Part II: Is the Breaststroke arm stroke a "Pull" or a "Scull"?

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Abstract. *At the present time swimmers seem to be moving away from using sculling motions in their arm strokes. The trend is back toward the use of drag-dominated propulsion where the hand and arm operate more like a paddle than a foil. While this is true in three of the competitive strokes, a great number of coaches still think breaststroke should be the exception to this trend. They believe swimmers in this stroke should be sculling their hands out and in. In this paper I want to present a case for breaststrokers using drag-dominated propulsion during their arm stroke. My rationale for suggesting this will be given early in the paper, followed by the presentation of visual and graphic data that support that rationale. In the final section, I will describe how I believe the arm stroke should be performed together with a short video showing an Olympic Gold Medalist swimming this way.*

Introduction to Part II.

Theories of propulsion were discussed in Part I of this paper. Shoulder adduction as a major propulsive stroking motion and the way it is performed in the front crawl, backstroke and butterfly were also described. In Part II, I want to describe how, I believe, shoulder adduction is used for propulsion during the breaststroke arm stroke.

Shoulder adduction in the breaststroke.

As I stated earlier in Part I of this paper, it seems logical to me that breaststrokers should use the same shoulder adducting motion that is employed for propulsion in the other three strokes, and that their propulsion should also be drag-dominated. The two photos in figure 1 show side views of a former U.S. national-level breaststroke swimmer using the same shoulder adducting motion in his stroke that was described for the other three competitive strokes in part 1 of this paper . Notice, that his catch is made with arms flexed at the elbows, and facing back (see photo on left in figure 1), following which, he sweeps his arms horizontally backward in a sideward, semi-circle that ends as they approach his ribs (see photo on right in figure 1).

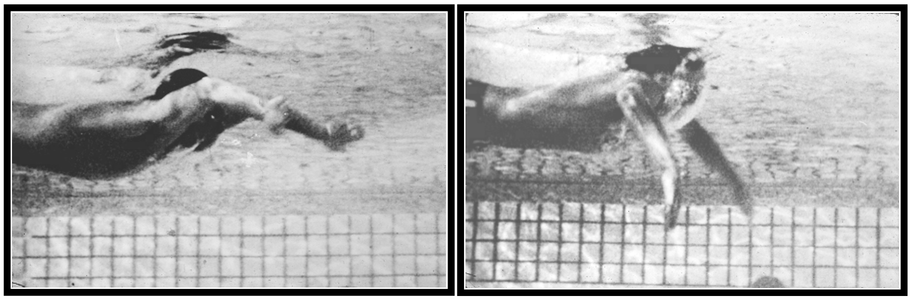

Figure 1. *Shoulder Adduction in the Breaststroke. The swimmer is Jim Johnson, former All American swimmer in the 200 y breaststroke.*

At this point, it would be reasonable to question why the stroke patterns of breaststroke swimmers show their hands traveling backward only a short distance during the propulsive phase of their arm stroke, if they are, in fact, pushing back against the water with them, (see figure 2). To answer this question we must differentiate between the ***distance*** a breaststroke swimmer's arms travel backward and the amount of ***backward force*** they apply to the water the during the underwater arm stroke.

The illustration in figure 2 is used for this purpose. The underneath view stroke patterns for both the swimmer's right and left hands show the actual paths they take through the water. The hand-path of the swimmer is drawn relative to the water, which is the most accurate way to demonstrate the relative amounts his hands travel out, in, and back during his arm stroke. The two drawings of his body in this figure, demonstrate its (his body's) forward movement during the arm stroke (from the shaded to un-shaded drawings).

You can see clearly that the swimmers hands move out and in, a considerably greater distance than they travel back during his underwater arm stroke. If a side view were included it would show that they also travel down and up to a greater extent than they move backward (see figure 1 in Part I of this paper).

