Swimming: An In-Depth Look at Mechanics, Pathomechanics and Management with a PRI Perspective

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Swimming Introduction

Swimming is a form of exercise or sport that is commonly utilized both for recreation and competition. According to the US Census Bureau in 2009, over 50 million Americans participated in swimming as a recreational activity at least 6 times a year which far out-numbered other activities such as basketball (24 million), golf (22 million), and even running/jogging (32 million) [1]. There are several levels of competitive swimming stemming from age group participation as early as age 5 or 6 up to master's level swimming competitions for all ages. According to USA Swimming in 2013, there were more than 340,000 year-round age group (age 18 and under) athletes registered with USA swimming, and about 30,000 seasonal (i.e. summer only) age group swimmers registered [2]. Per the US Masters swimming website there were approximately 60,000 registered masters swimmers (age 19 and up) registered in more than 1500 registered clubs through US masters swimming in 2013 [3]. At the high school level in 2011-2012, over 133,000 boys and 166,000 girls swam competitively in the US [4]. There is also competitive swimming at the collegiate level. Swimming is also consistently one of the most popular sports at the Summer Olympic Games leading to potential professional careers and sponsorships for the most highly successful swimmers. Following an Olympic year per the USA swimming website, year-round athlete participation in swimming increases 4-13% due to the popularity and exposure form the Olympic Games [2].

There are numerous benefits to swimming including the physical cardiovascular and musculoskeletal benefits gained from any form of exercise activity. The buoyancy of the water makes swimming a low impact activity that can be beneficial for those with joint issues such as arthritis. This allows them to participate in a cardiovascular or exercise activity without the strain placed on the joints [5]. It is an activity that can be enjoyed and beneficial to all age groups as seen in the participation numbers above. Competitive swimming also allows someone an opportunity to participate in a sport as an individual while still being part of a team and can be beneficial for social and psychological reasons.

Because of the unique biomechanical demands placed on the body with swimming, and particularly with competitive swimmers that train numerous hours a week, there is potential for injuries. In particular, the swimmer is susceptible to shoulder impingement, rotator cuff or bicipital tendonitis, and shoulder instability [6, 7, 8, 9, 10]. Shoulder pain is the most common musculoskeletal complaint in swimming with incidence of disabling shoulder pain ranging from 27% to 87% among competitive swimmers [6, 7, 8]. Other common areas of injury in swimmers includes low back and knees [7].

General Swimming Demands

Unique Demands of Swimming

In general, swimming is a sport or activity that is unique in many ways. Compared with other traditional cardiovascular exercises such as running, biking, skating, and skiing, swimming utilizes the upper extremity musculature as the primary method of propulsion rather than the lower extremity. However, when compared with those other activities, swimming is a fairly inefficient method of propulsion. The water in a pool for example moves as the swimmers hand pulls the body forward in comparison to the ground which does not move as a runners shoe or foot pushes the body forward over it. Thus, a considerable amount of energy can be spent to swim a much shorter distance compared to running.

Along with being a fairly inefficient manner of movement, swimming is highly dependent on technique to maximize the efficiency. Muscle power contributes less in ability of swimmers compared to technique. In fact, improvements in muscles strength alone do not necessarily correlate with swimming speed [7]. The higher resistance of the water also increases drag forces which slow the swimmer down more so than air does with running type activities. Minimizing this drag factor is also dependent more highly on technique rather than raw strength.

These issues, and others, lead to specific training demands on the swimmer, and especially the competitive swimmer that are different than other athletes. Swimming obviously requires repetitive upper extremity pulling for power, primarily using latissimus dorsi and pectoralis muscles. An average practice schedule for a competitive swimmer might consist of 6000 yards per practice x 6 practices a week. If that swimmer uses an average of 10 arm strokes per 25 yard length of a pool that equates to roughly 14,400 strokes or repetitive arm pulls a week [8]. Highly competitive swimmers often swim more than this on a year round basis.

Swimming is also a sport that is primarily done in a prone, belly down, position. This position encourages extension or backwards bending of the spine. The buoyancy of the water helps with this, but also doesn't require the swimmer to deal with the effects of gravity as much as during land-based exercise. Also with the higher resistance of the water compared to air, streamlining or being maximally hydrodynamic is essential to decrease this drag force and improve speed. Streamlining requires maximal shoulder flexion and abduction to be as effective as possible. This will be discussed more later.

One of the main issues that swimmers deal with more than other athletes is the demand placed on their respiratory systems. Swimmers must spend more time and effort focusing on breathing and breath control as they are often in a position with their face in or under the water. The primary method of breathing during swimming is deep breaths in through the mouth with prolonged holds or exhalation through the nose to prevent water getting in the nose. Swimmers "hold their breath" more than other athletes due to this demand. Proper efficient diaphragmatic breathing techniques encourage breathing in through the nose and out through the mouth. This difference means that swimmers spend a majority of their training activity breathing in a different, potentially less efficient manner. They often will carry this improper or dysfunctional breathing pattern, which is necessary in swimming, to other activities they are doing when not in the water. All of these differences in technique, demands of the musculoskeletal and respiratory systems and the highly repetitive nature of the sport lead to acquired patterns and postures unique to the swimmer.

Acquired Positions/Patterns

The main position or pattern that is commonly seen with swimmers is primarily influenced by three main and interrelated things. The respiratory demands of breath holding or hyperinflation, the prone position encouraging spinal and low back extension, and strong muscle imbalances from the repetitive arm pulling that reinforces and is influenced by the position of extension. This position is consistent with the Posterior Exterior Chain (PEC) pattern described by the Postural Restoration Institute®. This position of extension or hyperinflation can be described generally with the following characteristics:

- Deep low backs (tight erector spinae group)
- Elevated anterior ribs/rib flares
- Forward rounded shoulders (strong tight pectoral muscles and latissimus dorsi on a spine that is extending and ribs that are elevated and hyperinflated)
- Forward head postures (to compensate for the above positions)
- Anteriorly tilted pelvis from tight low backs and strong powerful hip flexor muscles from the demands of kicking
- Hyperextended knees when on “dry land”

As stated earlier, this position of extension or hyperinflation leads to and is influenced by potential muscle imbalances or inefficiencies. These can be generally summed up as follows:

- Strong, powerful, inflexible latissimus dorsum muscles. When these muscles become too tight or restricted they can limit rib cage expansion, trunk rotation and will encourage lumbar extension.
- Tight, strong pectoral muscles that lead to long, weak, improperly positioned intrascapular muscles that stabilize the shoulder blades. These tight muscles can also restrict rib depression and promote more hyperinflation or back extension. Weak scapular stabilizers have been implicated in shoulder impingement and injury.
- Strong powerful inflexible hip flexors and back extensors from flutter/dolphin kicking, and positionally tight from extension tendencies developed in the prone position.
- Improperly positioned long and inefficient abdominals (specifically transverse abdominis and abdominal obliques) for rib and pelvic stability and trunk rotation.
- Improperly positioned, inefficient diaphragm muscle (being pulled up in the front by rib position and down in the back by pelvic tilt and overactive and tight hip flexors). This leads to poor rib

expansion, inefficient respiration and overuse of neck and back muscles for ribcage support and breathing which will restrict cervical/neck rotation.

In addition to these acquired positions from the demands of swimming, we also need to realize and discuss normal acquired patterns and positions that our swimmers will also deal with because of their normal human patterns of asymmetrical form and function. The normal Left AIC / Right BC pattern described by the Postural Restoration Institute® will affect swimmers in their ability to move their trunk and/or necks in a reciprocal and alternating fashion. The normal pattern of pelvic and spinal orientation to the right and upper trunk rotation to the left will still hold true for the swimmer, making trunk and neck rotation, rib expansion and breathing more challenging on one side compared to the other. This will often be noticed in the swimmer as:

- A decreased ability to breathe as well to one side as the other during the freestyle stroke
- Decreased ability to reach or catch the water as effectively with one arm compared to the other
- Asymmetrical patterns of arm recovery in freestyle
- Limited shoulder turn in backstroke
- Shoulder impingement

These patterns, if unchecked, will lead to continued muscle imbalances that can increase the likelihood of shoulder or back pain, and at a minimum decreases the efficiency of the swimming strokes.

