to tilt forward, resulting in a noticeably increased lumbar curve (figure 51). This places an added stress on the hamstrings, because of their attachment on the back of the pelvis, and therefore is an added contributor to the tendon problems of breaststrokers.
Fig. 54 A Major function of the lateral hamstring muscle is external rotation of the lower leg on the femur as seen in the breaststroke.

Fig. 55 The hamstring tendon is very visible as the muscle acts to flex the knee in the recovery phase of breaststroke kicking.

Fig. 56 Hip extension during the breaststroke kick is a partial function of the hamstring, which is a prime activator in all aspects of this kick type.

Fig. 57 The strong quadriceps of breaststrokers cause the adaptive changes which are seen as increased lordosis and external rotation.
Ligamentous injury to the medial knee structures is also caused by the mechanics of the whip kick and is considered to be the primary classification of breaststroker's knee. The predisposing factor is the initial extension of the knee after the full recovery position, with the lower leg rotated outwardly (figure 54). At that point, and as the legs accelerate into the extension, the stress on the ligament is great enough to produce micro-tearing of the ligament fibers, which will produce an eventual disruption of the matrix structure after repetitive kicking.

Breaststroke swimmers most likely to experience tendon problems are those with pronounced lordosis (figure 51), tight hamstrings, tight lower back muscles (figures 49, 50) and tight quadriceps. Those swimmers with undefined, or poorly developed, quadriceps are more likely to experience ligamentous problems and pain which causes chronic disability and usually requires a long rest for recovery.

Preventative measures for ligamentous involvement includes strengthening the medial quadriceps with short knee arc extensions (figure 59), seated straight leg raises (figure 60) and knee flexing exercises (figure 61). To help prevent tendon problems, stretch the hamstrings and quadriceps (figure 62) and initiate postural exercises to stretch the lower back.

![Figs. 59, 60](image_url) Short arc extension exercise (on left) is performed with either manual or progressive resistance. The knee is placed over a wedge and straightened through an arc of 15-20 degrees. Preventive exercises for knee problems should include the long-leg, sitting-straight, leg-raise. These should be done in sets of eight for a count of five with the leg up.

A final area of concern deals with subtle and potentially debilitating problems affecting the spinal column. In general the spinal column should be thought of as a freestanding column of skeletal disks with guy-wire support that maintains the upright position. Each bony disk is separated from the other by a dense sponge cushion which has its position maintained with the aid of skeletal outcroppings. Finally, the column transmits nerves through openings in the sides of the bones in order to provide communication to the body.
The thoracic outlet syndrome, scoliosis, and lower back problems, which affect swimmers, all stem from the same basic problem, the accommodation and adaptation of the muscles to the requirements of swimming mechanics. This adaptation is seen as a functional imbalance of the body's muscles in such a way as to cause the muscles on one side of the body to become stronger and less able to elongate than the muscles working on the other side in an opposite function. Repetitive swimming training is the chief cause of this adaptation that produces an eventual imbalance in the muscles guy-wire function, resulting in the irregular spinal column sway that is known as "swimmer's posture" (figure 51).

Thoracic outlet syndrome is a partial closure of the major arterial vessels leading to the arm, as they pass down the muscles of the neck that connect to the collar bone (figure 63). When the muscles of the neck and chest shorten they pull the head forward (figure 51) and decrease the normal amount of space through which the vessels pass. This space is further decreased when the muscles surrounding the vessels must elongate to allow the head to rotate away from the arm that is being raised overhead simultaneously, as is done during freestyle breathing (figure 65). The obliteration of the vessel (figure 64) in a repetitive manner causes the swimmer to feel a sensory change in the hand or arm similar to the "pins and needles" feeling when the arm is said to "fall asleep."

The Scalenus Anticus Syndrome is a problem similar to the thoracic outlet syndrome. It results from an almost identical muscular adaptation and compression of intervening structures as a result of the overarm recovery and head rotation necessary for breathing.
In this case, however, the structures being compressed are nerves which pass between two neck muscles, the scalenus anticus and medius, and the sensory disturbance in the hand can be one of "heaviness," "burning," "cold" or "electric shocks."

In both cases, the potential problem exists due to the relative position of the nerves and arteries to the surrounding muscles and bones, which can be realigned by muscular imbalance to place a compressive force on these structures. These syndromes are seen predominantly in swimming because of the muscular imbalances that repetitive training causes.