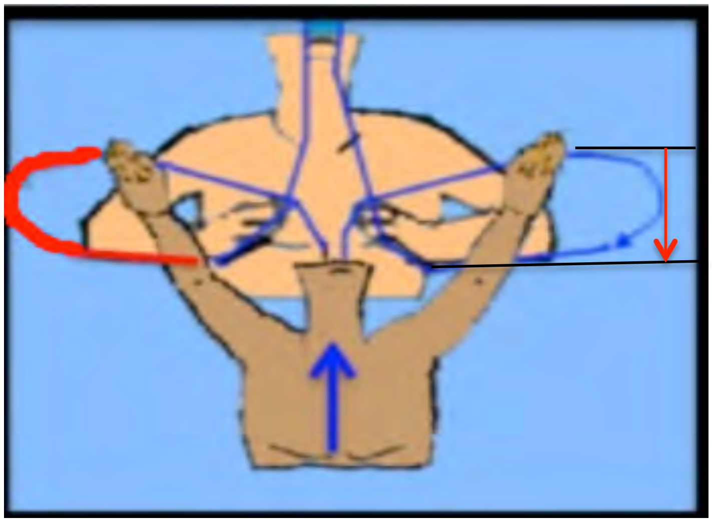

Figure 2. *The breaststroke arm stroke pattern drawn relative to the water. The illustration shows an underneath view of a typical hand-path pattern for a breaststroke swimmer. The pattern traces the movement of the swimmer' hands through the water. It is drawn relative to the water and provides the truest representation of* the two-dimensionl direction *swimmer's hands move during the arm stroke. The positions of his shaded and un-shaded body indicate its forward movement during his arm stroke. Notice that the swimmer's arms travel backward for only a short* ***distance*** *during their outward and inward sweeps (as indicated by the red arrow beside his left hand). Notice also the portion of his right hand stroke pattern that is in red. It indicates the length of time he spends exerting* ***backward force*** *against the water even while his hands are actually traveling diagonally out and in during their actual path through the water. This drawing is used to illustrate how swimmers can propel their bodies forward by pushing back even when their stroking motions are circular.*

The red arrow beside the stroke pattern for his left hand indicates the *distance* it actually travels back during one stroke cycle. When compared with the distance his hand travels out and in, it would be reasonable to assume that he is propelling his body forward by sculling his hands through the water. Let me explain why that assumption is not true. Notice the red portion of the stroke pattern for his right hand in the drawing in figure 2. It illustrates that portion of the stroke pattern when the swimmer is stroking *diagonally* backward. That, in turn, represents the length of time during the stroke pattern that the swimmer can apply *backward force* against the water, even when his hands and arms are stroking out and in. Therefore, swimmers can apply backward force against the water during the majority of their circular stroking patterns by directing their arms and hands diagonally backward while doing so This allows a longer propulsive phase in each competitive stroke than would a straight-backward push of the hands and arms.

The reason the swimmer's hands actually traveled directly back only a short distance while he was exerting backward force is, because the resistance of the water he pushes back against with his limbs is greater than the resistance of the water that is retarding his forward motion. Therefore, during actual swimming, his suspended body will be accelerated forward to a greater extent than his hands travel backward. Stroke *patterns are frequently illustrated in the literature as though a swimmer's hands were moving past his immobile body, but, in reality, his body is actually traveling forward past his hands to a far greater extent. (See figure 8 for an example of a stroke pattern drawn as though the swimmer was immobile in the water.). This type of illustration is useful for teaching swimmers how the hands and arms move in relation to the body. However, it is more useful to illustrate how the body moves in relation to the hands and arms (see figure 2) for purposes of depicting the propulsive effect of a swimmer's limbs..*

How do swimmers exert backward force while their arms are sweeping out and in (and down and up)? They do so by exerting very little force in those lateral and vertical directions. Instead, they maintain a backward-facing orientation with their hands and arms, from the catch onward, so they can use most of their force to press back against the resistance of the water even while they (their hands and arms) are moving in other directions. To reiterate this important point with different words, "Even though the swimmer in figure 2 is sweeping his hands and arms out and in, he is not exerting very much force in those directions. Instead, he maintains a backward orientation with them, (his hands and arms), so he can press back against the resistance of the water, while his hands are moving laterally and vertically. As described earlier, when the backward force he is exerting with his hands and arms is greater than the resistance of the water around his body, it (his body) will be accelerated forward to a greater extent than his hands and arms travel backward.

It should be emphasized, that the backward force he exerts against the resistance of the water will accelerate his body forward *so long as his hands and arms are moving backward to some extent* . Let me also repeat this last statement with other words to be sure you comprehend this significant point. *There must also be a backward component of motion to swimmers' arm strokes, during their circuitous route through the water, or their bodies will not accelerate forward.* Therefore, only that portion of the swimmers hand-path that is shown in red in the drawing in figure 2, will be propulsive.

Support for this explanation of the way swimmers apply propulsive force is evidenced by the fact that they prefer curvilinear to linear stroke patterns and because of CFD research that indicates how they combine the forces of lift and drag to effect propulsion. CFD stands for <u>C</u>omputational <u>F</u>luid <u>D</u>ynamics, a computerized technique that has emerged as an alternative to in-water testing for lift, drag, and propulsive forces. CFD analysis has been used to calculate accurately, the forces water and air produce on ships, automobiles and airplane wings during turbulent fluid flow.