General Needs for all Swimmers

Taking into account the unique demands of swimmers in general, as well as the underlying normal human asymmetrical pattern there are some general needs to address for swimmers. Our goals for swimmers should include:

- Balanced airflow and chest wall movement in all directions
- Increased strength of hamstrings and abdominals to decrease normal extension (PEC pattern) tendencies of the swimmer
- Increased strength and activity of the glutes, lower traps, triceps, serratus anterior, and rotator cuff (supscapularis in particular) to oppose the developing strong pattern of pulling performed by the swimmer (remember the 14,400 repetitions of pulling each arm per week)
- Properly positioned and efficient diaphragm muscle to meet the breathing/respiratory demands of the swimmer
- Flexibility in the hip flexors, back extensors, latissimus dorsi, pectorals, neck and external rotators of the shoulder

Therefore, programs developed for swimmers need to include activities to achieve and maintain a neutral postural pattern with an emphasis on trunk flexion and thoracic rotation with proper use of abdominals and breathing prior to starting and addressing scapular and shoulder issues. Postural patterns (Left AIC / Right BC or PEC) described by the Postural Restoration Institute® places the ribs and therefore the scapula in an in improper position, therefore influencing the proper activation and use of the scapular stabilizers and rotator cuff muscles, and if not addressed can lead to overuse and potential injury.

General Description of Swimming Strokes

Freestyle/"Crawl Stroke"

The freestyle or front crawl stroke is the most commonly used stroke in practice and is also the fastest of the 4 competitive strokes. In this stroke the arms pull alternately while the body is in a prone position with the face in the water. The arm stroke can be broken down into the glide phase, the pull through phase (early and late) and the recovery phase. An alternating flutter kick is used continuously throughout the stroke with the legs. The swimmer breathes by turning the head to the side (unilaterally or bilaterally) during the late pull through and early recovery phase of the arm stroke. Trunk or body roll/rotation is incorporated to maximize reaching arm pull and speed.

Butterfly Stroke

The Butterfly stroke is a similar stroke to the freestyle in that it is done in the prone position, however the arm strokes are done synchronously with the right and left arm, rather than alternately. The stroke uses the hips as a fulcrum for a more up and down motion with a dolphin or bilateral leg kick for forward propulsion. Breathing is typically done during the late pull through and early recovery phase by lifting the head up and looking forward, not with rotation. However, some butterfliers will still utilize a head turn to the side. The timing of the kicking and body undulation with the arm stroke is important for a fast, efficient butterfly stroke.

Backstroke

The Backstroke is the only competitive stroke done in the supine position with the face completely out of the water. The arm stroke is similar to the freestyle in that it is done in an alternating fashion. The arm enters the water above the head with the elbow straight and the body rolling towards the same side (while the head looks straight up). This body roll or trunk rotation allows the large trunk muscles to pull the body forward. The pulling arm bends as the arm continues to push down towards the feet ending near the hip. The opposite arm is recovering overhead during the pull phase and enters the water overhead a split second before the other arm ends its pull phase. As in freestyle, backstroke uses a constant flutter kick throughout the stroke.

Breaststroke

The breaststroke is the only stroke in which the arms or legs do not come out of the water throughout the stroke. The arm motion starts similarly to the butterfly stroke in that both arms move together starting from an overhead position. However in the breaststroke, the forearms do not continue under the body to the hips, but pulls just to shoulder level and then returns underwater back to the starting position of full flexion. The powerful whip kick is the main force for propulsion in the breaststroke and consists of pulling the hips into a position of external rotation, slight flexion and abduction, and knee flexion to about 90 degrees. The kick is a powerful hip adduction motion as the knees and hips extend, keeping the feet in an everted position until the legs internally rotate to neutral at the end of the kick. There is a high valgus stress placed on the knee during the kick motion. Breathing is done forward during the arm pull, as the arms pull the upper body up and out of the water. As in the butterfly, the key to a powerful efficient breaststroke is the timing of the stroke. The arm pull starts the stroke followed by a lunge of the body forward as the kick is completed, ending in a fully streamlined position.

Freestyle Considerations

Normal Mechanics

As described above, the freestyle or front crawl stroke consists of alternating strokes with the arms. The arm stroke is broken up into the glide phase, the pull through phase (early and late) and the recovery phase. The glide phase begins as the hand enters the water, thumb side first, in full flexion with the elbow slightly higher than the hand. During the glide phase, the arm is held forward in full flexion slightly lateral to the head (with some degree of variability). During the glide, typically the wrist and forearm will flex and pronate to “catch” the water prior to the pull-through phase. The early pull through phase occurs from the end of the glide phase to the time when the humerus is approximately 90 degrees flexed in front of the body, or when the hand is directly underneath the shoulder. The late pull through starts at this point and continues until the hand exits the water near to the hip. The path of the hand is typically in an “s” shape underneath the body as the swimmer tries to “catch” the water overhead and pull his or her body over that point. Rotation of the torso to the same side allows the arm to stay directly underneath the body and some feel that allows a deeper catch for a more powerful stroke [8, 9].

Breathing requires turning the head to the side during the late pull through and early recovery of the same side arm. This is also the same period of time that the trunk is rotating to the same side for a deeper catch on the contralateral side. When not breathing, the head stays stable looking forward. Therefore, more motion or rotation is actually occurring between the thorax and head (the neck) when the head is still as the body rolls during the stroke then when breathing is actually occurring.

Flutter kicking is done continuously throughout the freestyle stroke and can be described by the number of kicks per stroke. For example, a 2-beat kick would be 1 downward kick per leg per arm stroke, whereas a 6 beat kick would require 3 down beats per arm stroke. The kick primarily gets its power from hip flexion and extension rather than knee flexion and extension. The ankle stays plantar flexed.

Normal Muscle Activation

Numerous studies have been done regarding the muscle activation throughout the swim stroke and are summarized as follows [12, 13, 14]:

During the glide or reach phase of the stroke when the hand enters the water to the point of full overhead shoulder flexion, the scapula must achieve a position of upward rotation. The main muscle activation is in the anterior and middle deltoid to move the humerus as well as in the upper trapezius and rhomboid to place the scapula in the upwardly rotated position to avoid humeral-acromial impingement.

In the early pull through phase from the end of the reach phase until the arm is at 90 degrees of flexion, the pectoralis major and teres minor work to extend, adduct and internally rotate the arm while the body is rolling or orienting to the opposite side to get a deeper pull. In the late pull through phase, the latissimus dorsi and subscapularis extend and internally rotate the arm with power with continued body roll to the opposite side. Throughout the entire pull through phase, the serratus anterior, pectoralis major and latissimus dorsi are active to pull the body over a relatively fixed hand.

As the hand exits the water for the recovery phase of the stroke, the posterior and middle deltoid along with the supraspinatus extend and abduct the arm. The rhomboid muscle fires to retract the scapula and initiate the body roll to the opposite side. The upper trapezius and serratus anterior will fire to start to upwardly rotate the scapula throughout the recovery phase as the posterior, middle, and anterior deltoid fire in sequence to bring the arm to full flexion.

Common Pathomechanics

The number one issue in swimming from an injury perspective is “swimmers shoulder” which is really a term describing repetitive gleno-humeral impingement with tendonitis/tendonopathy [6, 7, 8]. Impingement most often occurs in the early pull through or early recovery phase of the stroke. Both are thought to occur due to humeral ‘hyperextension’ when the upper arm or humerus bone is posterior to the axis of the scapula [6]. It is hypothesized this occurs because the scapula is too far forward or anteriorly and downwardly rotated because of over activity or dominance of the pectoral and latissimus muscles. Limited body roll to the opposite side will also limit stroke depth in the pull through phase and limited roll to the same side will create hyperextension in the recovery phase and limit a “high elbow” finish. Some studies have also described poor positioning of the scapula on the rib cage as a factor in overhead impingement in swimming and other overhead activities [6, 7, 8, 10].

