The Technique of the Eggbeater Kick

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Eggbeater Kick

An important skill in synchronized swimming and water polo, that is used by the players to keep them afloat in an upright position while performing other skills. The skill consists of alternating circular movements of the legs that produce an upward force by the water on the swimmer in order to keep the swimmer afloat in a vertical position. The legs appear to move in a circular pattern, almost like alternating circumduction of the hips accompanied by knee flexion/extension and medial to lateral rotation. The legs move in alternate circular directions during the kick- the right leg moves counterclockwise and the left leg moves clockwise (Sanders 2005). The path of the feet traces an elongated oval during the kick (Figure 7). When one leg is in the recovery phase, the other leg is in the power phase. All the joints of the lower limb are active during the eggbeater kick: the hips, knees, ankles and the subtalar joints of the foot. The joint movements increase in linear velocity from proximal to distal joints, with the fastest linear movements occurring in the foot. The faster the movements of the feet, the greater the propulsive forces on the swimmer. It has been reported that the height maintained in the eggbeater kick is strongly related to foot speed (Sanders 2005).

Hydrodynamic Lift

The main force that keeps the swimmer suspended in the water while performing other skills is hydrodynamic lift force, which is caused by the flow of water over the foot and leg of the athlete. Daniel Bernoulli developed a law known as the Bernoulli principle, which states that as the velocity of a fluid increases the pressure exerted by that fluid decreases (Colwin 2002). When a foil, or in the case of eggbeater, the foot is moved through a water medium a pressure gradient is created on either side of the foot. If the flow of fluid is faster over the top of the foot due to the airfoil shape, then a low-pressure area is created. If a lower pressure system exists above the hand, and a higher-pressure system is located below the hand, the hand will be pulled upward into the area of decreased pressure, this is referred to as a “lift” force (McCabe and Sanders 2005)(Figure 1).

By maintaining a rigid leg segment connecting the hip and trunk any lift forces applied upward on the lower leg and foot will be transferred to the rest of the body. This will help the body to be suspended or lifted in the water. In the eggbeater kick producing maximal amounts of lift force by moving the lower legs and feet in optimal positions are one of the primary concerns of every coach. However, this is not the only source of forces to keep the athlete supported in the eggbeater, as the lift forces are limited by the following factors: a) the shape of the foot and lower leg need to be that of an asymmetrical wing, and the lower leg is not a lifting surface b) an intact boundary layer is essential for lift forces to be generated, but the boundary layer separates from the foot and c) the surface area of the foot is not large enough nor curved enough to produce the necessary lift (McCabe and Sanders 2005).

Propulsive Drag Forces

Propulsion through the water in swimming occurs from both lift forces and drag forces. Drag forces are always opposite to the direction of force application, so if the hand pushes the water backward the drag forces act to propel the body forward (Kreighbaum and Barthels 1996). This is the principle used in using a paddle to propel a canoe- the paddle pushes the water backward and the reaction force from the water pushes the canoe forward. Drag forces occur as the athlete pushes down on the water, the water pushes back up on the athlete helping in support. During the eggbeater when the legs push downwards on the water, the water pushes upwards on the leg and help to suspend the athlete in the water. When the lower leg and foot are flat and facing the bottom of the pool and then push downward on the water (Figure 7, 1-3), the water pushes up on the leg and foot and helps to support the athlete. The more the hip is medially rotated at the end of recovery the greater the surface area of the lower leg and foot facing downward and the greater the drag forces produced by the leg in the power stroke. A forceful downward and forward drive by the leg and foot will increase the propulsive drag forces.

If has been suggested that as a fluid moves around a foil the fluid is accelerated downward, and that force is directly proportional to the acceleration of the fluid. The force accelerating the fluid downward must be accompanied by an equal and opposite force (Newton/s third law) pushing the airfoil upward (Sprigings and Koehler 1990). It is likely that propulsion in the eggbeater is from a combination of both lift and drag components, as well as other possibilities such as Archimedes' screw, a simple mechanical device believed to have been invented by Archimedes in the 3rd century B.C. It consists of a cylinder inside of which a continuous screw, extending the length of the cylinder, forms a spiral chamber. By placing the lower end in water and revolving the screw, water is raised to the top. The legs in the eggbeater kick resemble the rotational motion of Archimedes' screw, and this motion may cause the water around the athlete to move upward in a circular pathway and provide some lift force to the swimmer as a result.

Gravity and Buoyancy Force

Gravity is a constant force pulling downward on the mass of all bodies toward the center of the earth. Gravity's pull will cause an object or person to sink into the water because water is a fluid that can flow with pressure. A person in the water is partially held up by the buoyancy force, which is the weight of the displaced water. In a floating person the gravitational force is equal to the buoyant force; to increase height above floating levels swimmers must create a lift force to compensate for the buoyant force decreasing with height (Berg 2004). A submerged body will displace a volume of water, and the body is buoyed up with a force equal to the weight of the displaced water. The greater the body volume of the submerged athlete, the greater the upward buoyant force that is acting to support the athlete in the water. If the weight of an object is less than the weight of an equal volume of water the object will float, partly in air, partly submerged (Hall 1985). A person with a higher fat content in the body will displace a greater volume of water and will experience a greater buoyancy force. This athlete may float on the top of the water when in a prone position.