Briefly, with this method, a wire diagram of a swimmer's hand and arm is constructed on a computer and subjected to conditions of turbulent water flow like those encountered during human swimming. Using this procedure, the actual water flow around the swimmers limb can be visualized at various speeds and directions of motion, and the many forces acting on it can be measured while it is simulating changes in direction and while accelerating or decelerating as it moves through the water. A picture of a simulated hand and forearm and the turbulent activity of water it passes through can be seen in figure 3.

Bixler, (2005), using a computerized model of a swimmer's hand and forearm like the one pictured in figure 3, reported that maximum propulsion is possible when they keep their hands facing directly back toward their feet even when

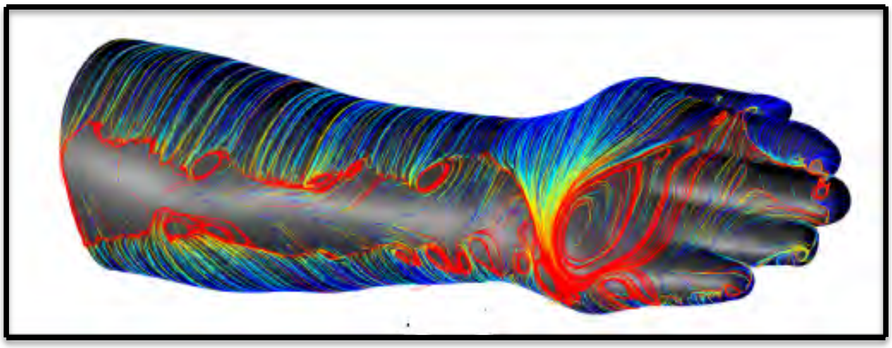

Figure 3. *A computerized wire-diagram of a swimmer's hand and arm showing the turbulent movement of water it displaces. This is similar to the diagrams used in CFD research to both visualize the water flow around a swimmer's hand and arm and calculate the magnitude of various forces when it simulate a swimmer's arm stroking through the water. The simulated hand/arm model was taken from research of the late Barry Bixler. Bixler, B. (2005). Resistance and Propulsion. In: J.A. Stager and D.A. Tanner, (Eds.). Swimming. (pp. 59-101). Oxford, U.K.: Blackwell Scientific Limited Publications.*

they are stroking them (their hands) diagonally through the water. This is one of the reasons swimmers have been reported to use hand angles of attack that are both less than, and greater than 90 degrees during various phases of their underwater arm strokes, (Capparet, 1993). Those angles of attack do not improve the sculling potential of the limb, as some have suggested. They are, most likely, the result of swimmers attempts to maintain a directly backward-facing position with their palms even when their hands and arms are not moving directly backward through the water.

Bixler went on to suggest that maximum hand propulsion in any stroke occurs when the sum of the stroking angle (the angle, from directly forward, at which the swimmer's hand is stroking diagonally back through the water) and the hand angle of attack (the inclination of the hand from a direction that is perpendicular to its direction of motion), equals approximately 95 degrees. An example of how the stroking angle and the angle of attack for a swimmer's hand are measured when it is traveling diagonally backward through the water is displayed in figure 4.

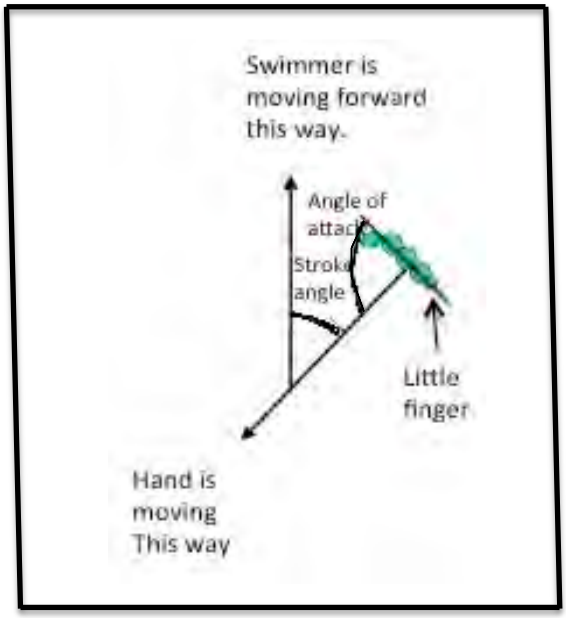

Figure 4. *An example of how the stroking angle and angle of attack of a swimmer's hand are calculated as they stroke through the water during the pull/insweep. Modified from: Riewald, S. & Bixler. 2001. " Computation of lift and drag forces for a model of a swimmer's hand and arm in unsteady flow using computational fluid dynamics." A report presented to the USOC Sport Science & Technology Committee. p. 23.*