Fig. 63 The thoracic outlet syndrome involves the subclavian artery. It is seen as a faint line running up the arm under the clavicle.

Fig. 64 The dark full artery indicates that blood flow up the arm is impaired by a musculoskeletal impingement.

Fig. 65 The overarm recovery, turning the head to breathe and the forward shoulder all contribute to thoracic outlet. The abduction and overhead flexion of recovery are part of the obliteration movement.
In swimmer's posture, the forward head and rounded shoulder will limit the ability of the collarbone to rotate externally because of tight anterior chest pectoral muscles (figure 27). Also, the head will have limitation in all ranges of motion due to tight anterior muscles at the front and sides of the neck. In general these muscular adaptations, and the subsequent postural problems that result, are caused by inadequate dry-land exercise programs, breathing only to one side in freestyle, late breathing, poor body roll, short follow-through in pulling and dropped elbows.

The swimmer who demonstrates the forward head and rounded shoulder posture is a potential victim of these syndromes and should be started on an exercise program stressing accommodating resistance, fatigue prevention, active stretching of tight anterior chest muscles and strengthening of posterior shoulder muscles (figure 23).

Scoliosis is a spinal curvature that may take on a variety of shapes but is always a potentially debilitating affliction. As the muscles on one side of the body grow gradually stronger than their opposite counterparts, their pull on the vertebral column increases proportionately and a curvature of appropriate shape and magnitude results. What occurs most commonly is the c-shaped curve (see x-ray in figure 66) but an equal incidence is shown as the s-shaped curve (see x-ray in figure 67), but these back types cause a compensating

Figs. 66, 67 On the left is the c-shape scoliosis curve. Note the rotation of the vertebrae along with the lateral curvature which causes the ribs to close in on the chest cavity. On the right is the s-shape scoliosis curve. This curve is most often seen in the idiopathic type of curvature.
reshaping of the attached ribs as a secondary complication.

The scoliotic curve is a primary example of what effect muscular imbalance will have on the freestanding vertebral column, especially from a swimming prospective. There are, however, other factors which are known to influence the incidence of scoliosis, such as, heredity, age, sex and developmental growth levels. The idiopathic, or unrecognizable cause, type of scoliosis exhibits the s-shaped curve and predominately affects the tall, thin, adolescent female. This type is known to have a high incidence of hereditary relationship. The c-shaped curve is also known to have a relationship to lower extremity skeletal growth, which can be affected either by trauma that disrupts the growth plates or by heredity. In both of these latter cases the skeletal curve, which may be present before the child begins swimming, may pose a potential problem if poor stroke mechanics and exercise programs worsen the outcome.

The swimmer likely to develop scoliosis through muscular imbalance usually demonstrates a stronger pull with one arm, breathes toward the weaker arm and shows a longer finish with the strong arm. The resultant unilateral overdevelopment of the latissimus and erector spinae muscles (figure 68) causes the swimmer to exhibit one shoulder which is higher, one arm with closer approximation to the body (figure 69), one latissimus that is more fully developed and a noticeable curve of the spine.

Figs. 68, 69 On the left, note the spinal curvature as demonstrated by the marked vertebrae. On the right, the shoulder height, arm to body distance and discrepancy in latissimus size are all keys to the presence of scoliosis.

Characteristics such as these cause poor trunk rotation to one side (figures 70, 71) which can limit the body roll necessary for freestyle and backstroke turns and strokes, and can in turn be an additional contributor to shoulder stress. Finally, irregular rib
curvature can develop as a secondary complication. This condition restructures the enclosure of the heart and lungs and therefore is potentially the most serious problem of all (figure 72).

Figs. 70, 71 Poor trunk rotation caused by tight muscles in the middle back. The tight muscles on the right side prevent rotation to the left which limits shoulder roll in swimming.

Once this problem has been identified, the coach should have the swimmer's physician evaluate the cause and extent of the problem, especially before initiating an exercise program to strengthen those muscles to reverse the effects and provide correction.

Lower back pain syndrome is a conglomerate of problems that can involve one or all of the musculo-skeletal components that affix the spinal column to the pelvis, causing pain and dysfunction for the swimmer. Muscular strains, sacroiliac ligament sprains, failure of joint articulations to hold the vertebrae in place and a number of associated nerve problems, such as sciatica, all fall into this category. The potential for one or any combination of these difficulties stems from the multi-axis pivot function of the lower back, or lumbar spine, the attachment of the shoulder and pelvic girdle muscles to the spinal column and pelvis, the shallow lumbar vertebral joints as well as some gender-related skeletal formations.