EMG studies on the freestyle stroke suggest that weakness in the serratus anterior muscles and supscapularis muscles correlate with ipsilateral shoulder impingement. By comparison, there is no shown difference in the power or activation of latissimus and pectoral muscles in painful vs. non-painful shoulders in swimmers [14].

The other main issue that is seen in the freestyle stroke that may or may not lead to pathology directly, but can be a cue to patterned imbalances is the inability to breathe in a bilateral fashion; that is the ability to breathe by turning the head to the right or to the left. Most swimmers have a dominant side for breathing. Limited ability to breathe bilaterally, while also beneficial from a racing perspective can also be beneficial for maintaining symmetrical trunk and neck mobility.

Rationale for Pathomechanics from a PRI Perspective

When discussing the above pathomechanics, and looking at them with an understanding of the normal human patterns described by the Postural Restoration Institute®, one can gain an appreciation for why these issues can be difficult to manage in a swimmer. A pattern of extension on one (Right BC) or both sides (PEC) both limits the ability of the thorax to flex and creates poor scapula-thoracic congruence. This scapula will now have to move forward and up with over activity of the upper traps and pectoral muscles. This position which is described in the Postural Respiration course, along with the pectoral and latissimus over activity of the swimmer, will limit full shoulder flexion without impingement.

This poor scapula-thoracic position also effectively disengages the serratus anterior from functioning properly as it needs thoracic flexion and proper scapula position to maintain adequate length-tension relationships to work properly. In addition, over activity of the latissimus dorsum along with an internally oriented scapula from pectoral tightness will require compensatory external rotation from the posterior rotator cuff and effectively inhibits the subscapularis muscle. This in turn places more demands on the already overactive latissimus dorsum for internal rotation activity. As described above, weak or inhibited serratus anterior and subscapularis muscles are implicated in shoulder impingement in swimmers. This is a common finding in a normal Right BC patient, which is also exacerbated with the general over activity of the last and pectoral muscles of the swimmer.

Limited trunk or neck rotation to one side or the other, which is also a common finding in a Right BC or PEC patterned individual, will make symmetrical or bilateral breathing difficult. Breathing to the right, which happens during the left pull through phase, encourages more trunk roll or orientation to the right and actually limits the need for cervical rotation to the left and increases cervical rotation to the right as the head stays down during the right pull through phase. This is usually the easier position for a Right BC individual who typically presents with limited thoracic orientation to the left (increased orientation to the right shown with limited horizontal abduction of the left shoulder) and limited cervical axial rotation to the left. Breathing to the left, therefore requires more trunk orientation to the left as breathing occurs during the right pull through phase, and cervical rotation to the left as the head stays still during the left pull through phase. This imbalance can also limit reciprocal mobility through the torso for symmetrical arm stroke, power, breathing efficiency, and neck mobility.

Tightness of hip flexors from flutter kicking, and back extensors from head and trunk positioning in a prone position, also anteriorly tilt the pelvis and elevates the anterior rib cage disengaging the anterior abdominal wall and exacerbates all of the above findings. This position would be consistent with a PEC patterned individual.

Management Focus

As with any individual, the initial management will consist of identifying their current pattern, PEC vs. Left AIC/ Right BC, and setting up a program to achieve neutrality. Then we can get into more specifics related to their sport specific activities.

Any competitive or recreational swimmer more likely than not does most of his or her training with the freestyle stroke, so these issues should be specifically addressed. All freestylers or swimmers need to focus on activities that promote:

- Lumbar and thoracic flexion with appropriate use of abdominals and breathing to restore proper diaphragmatic power, proper rib cage and scapular resting position and position for stabilizing muscles to work for their intended purpose. (Fig 1; Standing Wall Supported Reach)
- Improved glute strength for pelvic control in thoracic and lumbar flexion. (Fig 1; Standing Wall Supported Reach)
- Reciprocal trunk rotation with appropriate abdominal use and appropriate breathing mechanics once sagittal plane flexion is achieved and maintained. (Fig 2; All Four Belly Lift Reach)
    - The serratus anterior muscle is a) most active throughout the freestyle stroke, b) implicated as a cause of shoulder impingement when weak, c) commonly inhibited or inefficient due to position in the BC or PEC chained individual and d) essential for thoracic rotation, scapular/thoracic stability, rib cage mechanics and pulling power. The All Four Belly Lift reach is a great goal exercise to promote all of the above.
- Appropriate use of subscapularis muscle without over activity of the latissimus for humeral control in the glenoid to decrease anterior/superior impingement.
- Flexibility throughout the lateral chest wall, latissimus and hip flexor region.

Butterfly Considerations

Normal Mechanics

As stated in the last section, the majority of training time and mileage is spent doing the freestyle stroke, but the other strokes can present unique challenges and may need to be addressed for improved performance as well as for injury prevention and treatment. The butterfly stroke has a similar arm motion compared to the freestyle stroke with the exception that it is done with the arms recovering and pulling at the same time rather than alternating as in freestyle. The kick is an undulating dolphin kick keeping both feet together. The down beat of the kick is for power with 2 kicks per arm stroke. One powerful kick is done at the end of the recovers phase to propel the head forward and out of the water to breathe forward and one during the glide phase to help lunge or dive the arms forward. There is no rotation of the thorax or neck throughout the stroke, but more emphasis on trunk and neck extension to initiate the dolphin kicking and breathing throughout the stroke. [8, 9, 11]

Normal Muscle Activation

At hand entry and glide phase the deltoid muscles and rotator cuff muscles are putting the humerus bone in abduction and external rotation with Rhomboids and upper traps upwardly rotating the scapula for proper glenoid position. [15]

Throughout the pull through phase, similarly to the freestyle stroke, the pectoralis major and latissimus dorsi are the most active to generate the powerful pulling motion. The subscapularis and teres minor are active for humeral-glenoid control, and the serratus anterior is active to pull the thorax/ribcage forward on the scapulae in a true thoracic-scapular (TS) fashion. [15]

The recovery phase of the butterfly does not have as high of an elbow recovery since the trunk does not rotate to encourage this but the deltoid still works with the supraspinatus and infraspinatus to abduct and externally rotate the arm to the start position again. The serratus anterior, rhomboids and upper traps also fire throughout the recovery to retract and upwardly rotate the scapula. [15]

As in freestyle, the two most active muscles throughout the stroke are the subscapularis and serratus anterior so they are again at risk for fatigue and injury. [15]

The undulating motion of the kick is typically initiated with back and neck extension to get the head out of the water for breathing followed by a lunge forward and downward with a down beat of the legs utilizing hip flexion more so than knee extension, to propel the body forward.

Common Pathomechanics

As in the freestyle stroke, the number one complaint in the butterfly stroke is shoulder impingement or tendinitis/tendonopathy. [8, 9] The same rationale for impingement applies for butterfly as for freestyle which is implicated mainly due to poor scapular positioning at full flexion and in adequate scapular retraction and upward rotation during the recovery leading to humeral 'hyperextension' and impingement in the recovery phase. This is more common in the butterfly stroke due to the strong powerful latissimus and pectoral muscles and the limited trunk rotation to decrease the impingement or hyperextension. [8, 9]

Studies have shown that butterfliers with painful shoulders tend to have the following findings when compared with butterfliers without pain [16]:

- A wider hand entry, possibly to limit the impingement at full flexion. This will decrease the overall efficiency of the stroke.
- Decreased activity of the serratus anterior at hand entry but no change in rhomboid firing leading to a net downward rotation of the scapula when the humerus should be at full flexion.
- Decreased subscapularis and teres minor activity.
- Latissimus dorsum and pectoralis major activity was not changed in painful vs. non-painful shoulders, however significantly less serratus anterior function was found throughout the stroke.