The center of mass velocity pattern for Mike Barrowman in figure 5, illustrates what I have just said about the importance of including a backward component of motion in the stroke pattern. *When combined with his underneath stroke pattern it shows clearly that his body does not begin to accelerate forward during the "outsweep" of his arm stroke, until his hands are traveling back, as well as out. Further, it shows that his forward velocity decelerates rapidly once his arms stop moving back as they travel in under his body during the insweep.* The red arrows on the drawing of his stroke pattern, show the points in the pattern where his hands begin moving backward during the outsweep, (where he makes his catch), and stop moving back during the insweep (the release). Corresponding red arrows on his velocity graph indicate that his body accelerates forward at that same point in the outsweep where his hands begin traveling diagonally backward, and that it begins to decelerate at the point in his stroke pattern where his hands begin moving forward during the insweep.

The two photos at the top of the figure show the position of his hands and arms in his stroke cycle where he starts to accelerate (the catch) and decelerate (the release and recovery). The first photo shows his catch point during the outsweep of his arms, and a yellow arrow connects the photo to the point on his graph where his body velocity begins to accelerate forward, during the outsweep. The final photo (on the extreme right of the figure) shows the position of his arms when his body stops accelerating forward. A yellow arrow also connects that photo to the point on his graph where his forward velocity begins to decelerate (the release). You can see, by comparing the photo and velocity graph, that he begins to decelerate when his hands are coming in and up under his body during the insweep.

