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ENERGY DISPERSAL IN COMPETITIVE SWIMMING

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This treatise covers the dispersal of energy from the active components of swimming movements. There are three forms of resistance (surface, frontal, and wave resistance) that have been discussed elsewhere (Rushall, Sprigings, Holt, & Cappaert, no date) and will not be repeated here. Only when the active and passive influences on energy production in swimming are considered will a close to complete picture of the true costs of swimming strokes be understood.

The Transfer of Energy in Swimming Activities

Energy is consumed by events that happen 1) internal to the organism (i.e., muscles moving against internal pressures, resistances, and forces), and 2) external to the organism (i.e., muscles moving body segments to act on the environment). From a coaching perspective, little can be done about the energy cost of internal movements but much can be done about the energy cost of external movements.

In elite competitions, filtration systems are supposed to be non-functional during races rendering the water in a competitive swimming pool to be largely without motion. If a pool's filtration system were kept running, movement of the fluid would be minor and in deep facilities, a considerable distance away from the surface. For water to move in quiescent conditions, energy has to come from somewhere. In competitive swimming races, usually when pool water is set in motion, the energy that causes the motion normally comes from swimmers.

Occasionally, it is possible to view several swimmers and determine that one or more are causing more water movement than others. Some cues are the amount of white water surrounding and following the swimmer, the amount of splash, and more importantly, the size of the waves that flow laterally to the lane ropes. In that last phenomenon, the higher the waves, the greater is the amount of energy imparted from the swimmer to the water. Since swimmers take a finite amount of energy into races, the greater the amount of energy used to set water in motion, the less energy there will be to use for propulsion.

It is in a swimmer's best competitive interest to scythe through the water disturbing (i.e., transferring energy) the water as little as possible. There are a variety of forms of energy production that reduce a swimmer's proficiency for moving through water. Some major causes are discussed below.

The Misdirection of Energy in Swimming Strokes

In its simplest description, a swimmer in a race should produce forces that result in direct forward propulsion. Any movement that requires forces to be developed in the vertical or lateral planes most likely will be wasted energy. Since the human body and its limbs are not designed to progress through water, some lateral and vertical movements are needed in body segments to develop the most efficient form of resultant force production that propels a swimmer in a direct line down a pool lane. The proportion of propulsive force developed in the total movement will depend on the stroke being swum, the pattern of the stroke movement, and the stage of the propulsive phase that is considered.

A problem is created when swimmers exaggerate vertical and lateral movement components beyond the minimally needed amount. This "waste" of energy is seen in many forms. Some common examples follow.

- In butterfly, trying to "fly over the water". Forces have to be created to elevate the body upward to an unnecessary degree.
- In breaststroke, recovering the hands forward over the water "to create less resistance" is a myth because the energy saved in no way matches the energy expended to create and compensate the movement itself. As well, breathing unnecessarily high is wasted effort. The amount of oxygen inhaled can be the same one inch above the water surface as it is nine inches above the surface. A "high breath" requires much more energy than a "low breath".
- In crawl stroke, sliding the hands forward underwater at the end of the recovery requires energy not only to extend the arm but also to cause water to part to facilitate the stretch. Further energy-sapping forces in performing this type of recovery are surface and frontal resistance. Another costly crawl stroke movement is recovering with a sweeping straight arm. The energy required to generate the momentum involved with a ballistic recovery movement and its long lever length is greater than that required to perform a preferable bent arm more horizontal recovery.
- In backstroke, entering the arms/hands behind the head requires energy to push water to the sides before the hand/forearm/upper-arms are positioned where beneficial propulsive forces can be developed. This unnecessary movement not only costs energy but it also requires counterbalancing somewhere else in the swimming action, which requires further energy expenditure.

These examples are complicated further by two phenomena. One involves the transfer of further energy to the water as a result of unnecessary but associated lateral and/or vertical movement components (normally in the arms) and the other is Newton's Third Law of motion.