Rationale for Pathomechanics from a PRI Perspective

The butterfly stroke in its overall demands promotes more of an extension or PEC pattern. The over activity of the hip flexors compared to the gluteal muscles as well as increased back, head and neck extension for breathing elevates the anterior ribs and places the diaphragm at a disadvantage for respiration which will lead to increased activity of accessory respiratory muscles which will further influence scapular and rib positioning as described previously. This overall extension position at the rib cage along with tight, short, strong latissimus and pectoral muscles effectively inhibits or disengages the interscapular muscles, serratus anterior muscles, teres minor and subscapularis muscles secondary to poor scapular positioning. This pattern in and of itself will weaken the muscles associated with painful shoulders in the butterfly stroke. This PEC pattern also limits the ability for the humerus to achieve full HG flexion and HG horizontal abduction. Both of these motions are necessary to perform the butterfly without impingement or compensation with excessive lumbar and thoracic extension. The limited ability to utilize the serratus anterior and subscapularis throughout the pull through phase will increase the demand on the latissimus and pectorals to fire for power, effectively strengthening the extension pattern.

The limited rotational demand in the butterfly also reinforces the need for proper thoracic and rib position in the sagittal plane for adequate mobility and stability at the scapulo-thoracic and gleno-humeral joints. The underlying pattern of asymmetry may also make this more challenging on one side compared to the other.

Management Focus

In general, the demands of the butterfly favor the posterior exterior chain muscles. Therefore once neutrality is achieved and maintained activities to inhibit the PEC chain are necessary for the butterfly swimmer even more so than for the freestyle swimmer. The butterfly swimmer needs to:

- Emphasize the sagittal plane demands of abdominals, hamstrings and glutes to limit the extension tendencies and inhibit the PEC pattern. (Fig 3; Functional Squat with Low Trap)
- Encourage posterior mediastinum expansion. (Fig 4; Squatting Bar Reverse Reach)
- Maintain proper latissimus and pectoral flexibility in thoracic flexion. (Fig 4; Squatting Bar Reverse Reach)

Exercise options may include All Four Belly Lift activities, Reverse Door Squats (See Fig 4), Paraspinal Inhibition activities, Lower Trap Press Downs with Abdominals, and ultimately a Squat with Lower Trap would be a great integrated exercise for the butterflier to master at a level 3-4 (see Fig 3).

Backstroke Considerations

Normal Mechanics

The backstroke is similar to the freestyle stroke in that the arm motions are done in a reciprocal fashion with a significant amount of body roll and a flutter kick. The main difference, of course, is the fact that the backstroke is done in a supine position with the face out of the water and not in the prone position as the freestyle is. This takes a lot of the respiratory demand down in the backstroke. The phases are the same for the backstroke as the freestyle. The pull through phase starts as the hand enters the water pinky side first at full shoulder flexion with the arm in an internally rotated position. The trunk should be rotating to the same side as the hand enters the water to allow the hand to submerge and catch the water. Timing of body roll is important at this phase to limit shoulder impingement. Mid pull through is when the humerus bone is perpendicular to the body. Typically at this point maximal body roll has occurred to the same side and starts to rotate back to a neutral position. The late pull through continues as the elbow straightens out and the wrist straightens as if it were pushing the water from the hip down towards the feet. The recovery phase begins as the hand exits the water by the hip thumb side first and travels straight overhead to the point of hand entry. The elbow stays in full extension throughout the recovery phase. The arm rotates from a position of thumb up to thumb down throughout the recovery phase. [8, 9]

Normal Muscle Activation

Because of the difference in body position and the arm rotating in a different direction than for the freestyle and butterfly, the backstroke demands different muscles. The muscles most active throughout the backstroke are the teres minor and subscapularis, which are not commonly used as power muscles. Rather they are primarily stabilizers that in the backstroke are demanded to be power muscles. This places them at higher risk for fatigue and injury. EMG data shows that the powerful latissimus muscle has 30% less action than the teres minor and subscapularis. Throughout the pull through phase, the teres minor and subscapularis are active to at least 30% voluntary maximum. The rhomboid muscles are active throughout the early pull through phase for scapular retraction and trunk rotation. [17]

Common Pathomechanics

The main issue for swimming the backstroke is humeral impingement and anterior instability from excessive humeral hyperextension. If the body roll is not adequate at hand entry and early pull through, and a deep catch is required, the humerus will go into a position of hyperextension and anterior laxity or strain will ensue. [8, 9] The point of hand entry is a position of full shoulder flexion with humeral internal rotation which may also place the shoulder in a position at risk for impingement. The fact that the main muscles used for power in the backstroke are also muscles responsible for humeral stability, places them at risk for injury as well. Limited EMG activity of the rotator cuff muscles is implicated in backstrokers with painful shoulders, which may be due to inhibition from impingement or other factors. [18]

Rationale for Pathomechanics from a PRI Perspective

The demand placed on the anterior rotator cuff and specifically the subscapularis is heightened in the backstroke. Technique and adequate body roll is also of utmost importance to place the scapula and humerus in a position to avoid anterior strain and impingement. Someone with a poorly positioned scapula from an asymmetrical or poor rib cage position will demonstrate asymmetrical trunk rotation, and scapular rotation to one side or both. Hyperactivity of the pectorals and limited ribcage expansion will limit rotation and may limit proper trunk rotation. Subscapularis is also typically inhibited in PEC or Right BC patterned individuals and due to the demands of the subscapularis in backstroke and potential humeral anterior laxity from hyperextension forces, the risk for injury or instability is high. The ability of the rhomboids and lower trapezius to retract the scapula and rotate the trunk during late recovery is also of great importance and has not been addressed in research. If the lower trapezius is inefficient in these activities, proper scapular positioning during rotation will be challenged leading to the above issues as well. The other factor that may also need to be addressed is the ability of the cervical spine to rotate. Throughout the stroke the head stays in still position as the thorax rotates underneath it. If cervical axial rotation is limited, which is common in a Right BC or PEC chained individual, so will thoracic rotation, and body roll.

Management Focus

Along with the demands that need to be addressed for freestylers, for the backstroke, trunk rotation (thoracic and cervical), lower trap function and subscapularis function is of utmost concern. Therefore management or training with for backstroke should emphasize:

- Thoracic rotation with Lower Trapezius and Triceps activation. (Fig 5; Standing Resisted Right Diagonal Flexion in the Right AIC)
- Humeral Glenoid Internal Rotation with concurrent lower trapezius and without Latissimus Dorsi activation. (Fig 6; Supine Resisted Right HG IR with Left HG ER)
- Dynamic humeral-glenoid stabilization with appropriate scapula-thoracic/thoracic-scapular stability.

Breaststroke Considerations

Normal Mechanics

The breaststroke is considered the oldest of the competitive swim strokes and is very unique in its technique. The legs are the main driver of the body and this is the only stroke in which the hands do not exit the water. This fact, along with the decreased demands for trunk rotation and humeral hyper extension (the arms are always in front of the body) makes the breaststroke the least common stroke to have shoulder complaints with. The bilateral arm-pull starts at full flexion and starts similarly to the butterfly stroke. However, in the breaststroke when the hands are in line with the chest they sweep together, pulling the head out of the water to breathe, and then thrust forward to the starting position as the kick powers the body forward and the head returns to the water. The breathing motion is forward, but unlike the butterfly stroke the arm motion naturally leads the body up and out of the water limiting the demand for neck or trunk extension for breathing. This reduces the potential for back pain with the breaststroke. [8, 9]

The kick, which is the main power force in the breaststroke, is a whip kick in which the legs start fully extended during the glide portion of the stroke. The legs are then flexed as the heels are brought close to the buttocks. At this point, the feet turn outward into eversion and the hips internally rotate to move the feet wider than the hips. The feet and knees then forcefully push back and in with a strong extension and adduction force until they are once again fully straight. [8, 9]

As in the butterfly, timing of the stroke is essential to the success with the breaststroke. In general, the stroke starts in a fully streamlined position, the arms start the pull phase lifting the head up as the knees and hips bend. The kick is completed as the arms recover forward with both arms and legs ending up in a streamlined to an extended position simultaneously. Once there, the body glides forward utilizing the momentum of the kick. The sequence is therefore pull - kick - glide.