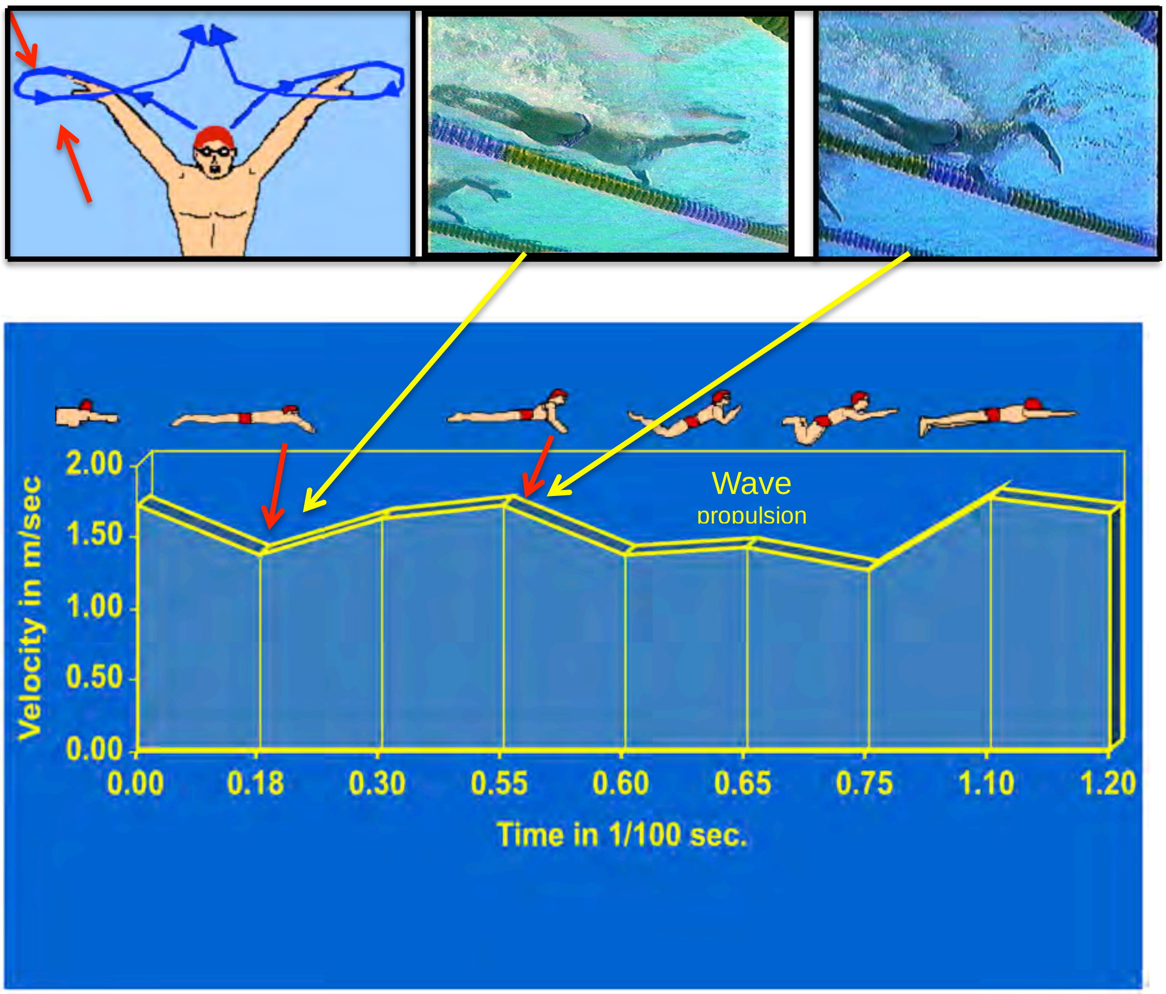

Figure 5. *A forward velocity graph for Olympic Champion and World Record Holder in the 200 m breaststroke, Mike Barrowman. This graph is modified from data in* *Biomechanic Analysis of Champion Swimmers,* *by Capparet, J. and B.S. Rushall, pp. 4.1 and 4.2, with permission.*

This same propulsive pattern is present for other world-class breaststroke swimmers, both male and female, in a publication by Capparet and Rushall (1994), where the velocity graphs and stroke patterns of several 1992 Olympic breaststroke swimmers are available. It is unfortunate that center of mass velocity patterns and stroke patterns are not available for more world-class swimmers in all strokes. There is much to be learned from them.

It may have come as a surprise that Barrowman was releases the water so early during the insweep of his arm stroke. However, what you see here is the rule rather than the exception. Further evidence that swimmers are not propelling themselves forward during the final third of their insweep, is provided in figures 6 and 7. In figure 6, there is an actual in-competition, underneath-view of Kosuke Kitajima, multiple Olympic Champion and former World Record Holder in the 100 and 200 m breaststrokes. The circled areas show him, like Barrowman, releasing the water with his hands early in the insweep. This may not be readily apparent because of the turbulence around his hands. Consequently, I have circled his hands and drawn lines beside each that indicate the extent to which his palms are facing in at this time.

Figure 6. *An underwater photo of Kosuke Kitajima during the insweep of his arms. It should be apparent from the angle of his palms that he is no longer pushing back against the water. Nor is he using his hands like a foil to scull them through the water. Instead his hands are beginning to recover up and forward while slicing through the water thumbs- first.*

You can see that his hands are turned in far too much to be used as effective paddles or hydrofoils. The ideal angle of attack for a paddle would be closer to 90 degrees to produce a significant amount of drag at this time, while the angle of attack for a hand being used as a hydrofoil should be in the neighborhood of 30 to 40 degrees to produce a significant amount of lift. The angle of attack of his hands is much closer to zero, as his hands come in under his body. His hands are on edge, slicing forward (and up) through the water during their in and up motions. Obviously, this position of the hands is much more effective for reducing hand and arm resistance during the recovery than for increasing lift or drag force during the arm stroke. Therefore, his hand angles of attack and the direction they appear to be traveling suggest that the propulsive phase of his arm stroke is over and he is actually recovering his hands and arms from this point onward.

The fallacy of sculling the hands in to gain propulsive force is even more evident in figure 7. It shows a forward velocity graph that was developed, by the author, from videos of U.S. Olympian, John Moffet, at the U.S. Olympic Training Camp in 1984. His forward velocity (the green line in figure 7) demonstrates a large decrease during the final third of his insweep. This occurs at the same time his hands begin to travel forward as can be seen from his underneath stroke pattern. (The corresponding blue arrows on both his velocity graph and stroke pattern show that his loss of velocity coincides with the forward and inward sweep of his hands). The picture on the left shows the position of his arms and hands in the stroke cycle at this same time, and the picture on the right shows their position approximately 0.2 seconds later when his forward velocity has decelerated even more.