When a swimmer lifts some part of the body out of the water, as in the two examples stated above in breaststroke, there is a consequence to those actions. When the hands recover up and over the water they have to crash back into the water to be repositioned to pull. That re-entry causes water to move quite markedly. The energy that causes that fluid motion comes from the swimmer. A recovery of this form therefore, has a double cost: 1) excessive energy is used to produce the vertical and horizontal force components to get the arms over the water, and 2) excessive energy loss occurs as a considerable volume of water is set in motion through re-entering toward the end of the recovery. A similar phenomenon also happens with high-breathing. The energy cost is that required to elevate the swimmer plus that which results from the forced movement of water when the swimmer returns to some underwater posture. [It is not uncommon to see a large plume of water thrust forward and upward during the return in breaststroke swimming, indicating an energy-demanding action that is contrary to forward movement.] The more these two movements are exaggerated, the greater will be the energy loss from the swimmer which in turn reduces the effort capacity of the swimmer for use in a race.

The Center of Buoyancy is the one point in a swimmer about which all forces are equalized. It can be considered to have equal portions on either side of that point. When a force is created on one side of the Center of Buoyancy, it often must be matched by an equal and opposite force on the other side of the Center. Newton's Third Law of motion happens in every movement performed by an organism. Consequently, when one part of a swimmer is raised, as with the breaststroke recovery and high-breathing actions, often another part of the body on the other side of the Center of Buoyancy does the equal and opposite movement, that is something sinks.

For example, when the upper body and head are raised in a breaststroke breathing action, the hips and legs drop lower in the water (see Figure 1). Since the hips and legs were not in that position originally, their movement to the new position requires energy for the movement itself plus energy to cause the water to part in the repositioning. This gives rise to energy being used to perform one unnecessarily exaggerated movement plus a consequential energy cost to accommodate the opposite action in accordance with Newton's Third Law.

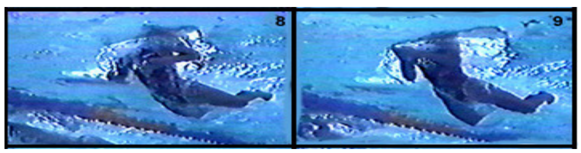

Figure 1. Samantha Reilly breathing in breaststroke with a high body action. Her hips and thighs have dropped noticeably away from the surface as a manifestation of Newton's Third Law of motion.

Unnecessary movements do not have to occur out of the water. Using the same breaststroke swimmer, her underwater dive with the head and shoulders after the high breath also causes her hips to rise (see Figure 2). Not only does that disrupt streamline, but a large volume of water has to be displaced by the upward torso, hips, and leg movements. The total energy cost is very large and considerably diminishes the swimmer's capacity to energize a performance.

Figure 2. Samantha Reilly "diving" down after breathing in breaststroke. Her hips and thighs rise noticeably as a manifestation of Newton's Third Law of motion.

In crawl stroke, there are coaches who are teaching swimmers to recover with straight arms. To achieve a long-arm recovery, not only do the hand and forearm push too far back underwater (creating much more resistance than propulsion), but during the recovery the height of the center of mass of the arm is greater and often laterally further from the swimmer. That produces a reaction underwater in the counterbalancing arm that forces a longer, deeper, and wider arm movement, features that diminish direct forces that could be developed to propel a swimmer forward. Figure 3 illustrates the World Champion 1,500 m swimmer, Lotte Friis, executing a right arm underwater counterbalancing action to a straight left arm recovery.

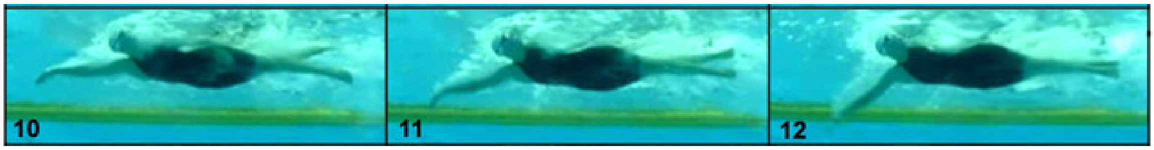

Figure 3. Lotte Friis exhibiting a long deep right arm movement that counterbalances her straight left arm recovery (Newton's Third Law in action).