Normal Muscle Activation

The main shoulder muscles that are the most active throughout the breaststroke are the serratus anterior and teres minor muscles which both fire consistently at or above 15% of maximal voluntary contraction. They are the most susceptible to fatigue and injury. In breaststrokers with painful shoulders, it was shown that there was decreased activation of the teres minor, supraspinatus and upper trap muscles vs. non-painful shoulders. However, due to the decreased mechanical demand on the shoulders, the risk for shoulder injury is much less in the breaststroke population. [19]

Common Pathomechanics

As described above, the shoulder has some risk of injury with fatigue of serratus anterior and teres minor muscles, which should be being trained well with a swimming specific program. [19] The most common complaint that is unique to breaststrokers is medial knee pain. [20] In fact, it is unique enough among swimmers that it has been coined “breaststrokers knee”. This is thought to be from strain to the medial collateral ligament from the valgus stress to the knees from the whip kick. Other potential causes of knee pain in breaststrokers are patella-femoral syndrome, condromalacia, and pes anserine bursitis. It has been shown by Stulberg et al that breaststrokers with knee pain had a whip kick with higher abduction values, and therefore more adduction/valgus strain, during the propulsion phase of the kick than those without knee pain. [10, 21, 22] Rovere and Nicholas also reported a significant decrease in hip internal rotation in hips of breaststroke swimmers with medial knee pain than those without. [23]

Rationale for Pathomechanics from a PRI Perspective

Management of shoulder symptoms in the breaststroke should closely coincide with the butterfly, however the extension tendencies of the breaststroke are much less than the butterfly, which is why the incidence of shoulder pain in breaststrokers is much less than butterfliers.

The main pathology unique to the breaststroke as described above is medial knee pain or “breaststrokers knee”. Regardless of the specific pathology, medial collateral ligament, pes anserine bursitis or patella-femoral symptoms, it has been shown that a whip kick with increased hip abduction and decreased internal rotation correlates with medial knee pain. From a Postural Restoration® perspective, a swimmer who does a significant amount of mileage for training with the freestyle stroke and flutter kick is predisposed to tightness in the hip flexor group and an anterior positioned pelvis as described above. This will have a tendency to orient the acetabulum internally leading to compensatory external rotation and abduction. This is seen as limited FA IR and adduction with evaluation, which in the case of breaststroke will predispose medial knee pain.

Management Focus

As described above, the unique pathology with breaststrokers is medial knee pain. Management of medial knee pain in the breaststroke needs to be aimed at improving whip kick mechanics:

- Proper lumbo-pelvic- femoral positioning and control
- Hip internal rotation mobility assessing the posterior hip capsule and/or posterior outlet (Fig 7; Right Sidelying Supported Left Glute Med in Hip Extension)
- Hip Internal rotation mobility/strength with adductors and gluteus medius (Fig 8; Seated Resisted Alternating Reciprocal Quad Sets with FA IR)

Other issues involved in competitive swimming

The only time the swimmer has a stable surface to push off of for speed and support is during the start and turn of the race. This is when the swimmer can utilize the legs to push forward to initiate speed for the race. If a swimmer is to have success, they need to maximize this time to gain and maintain speed.

Starts

The start position requires full thoracic and lumbar flexion to attain without sacrificing positioning of the glute and leg muscles to power the body forward at the sound of the gun. If this position cannot be attained comfortably, paraspinal release activities should be initiated and encouraged.

Turns (touch and flip)

The freestyle and backstroke strokes utilize a flip turn at each wall whereby the swimmer as they approach the wall tucks his head and rolls into a ball bringing the feet over the head until they hit the wall and then the swimmer can push off away from the wall. In the backstroke, the swimmer is allowed one stroke to flip over onto their front and then performs a flip turn similar to the freestyle stroke. This position is similar to the Full Functional Squat position utilized to assess paraspinal/ extension tone inhibition. If a swimmer cannot attain a Full Functional Squat they will not be able to achieve a tight, fast flip turn, nor have the gluteal position and power for a full push off once they hit the wall.

In butterfly and breaststroke, the swimmer must touch the wall with both hands prior to initiating a turn. This is called a touch turn. Once the swimmer touches the wall with both hands, the swimmer turns either to the right or the left as they pull their feet to the wall, again imitating a full tucked squat position before pushing away from the wall with the legs. Again, a Full Functional Squat and powerful glutes from this position is necessary and can be trained using the Reverse Squat techniques (See Fig 9; Full Functional Squat)

Streamline positions

To maximize the power and speed gained from the push off at the start and turn, the swimmer needs to minimize the drag of the water as they glide through the water. This is accomplished with the streamline position which consists of full shoulder flexion with the arms touching the side of the head and the head in a neutral position. If the extension tendencies are great and the scapular position is submaximal, this becomes a position of potential impingement for the swimmers shoulder and needs to be addressed. One other potential limiting factor of a streamline position is restricted latissimus dorsi mobility. Swimmers need to maintain good latissimus flexibility to achieve good streamlining positions. The Latissimus Hang Stretch (Fig 10; Latissimus Hang Stretch) is a great activity for encouraging not only lat flexibility, but appropriate pelvic positioning as well.

Conclusion

The swimmer is subjected to different demands from a physical, respiratory and neurological standpoint as well as the normal asymmetrical human patterned demands we all face, as described further by the Postural Restoration Institute®. Management of the swimmer for injury prevention or performance enhancement must therefore assess and address both. This document goes through a general guideline, but as with anything, each individual needs to be assessed for their particular demands, patterns, and techniques that cannot be addressed with a cookbook program outlined for everyone. If management is difficult, a trained individual should be sought out and utilized.

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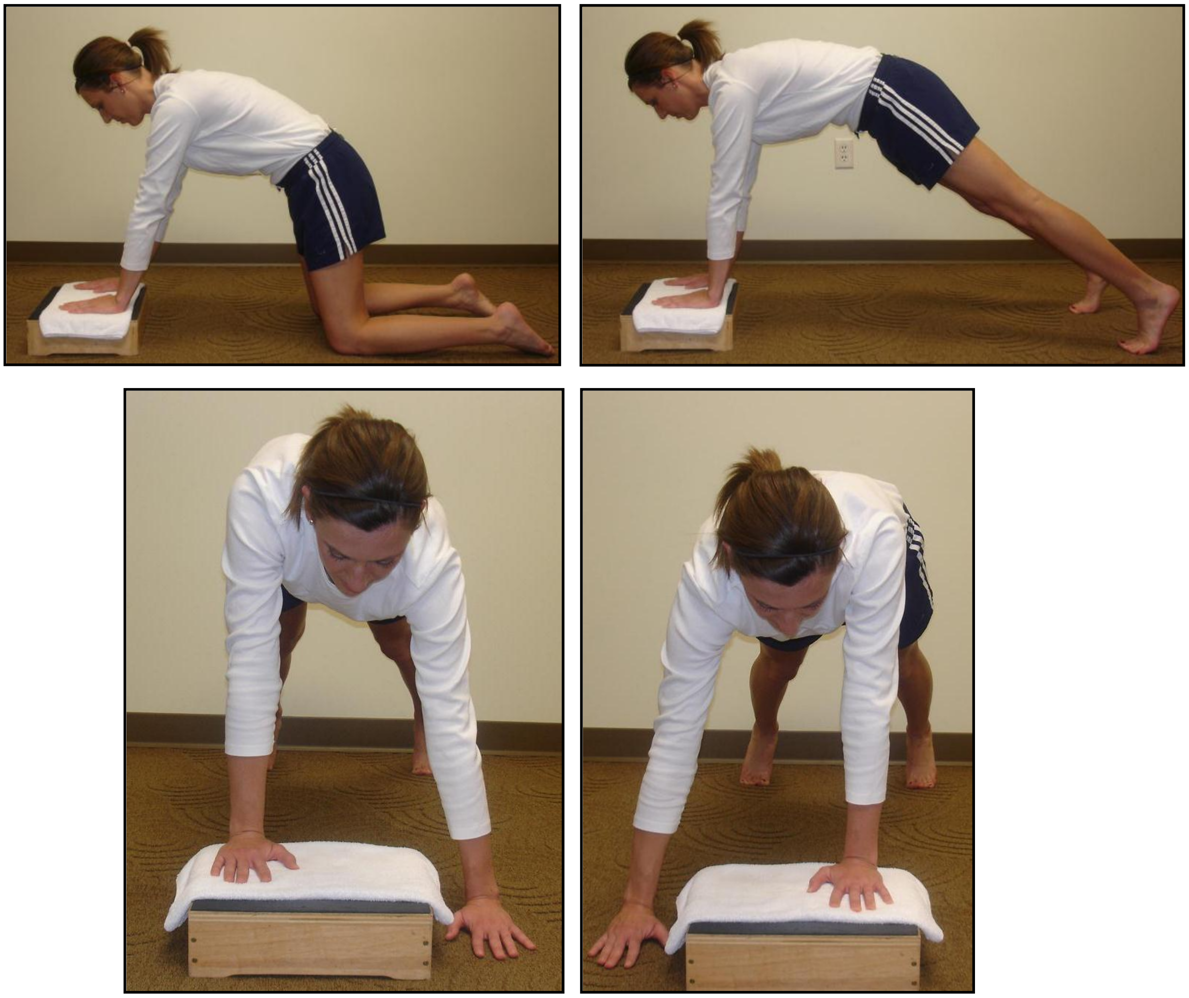
Figure 1:
Standing Wall Supported Reach