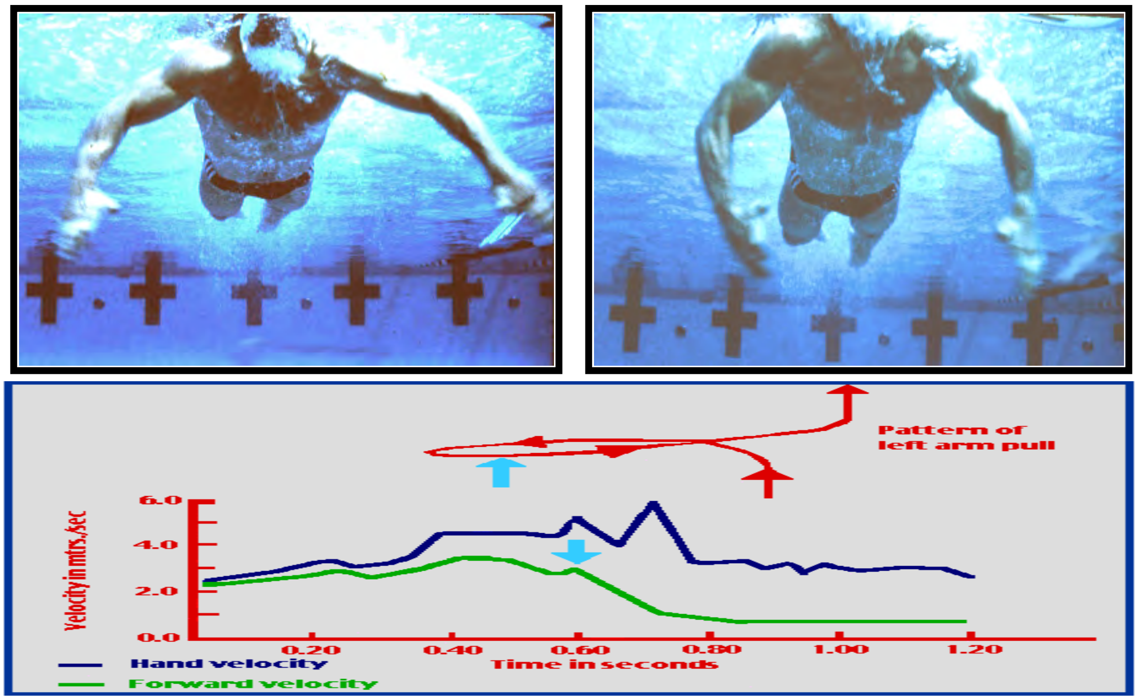

Figure 7. *Forward velocity and hand velocity graphs for Olympian John Moffett together with photos of the final third of his insweep.*

You can see clearly from the photos, that the angle of attack of his hands would also not be very effective for producing lift or drag forces during this time. It is also interesting to note that his hand velocity increases as he sweeps them in. (His hand velocity is represented by the blue line on the graph). This suggests he is trying to apply propulsive force with his hands as they come together under his body. It is obvious, however, that this effort did not increase his forward velocity, but, instead, reduced it even further. The fact that his forward velocity slows as his hands accelerate at this point in the arm stroke, may mean that he was wasting muscular effort trying to increase his forward speed as he sculled his hands in and forward under his body.

The Mechanics of the Breaststroke Arm stroke:

As I've said several times earlier, I believe breaststrokers should also use their hands and arms like paddles during their arm stroke. Additionally, their arms should travel back in a large sideward, shoulder adducting, semicircular, sweep , just as they do when executing the insweep of the other competitive strokes, (see the drawing in figure 8).

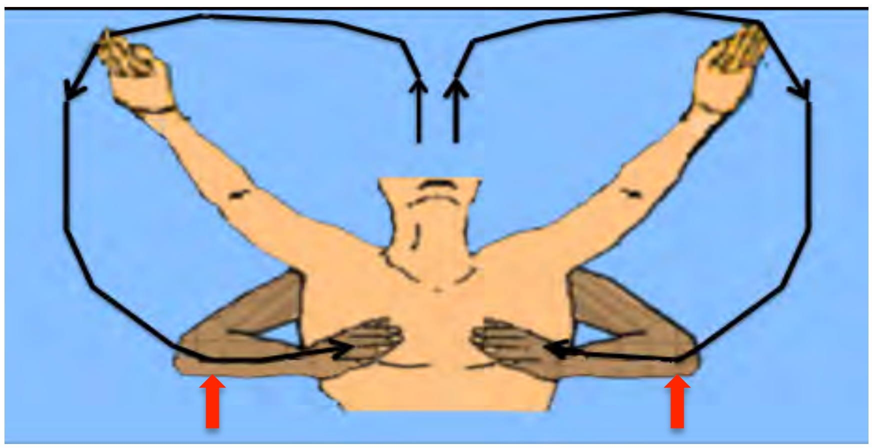

Figure 8. *Shoulder adduction in the breaststroke.*

Having said that, there is one difference between the way a breaststroker does a shoulder-adducting insweep and the way it is performed in the freestyle and butterfly. That difference being that the propulsive phase of the breaststrokers insweep should not continue back until his arms are near his ribs.* In breaststroke, the propulsive phase of the insweep should terminate and the recovery should begin after the swimmer has completed approximately two-thirds of his insweep . That point in the stroke pattern is marked with red arrows in figure 8. It occurs when the swimmers arms have just passed in and back behind his shoulders and start traveling up and forward under his body.