The muscles which are most usually strained are those that connect across the lower back and have a rotary, bend and straighten function. These muscles tend to shorten as an adaptation to the forward tilt of the pelvis, that many swimmers have because of the tight
hip flexor muscles/lordotic posture. The lordotic curve is also present as a result of the pull which the latissimus and upper girdle muscles exert on the pelvis (figure 73), the training position of the butterfly and breaststroke kick and poor exercise technique when using the leaper (figure 74) or in doing squats. A lack of hamstring and lower back stretching also contribute to the tight lower back musculature and may contribute to a swimmer turning more slowly around a greater axis of rotation during the flip turn.

Figs. 72, 73 In the picture on the left, the rib hump seen on the right side means that the vertebrae has rotated and reshaped the ribs, placing pressure on the anterior chest cavity. The picture on the right demonstrates that a strong contraction of the latissimus causes the muscle to exert a pull on the top part of the posterior pelvis.

Skeletal configuration often leads to more serious problems that result from abnormal movement in the articulating vertebral joints. The shallow facet joints rock back and forth on each other as the swimmer kicks breaststroke and butterfly. If slippage to any great degree occurs, such as in a condition called spondylothesis, the associated soft tissues and nerves which surround and course between the bones may become impinged or disrupted. The incidence of this problem is often increased in the female swimmer because their lumbar skeletal formation is less stable, due to their role as the child-bearing member of the species.

Lower back muscular strains and ligamentous sprains, which afflict the swimmer, usually develop a potential for occurrence over a long period as the muscles adapt themselves to the requirements of the kicking, pulling, turning and body rotation. The incident which triggers the problem is generally a sudden twist, an exceptionally hard turn or an unexpectedly hard effort in weight lifting involving the muscles that are directly connected to the vertebrae. These incidents are likely to create a pressure on the nerves transmitted from the spinal cord. Problems of this type can be localized or can radiate down the nerve pathways into the legs, which is the syndrome known as sciatica.
Swimmers are prone to back problems because the muscles overlying and connecting to the vertebrae often adapt themselves to accommodate the quadriceps, which enlarge due to kicking, the latissimus, which strengthens from pulling and the constant turning and twisting of the back as the sport is pursued. The resultant skeletal alignment produced by these muscular forces is an increased lumbar curve or lordosis, which is seen predominately in butterflyers, breaststrokers and sprinters.

The characteristic lordotic curve, large quadriceps and poor sit and reach ability (figure 50) that swimmers may have are key signs that corrections or additions in stretching and strengthening programs may be indicated. These may include the kneeling quad stretch (figure 62), standing hamstring stretch (figure 53) and lower back stretching.

Correct use of the leaper, or jumper, type of exercise apparatus will also be effective in decreasing the incidence of lower back muscular problems (figures 74, 75, 76, 77).

Figures 74, 75 If done properly, leaper-type exercises will help avoid lower back problems. However, if done improperly exercises on this type of equipment will help cause lower back problems. On the left, the arched back position can produce tight lower back muscles and cause lower back pain and disability. On the right, the forward foot position, with buttocks tucked forward, is desirable to mimic the quadricep contraction used in the start.
Figures 76, 77 The swimmer's position in the start (left picture) can be compared with the position on the leaper (right picture).

In exercising on the leaper, in order to produce a favorable result in quadriceps strength, while minimizing stress on the lower back, the swimmer places the feet forward on the foot plates, bends the knees forward toward the center post and tilts the pelvis forward to flatten the back. This position ideally protects the back while at the same time providing the specificity of exercise which mimics the swimming start (figures 76, 77). The exercise places less stress on the back, while providing an increased resistance for the lateral and anterior quadriceps muscles, which should aid in improving this aspect of the swimmer's performance.

To deal effectively and practically with swimming injuries, the coach must serve as a preliminary intermediary between the stresses which cause the problems and the syndromes which are of a debilitating nature. This essentially involves the promotion of good stroke mechanics, a pre-season screening of athletes for signs and characteristics that are precursors to injury and the initiation of appropriate exercise programs that will be followed with good compliance.

The key factor in injury prevention is observation of defects, either mechanical or anatomical, which will place the athlete at risk, then effectively and practically working to reverse or eliminate the stresses. When these items have been addressed, the athlete gains through his ability to continue participating, the coach gains through the athlete's continued performance and swimming gains because another athlete becomes a potential champion.