1. Stand facing away from a door, and place your heels 7-10 inches from the wall.
2. Stand up straight with a ball between your knees and feet shoulder width apart.
3. Bring your arms out in front of you as you round out your back, performing a pelvic tilt so your lower back (mid-back and down) is flat on the wall.
4. Squat down slightly as you squeeze the ball.
5. Keeping your lower back flat on the wall, inhale through your nose.
6. As you exhale through your mouth, reach your arms forward and down so your upper back comes off the wall (your lower back should stay flat on the wall).
7. Hold your arms steadily in this position (reach), as you inhale through your nose again and expand your upper back. You should feel a stretch in your upper back.
8. Exhale and reach further forward. You should feel the muscles on the front of your thighs and outer abdominals engage.
9. Repeat this breathing sequence for a total of 4-5 deep breaths, in through your nose and out through your mouth.
10. Slowly stand up by pushing through your heels, keeping your lower back flat on the wall.
11. Relax and repeat 4 more times.

Reference Center(s): Left abdominals, Left heel, Right arch

Figure 2:
All Four Belly Lift Reach



1. Position yourself on your hands and knees with your hands on a 2-6 inch block.
2. Place your knees at shoulder width or slightly wider and round your back.
3. Maintaining a rounded back, raise your knees off the floor until your legs are straight. Shift your weight forward so your nose is over your fingertips. You should feel your outer abdominals.
4. Shift your weight to your right side and reach towards the floor with your left hand without bending your right elbow. You should feel the muscles in your shoulder blades engage.
5. Inhale through your nose, filling up the back of your right chest wall with air.
6. Exhale through your mouth and reach or push with your left hand.
7. Place your left hand back on the block and shift your weight to your left side.
8. Reach towards the floor with your right hand without bending your left elbow.
9. Inhale, filling the back of your left chest wall with air.
10. Exhale and reach or push with your right hand.
11. Continue this sequence of breathing taking 4-5 deep breaths, in through the nose and out through the mouth while holding one position at a time.
12. Relax and repeat 4 more times with each arm.

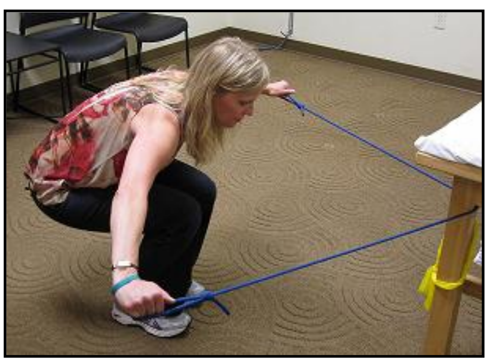
Figure 3:
Functional Squat with Low Trap

Start Position

- Stand facing a leg of a table.
- Place a band around the table leg, and hold onto a loop in each hand.
- Keep your feet together and pointed straight ahead. Your weight should be through your mid-foot/heels.
- Round out your back as you tuck your bottom under you.

Level Three

- After achieving the start position, squat down while keeping your back rounded and heels down. Squat until your hips are at the level of your knees.
- Inhale through your nose and fill the back of your chest with air. Exhale through your mouth as you pull your arms back and keep your back rounded. You should feel the muscles on the back of your shoulder blades engage.
- Keep your shoulder blades pulled back as you breathe for 4-5 deep breaths, attempting to fill or expand your upper back with air on inhalation.
- On the final exhale, push through your heels and slowly stand up keeping your back rounded.



Level Four

- Squat until your hips are below the level of your knees.
- Maintain this position and perform the breathing sequence above.

**This is the most difficult position to perform this exercise in.*

Level Five

- Squat until you have achieved a full squat position (bottom to your heel cords). Keep your weight through your mid-foot/heels.
- Maintain this position and perform the breathing sequence above.

Reference Center(s): Left abdominals, Left heel, Right arch

Figure 4:
Squatting Bar Reverse Reach

1. Hold onto a wooden pole across a door frame and find the best functional squat position (bottom of pelvis to heel cords), while keeping your heels down and knees inside your elbows. You may need to stand back up and re-position your feet so you can get your bottom down as far as allowed.
2. Once you have positioned yourself in the most optimal squat position, take a deep breath, in through your nose, and fill the back of your chest wall with air while keeping your eyes up or level with the floor. Exhale through your mouth as you lean back until all your air is out. Repeat this sequence of inhalation and exhalation 3 to 4 more times, always allowing your heel cords, front of your thighs/knees and your back muscles to relax and stretch.

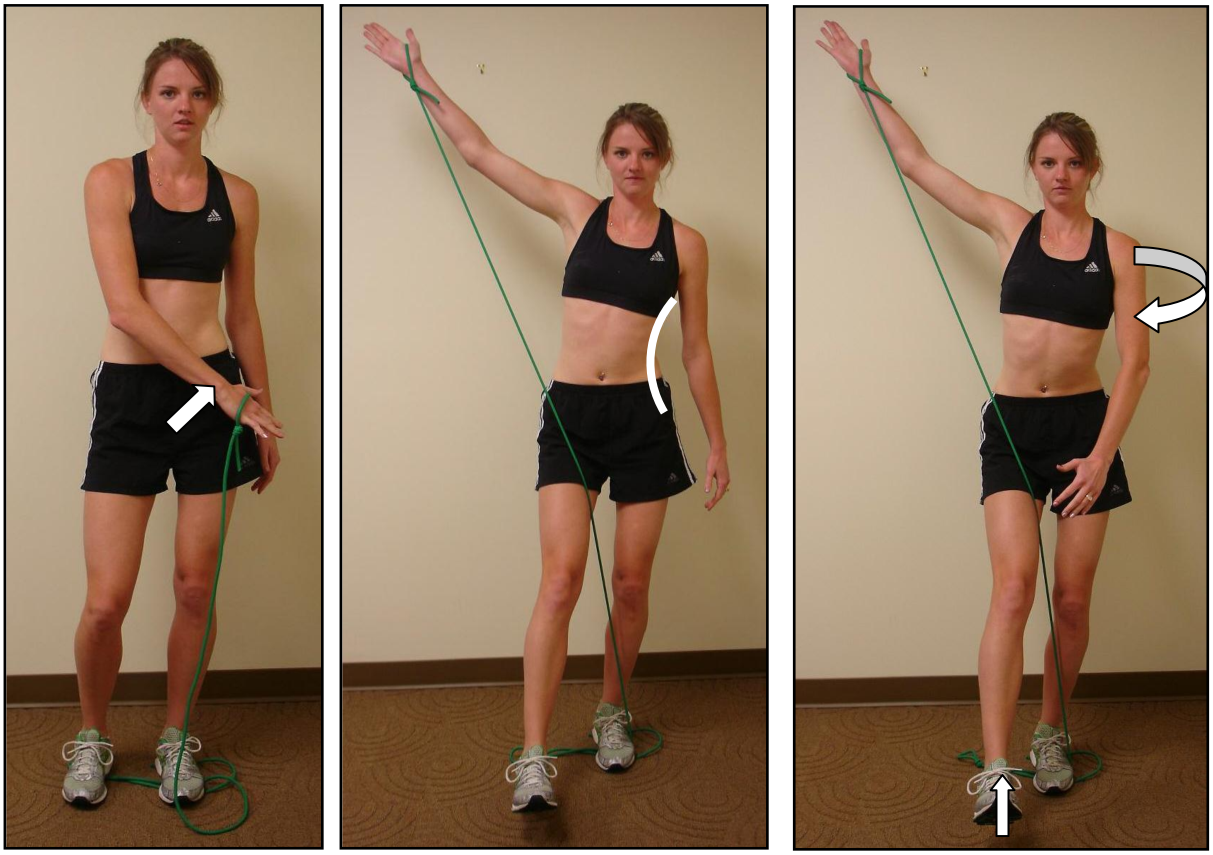
3. After the fourth breath in, exhale and begin to stand up pushing down through your heels and keeping your back rounded while sliding the pole up the door frame as necessary to assist you in coming up.
4. Lower the pole and repeat the process 4 more times.
5. The goal is to perform the first 3 steps above with the pole at the level of your ankle, with your elbows straight, with your knees in your chest and with the bottom of your pelvis on your heel cords (PRI Squat Level Four or Five).