**This statement was made more for effect than accuracy. In the past it may have been accurate to say that most freestyle and butterfly swimmers were bringing their hands in under the midline of their bodies during the pull/ insweep, or, at least, were being taught to do so (in some cases freestylers actually crossed the midline). Backstrokers were also being taught to bring their arms in close to their bodies and their hands up close to the surface during their pull/upsweep. It appears now that many excellent swimmers in these strokes are transitioning from the insweep (upsweep in backstroke) to the next propulsive phase of their arm stroke when their hands are at nearly the same point indicated for breaststrokers, in figure 8. (see the underwater photos of the butterfly and backstroke swimmers in figure 7 of Part I, for the approximate point in those strokes where that transition takes place) .*

Contrary to conventional wisdom, his elbows *should* travel back beyond his shoulders in order to lengthen the propulsive phase of the insweep. This will not delay their recovery if that recovery is performed correctly. That is, by "snapping" the upper arms down and in under the swimmer's body when the propulsive phase of the arm stroke ends. The downward motion of the arms should overcome their backward inertia and change their direction from back to forward, with no hesitation. In addition, it will shoot the swimmer's hands up to the surface rapidly during the time he is recovering his legs, and riding his wave propulsion.

There are at least two possible reasons why breaststroke swimmers should terminate the propulsive phase of the insweep earlier. First, because it is probable that only the first two-thirds of the insweep is propulsive. As you can see from the stroke pattern in figure 8, the swimmer's hands are traveling in and forward, (and up), from that point on. Consequently, it seems reasonable that he should stop applying backward force to the water at this time, and begin recovering his arms and hands up to the surface.

The second reason is that there is no need for breaststrokers to transition from the insweep to another backward propulsive sweep as swimmers do in the other three competitive strokes. In those strokes, the final one-third of the insweep is also not propulsive, but, instead, is used to transition to the upsweep in butterfly and freestyle and the downsweep in backstroke. However, for breaststrokers, there should be no need to continue the insweep when it is no longer propulsive, because it will not be followed by another propulsive sweep. Consequently, it makes sense to transition into the recovery phase of their arm stroke when their forward velocity begins to decelerate during the insweep.

I believe the arm stroke should be performed in the manner shown by the series of photos in figure 9 . They display the underwater arm stroke of Anita Nall, former World Record Holder in the 200 m Breaststroke; a record she set at age 13.

Her arm stroke consists of an outsweep, insweep, and arm recovery. The outsweep begins as her arms are nearing full extension in front (see the photo at the top left of figure 9). The outsweep should be a stretch forward with her arms as they travel out. Her elbows should flex gradually as she stretches her arms out and forward, until they, (her arms), are somewhere outside her shoulders and the palms of her hands, and the undersides of her forearms and upper arms are facing back against the water (see photo on upper right in figure 9). That is where the catch takes place.

From the catch, she should accelerate her arms back with a sideward, semi-circular, shoulder-adducting insweep, like the one I described earlier, until she has completed approximately two-thirds of it and her hands are coming under her shoulders (see photo on lower left in figure 9). The sweep should be performed with elbows above the hands and with the arms pressing horizontally backward (see figure 1 for a side view of the breaststroke insweep). Swimmers should make the largest possible paddle with the undersides of their arms and the palms of their hands as they push back against the resistance of the water with them.

The propulsive phase of Anita's insweep ends at approximately the point in her arm stroke shown in the bottom left photo. From there she should snap her elbows down and in under her body, and her hands up to the surface directly in front of her face. Then, she should extend her arms forward in a streamlined position, either just under or just over the water, while she returns her head and trunk to the water.

Figure 9. *The breaststroke arm stroke of Anita Nall. Photo 1, top left, shows her beginning the outsweep. Photo 2, top right, shows her at the catch position. Photo 3, bottom left, shows her completing the insweep and in photo 4, bottom right, she has completed her recovery and is ready to begin another arm stroke.*

The point in the underwater arm stroke when breaststroke swimmers should begin lifting their heads toward the surface for a breath continues to be a mystery to me. Most begin to lift their head and shoulders for a breath during the outsweep of their arms, starting just before or just after their catch as Anita is doing in the top right photo of figure 9. This means that part of the force from her arm stroke is probably used to lift her head and trunk up and out of the water. As a result, some of the backward force of the arm stroke will be replaced with downward force that is not useful for propulsion.

It seems that breaststroke swimmers could gain more velocity and distance per stroke by keeping their faces and bodies underwater and streamlined for as much of the propulsive phase of their underwater arm strokes, as possible. However, because so few breaststrokers swim this way, I'm not sure if I am advocating a technique that might be detrimental to their performance. Nevertheless, I am suggesting it might be more effective if breaststroke swimmers, delayed their head lift until the start of their arm recovery. Perhaps they feel delaying their head lift will not give them enough time to inhale. Nevertheless, I think breaststroke swimmers should be able get their head elevated above the water in time for an adequate inhalation after the propulsive phase of their armstroke if they use their upper arms to help elevate their head and shoulders above the surface of the water during their recovery. They may be able to do this by pushing down with their upper arms as they start the recovery. This action is illustrated by the two photos in figure 10.