When swimmers are taught to exaggerate movements that do not directly affect propulsion, the energy cost results in a loss of performance potential. No matter what form of physical training is employed, that loss can never be recovered. Many current swimming technique fads feature energy-sapping movements that move water, often causing counterbalancing actions in other parts of the body which also require excessive energy, and lead one to conclude that swimming performances are nowhere near where they could/should be in terms of movement proficiency.

Balanced Force Production. Unnecessary swimming actions are not always counterbalanced across the Center of Buoyancy. It is possible to develop forces within techniques which support unnecessary movements but do not invoke a postural manifestation of Newton's Third Law as described above. Instead of a pulling action being directly backward in its resultant force, some lateral or vertical force component can be developed within an arm-pull to accommodate energy-sapping movements. Some of these compromising movements cannot be avoided. Figure 4 shows Petria Thomas sculling outward with her hands and inclining her arms to produce a sufficiently vertical force component force to reposition her head and shoulders in butterfly. By modifying the arm-pull force production to alter the position of the head and shoulders, the hip and leg streamline is maintained. If this accommodation with the pull were not made, the swimmer's hips and legs would have risen, in a manner similar to that illustrated with Samantha Reilly's breaststroke.

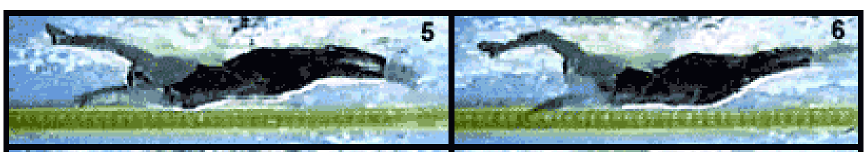

Figure 4. Petria Thomas using her arms to redirect her head and shoulders in butterfly rather than for propulsion.

Compromising the arm pull is a common way of counterbalancing undesirable features of swimming techniques, particularly breathing. While that might result in a swimmer maintaining body and leg streamline, unfortunately it reduces the amount of power that can be developed for propulsion. No amount of strength training will ever make-up for the gap in a compromised propulsive arm movement. While it may be necessary to include in some part of a propulsive pull some modification of directness to support a movement characteristic, a coaching endeavor should be to modify those non-propulsive actions so they minimize the degradation of the propulsive pull.

A coach and swimmer have to consider the total energy cost of swimming actions. When a swimmer wastes a considerable amount of energy moving water and performing unnecessary movements, no amount of physical conditioning will develop the swimmer to a comparable performance potential of another swimmer who performs with more energy-efficient stroke mechanics. Squandering energy in inefficient stroke characteristics is energy lost and a handicap for the swimmer in which it occurs. When one considers the number of top swimmers who perform in very much less than proficient manners, the careful management of energy expenditure is one coaching ploy that could bring lesser talented swimmers up to the level of more talented individuals in the sport.

Implication

Very often when coaching technique, coaches only consider what is to be done in isolation from what would occur in the swimmer's total reaction. That partial focus often leads to a change in a swimmer's technique (an "improvement") but also the development of another "fault" as a consequence of the singular partial movement focus. It is necessary to change that instructional shortcoming. Before coaching a swimmer to change an action, careful consideration of the following should be entertained before embarking on the change.

- What are the gross counterbalancing or reactional actions resulting from the change that will occur elsewhere in the swimmer?
- Will propulsive force production be compromised by altering the arm actions to produce counterbalancing or reactional non-propulsive force components?
- Will the change increase or decrease the overall energy cost of the swimming action?

If any of the above questions have negative implications, the introduction of the change should be re-evaluated.

References

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