Once you've achieved the above goal, repeat the first three steps. After the fourth breath in, reach forward with your hands as you exhale so that the pole loses contact with the door frame. As you exhale, begin to stand up, pushing through your heels and continuing to reach forward so that the pole doesn't touch the door frame.

Go to your local hardware store and purchase a 1 inch x 4 foot wooden pole. For cushion, encase the pole in pipe insulation.

Reference Center(s): Left abdominals, Left heel, Right arch

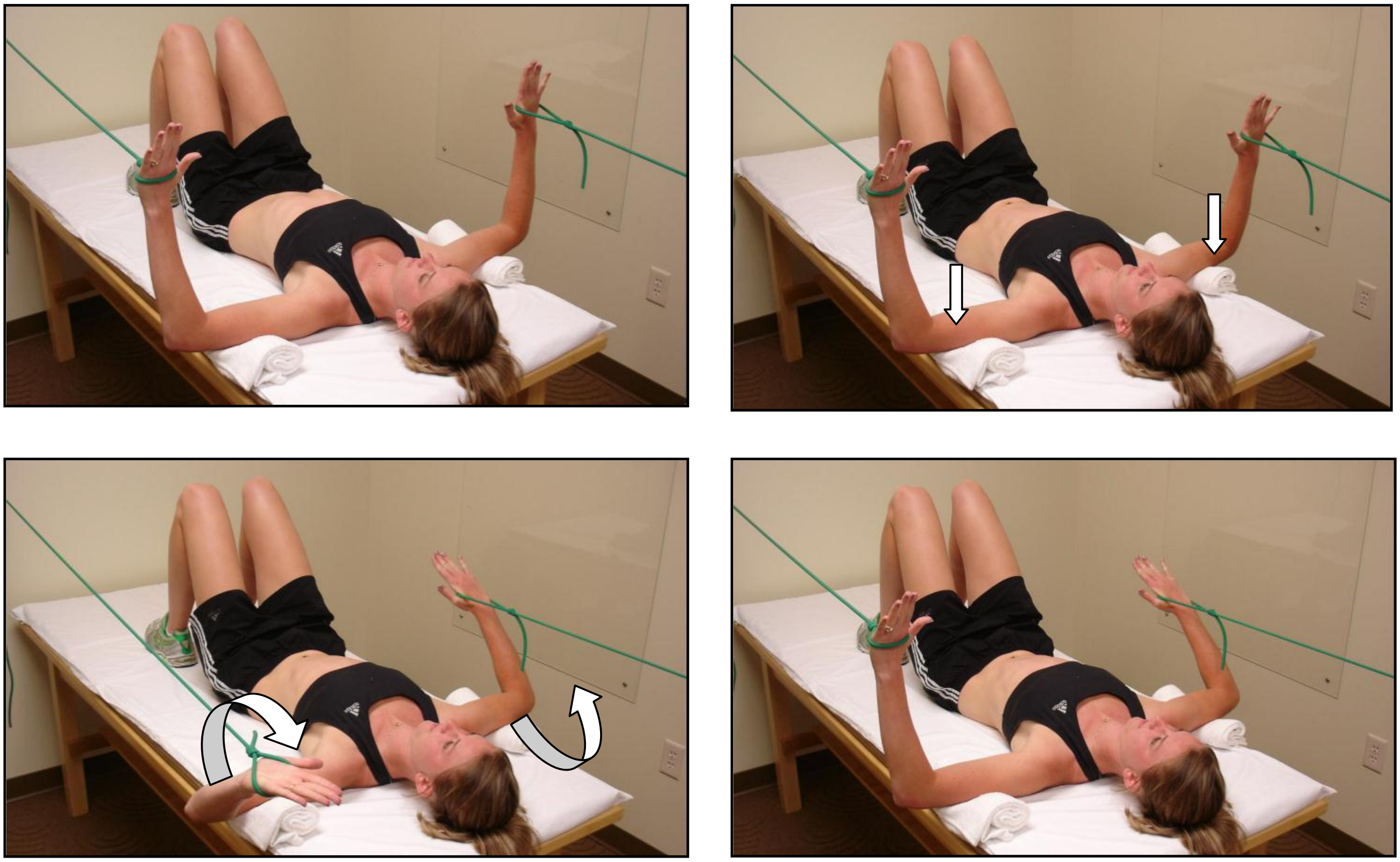
Figure 5:
Standing Resisted Right Diagonal Flexion in Right AIC



1. Place a piece of tubing underneath your left foot, and place the other end in your right hand.
2. Shift your left hip back, and sidebend your trunk to the left.
3. Pull your shoulder blades down and together.
4. Begin to raise your right hand up and out to the side as you rotate your palm up. You should feel the muscles on the back of your right shoulder blade engage.
5. Lift your right foot in front of you.
6. Try to balance on your left leg as you reach forward and across the midline of your body with your left hand. You should feel the muscles on the back of your right shoulder, the front of your left thigh, left outer hip (buttock) and left abdominals engage.
7. Hold this position while you take 4-5 deep breaths, in through your nose and out through you mouth.
8. Relax and repeat 4 more times.