In these photos, the swimmer changes the direction of his arms from back to forward after they pass his shoulders by pressing down and in with his upper arms, while slicing his hands and forearms up to the surface. Because this down and in motion is not propulsive, swimmers should exert only enough force with their upper arms, to raise their head and shoulders above the surface. At the same time, they should lead the recovery with their hands on edge (also see photos of Kitajima in figure 6), sweeping them in and up, with thumbs leading, so they (their hands) slip through the water smoothly and easily. They should not try to extend their arms and hands forward until they (their arms and hands) reach the surface. Extending their arms forward underwater will produce considerable drag and decelerate their forward speed even more than they are already decelerating during this time. Once their arms reach the surface, they should extend them forward, either, over, or on the surface of the water, holding them close together in a streamlined position until they are nearly extended.

The insweep and arm recovery I just described should be more effective for three reasons. First, as indicated earlier, swimmers' bodies would remain streamlined during more of the propulsive phase of their arm stroke, and this should provide greater distance per stroke and faster forward velocity. Second, they should still be able to recover their hands and arms quickly forward by rounding-off their change of direction from backward to forward as they press their upper arms down. Third, recovering in this way should also allow them to press back further with their arms in the propulsive phase of their arm stroke and still get their head above the surface quickly enough to get an adequate inhalation during the last part of their arm recovery.

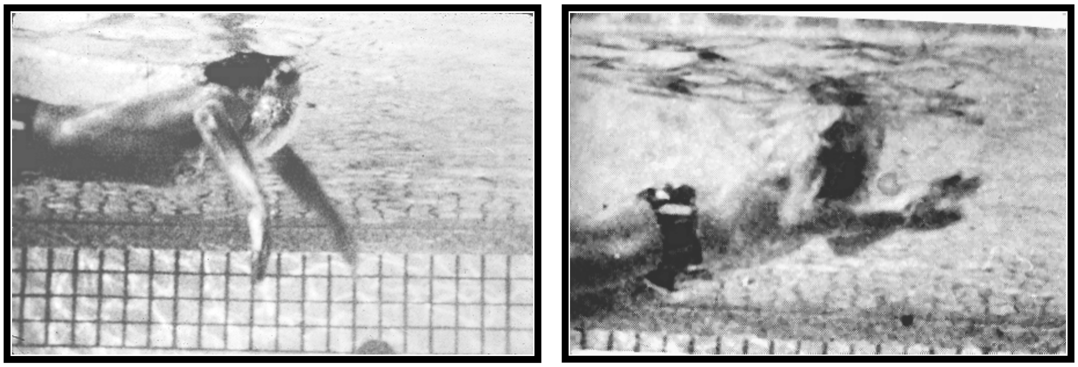

Figure 10. *A suggestion for the breaststroke arm recovery. The photo on the left shows the swimmer nearing completion of the propulsive phase of his underwater arm stroke. From there he should press his upper arms down and in under his body until they reach a position similar to the one in the photo on the right. The movement of his elbows should aid in lifting his head and trunk above the surface where he can take a breath, while at the same "shooting" his hands up to the surface so there is no hesitation between the end of the propulsive phase of his arm stroke and the start of his arm recovery.*

The mystery I spoke of earlier is, considering the possible benefits of better streamlining and greater velocity during the propulsive phase of the arm stroke, the vast majority of world-class breaststroke swimmers continue to lift their heads toward the surface during their arm pull. Consequently, I'm not sure if this early lifting of the head is a technical error, or if I am suggesting a technique that would be detrimental to their performance.

Perhaps, as I mentioned earlier, they must get their heads to the surface earlier to provide time for an adequate inhalation of air. Or they may be trying to get their trunks out of the water sufficiently to gain some wave propulsion while they recover their arms. On the other hand, it may be that many have been taught, or intuitively feel, they should lift their head and trunk out of the water as they start to sweep their arms out. I will leave this mystery for those who are presently coaching to solve.

Let me finish this paper by showing a video of an Olympic Champion's arm stroke. The underwater video (see attached), is taken from Daniel Gyurta's Gold Medal 200m breaststroke swim at the London Olympic Games. Please double click on it for viewing. It would also be wise to turn your sound off.

Take notice of his use of shoulder adduction during the arm stroke. In other words, notice the way his arms sweep horizontally back, in a sideward, semi-circle after the catch. They do not scull down and in. Notice also, where he seems to release pressure on the water and start his recovery; after the first two-thirds of his insweep, when the palms of his hands are turning in and up as they sweep under his body.

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