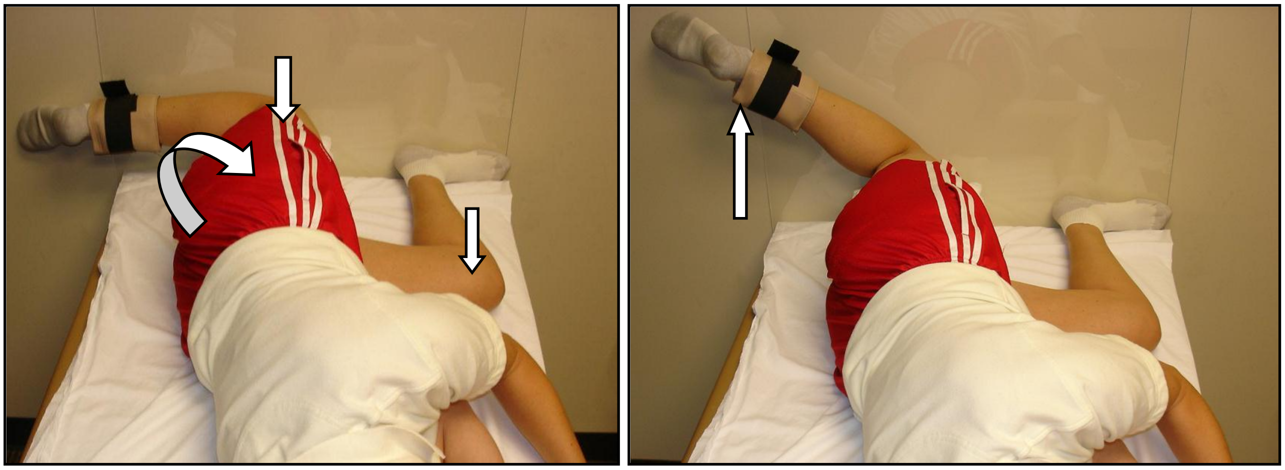
Reference Center(s): Left abdominals, Left heel

Figure 6:
Supine Resisted Right HG IR with Left HG ER



1. Lie on your back with your knees bent.
2. Anchor a piece of tubing above your right arm and below your left arm.
3. Place both arms at shoulder level and rest them on bolsters.
4. Bend both elbows at a 90-degree angle and place both ends of the tubing in each hand.
5. Pull your shoulder blades down and together and press your elbows into the bolsters.
6. Keeping your elbows pressed down into the bolsters, turn your right hand down and your left hand up against the resistance of the tubing. You should feel the muscles on the front of your right shoulder and the back of your left shoulder engage.
7. Hold this position while you take 4-5 deep breaths, in through your nose and out through your mouth.
8. Slowly bring both arms back to start position.
9. Relax and repeat 4 more times.

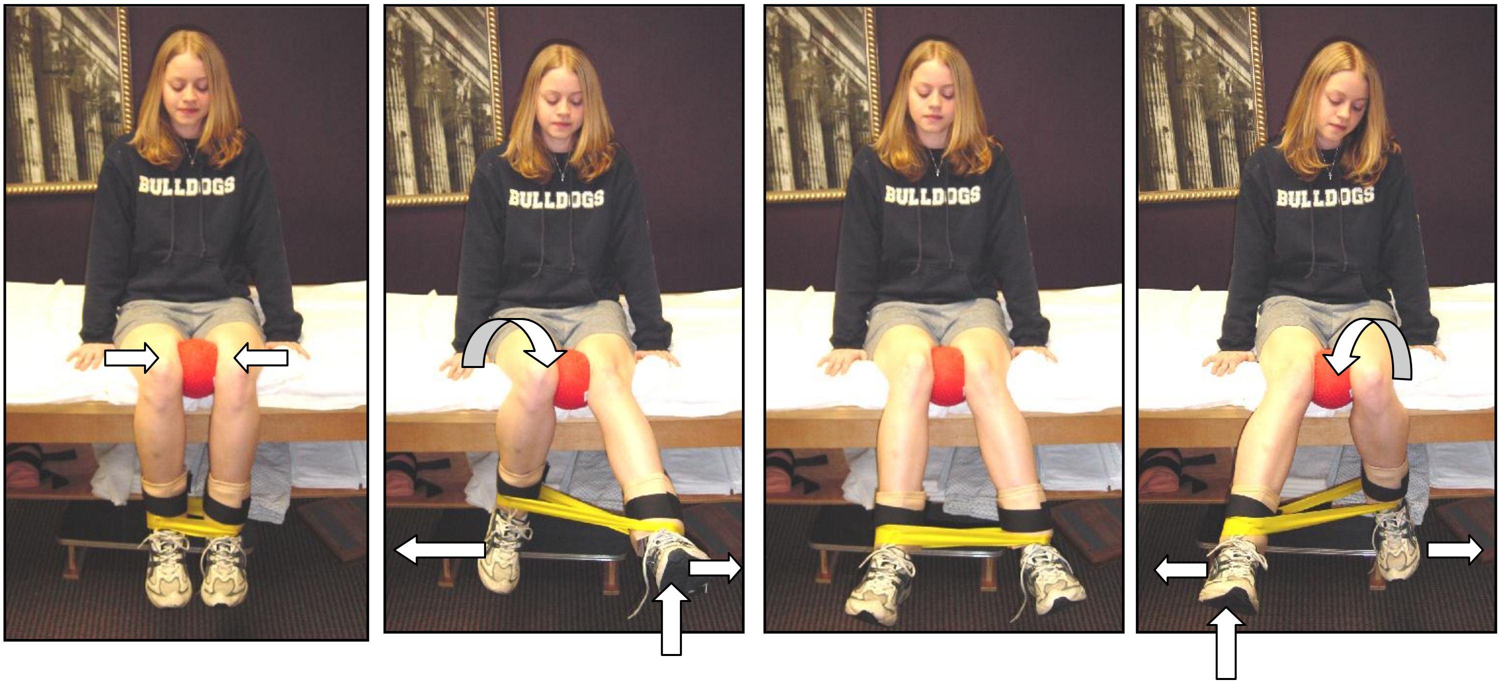
Figure 7:
Right Sidelying Supported Left Glute Med in Hip Extension



1. Lie on your right side with your right hip bent at a 90-degree angle and your right foot placed on the wall. Keep your back and neck relaxed.
2. Place a 3-5 lb ankle weight around your left ankle. Keep your left hip neutral (left knee, hip and shoulder in line with each other) and place your left knee on a bolster so that your knee is level with your hips.
3. Move your left knee toward the wall and touch the wall.
4. Press your right foot into the wall and your left knee down into the bolster. You should feel your left inner thigh engage.
5. With your right foot into the wall and your left knee down, turn your left lower leg up towards the ceiling. You should feel your left outer hip (buttock) engage.
6. Hold this position while you take 4-5 deep breaths, in through your nose and out through your mouth.
7. Relax and repeat 4 more times.

Reference Center(s): Right arch

Figure 8:
Seated Resisted Alternating Reciprocal Quad Sets with FA IR



1. Sit on the edge of a table and place 3-5 lb ankle weights around your ankles and a band between the ankle weights and your feet.
2. Place a ball between your knees and squeeze.
3. Round out your back and roll your pelvis back, feeling your “sit bones.”
4. Straighten your left leg as you simultaneously pull back your right leg.
5. Turn your right lower leg out to the side. You should feel the outside of your right hip (buttock) along with the back of your right thigh and the top of your left thigh.
6. Hold this position as you take 4-5 deep breaths, in through your nose and out through your mouth.
7. Slowly lower your left leg and pull it back as you simultaneously straighten your right leg. Turn your left lower leg out to the side. You should feel your left outside hip (buttock) along with the back of your left thigh and top of your right thigh.
8. Hold this position as you take 4-5 deep breaths, in through your nose and out through your mouth.
9. Continue to repeat the above sequence until you have completed 4-5 repetitions with each leg.

Figure 9:
Full Functional Squat

1. Stand away from a wall.
2. Squat down until your knees are maximally bent. Keep your heels down.
3. Rest your hands on the tops of your knees and attempt to maintain your bodyweight through your heels, not your toes. Your back should be rounded and relaxed.
4. Hold this position for 4-5 deep breaths, in through your nose and out through your mouth. On each inhalation, attempt to fill or expand your upper back with air.
5. Slowly stand up by pushing through your heels and keeping your back rounded.
6. Relax and repeat 4 more times.

Figure 10:
Latissimus Hang Stretch

Bilateral Lat Stretch

Right Lat Stretch
Right Chest Expansion

Left Lat Stretch
Left Chest Expansion

1. Place both hands on an overhead bar.
2. Place your feet in front of you shoulder width apart and begin lowering your body until all of the slack is taken up through your trunk.
3. Once you are all the way down, perform a posterior pelvic tilt by tucking your bottom under you. You should feel a stretch in your armpit area and across the front of your chest.
4. Hold this position while you take 4-5 deep breaths, in through your nose and out through your mouth.
5. Relax and repeat 4 more times.
6. *An alternative to this technique would be to perform the steps above and then lift your left or right leg off of the ground.*