The athlete performing the eggbeater does not have to produce the same amount of upward force as required to support the body on land, but only the amount of upward force to supplement the buoyant force already being supplied by the water. This upward force must counteract the downward force of the body weight of the athlete that is pulling the athlete down toward the bottom of the pool. A study of the vertical force exerted during the eggbeater kick in water polo concluded that the vertical force of the kick ranged from 60 to 112 N force (Yanagi, Amano et al. 1995). For an athlete with a weight of 600 N the eggbeater contributes from 10-20% of the upward force required to balance the body weight.

Eggbeater Technique

Body Position

The body position is vertical from the head to the hips. The head is erect and above the surface of the water. The upper body is held in an erect sitting position with perfect posture: the neck extended, chin up, back flat, and shoulders in neutral position. The ears, shoulders and hips are in alignment and the head is held high (Berg 2004). The water line should be no higher than mid-shoulder when sculling and kicking, and just below the shoulders when performing above water arm movements in order to minimize the splashing.

FIGURE 1 : Above water view . FIGURE 2 : Below water view

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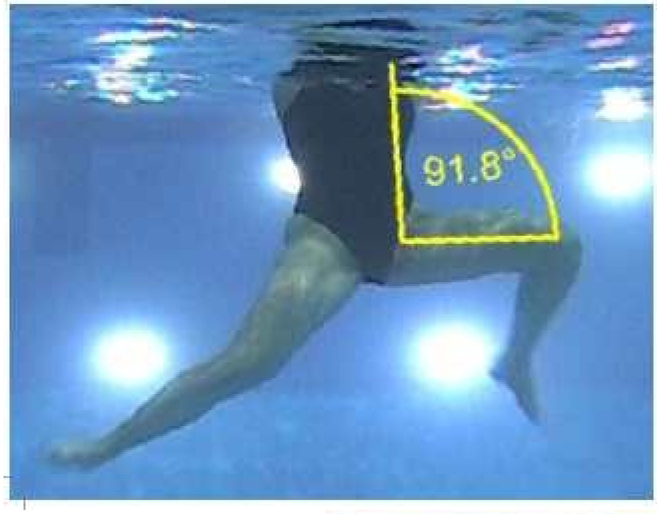
Kicking Action

Swimmer uses an alternating rotating kick to maintain body height and position. The hips start in a position close to 80 degrees of flexion and 90 degrees of abduction, with close to 30 degrees of lateral rotation. The knee is flexed close to 15 degrees and laterally rotated at the start of the kick. During the kick, the hips and knees are extended, adducted and medially rotated to produce power in the stroke.



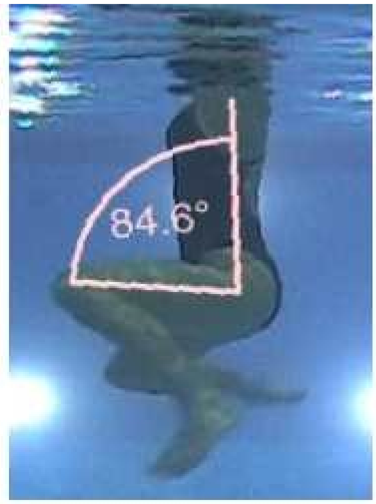


FIGURE 3 : Hip abduction . FIGURE 4 : Hip flexion . FIGURE 5 : Knee flexion

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Propulsion occurs due to hydrodynamic lift forces as well as drag forces that are created by the rapid downward and inward movements of the foot and leg during the stroke. Propulsion is gained from the water by the inwards and downward movements of the lower legs and feet that are moving alternately. When one knee is flexed in recovery the other is extended during the drive phase. The hips are also moved from flexion and adduction during recovery to extension and abduction during the propulsive phase. Some sources (Berg 2004) have suggested that the thighs remain stationary and parallel to the surface during the kick, but this has been proven to be untrue in all of the athletes in this sample. As the lower legs and feet are driven downward, inward and forward towards the midline, the water passes faster over the top of the foot and leg which acts like an airfoil. An important consideration in the eggbeater is the pitch angles of the feet, which should be small and positive (Sanders 2005). At the beginning of the power phase, the knee is maximally flexed, the ankle is dorsiflexed and the foot is in eversion to attain the optimal pitch angle of the foot for the inward, forward motion of the foot. As the foot approaches the lowest position, the ankle is plantarflexed and the foot is moved into inversion to maintain the correct pitch angle relative to the flow (Fig 7, 1-3).

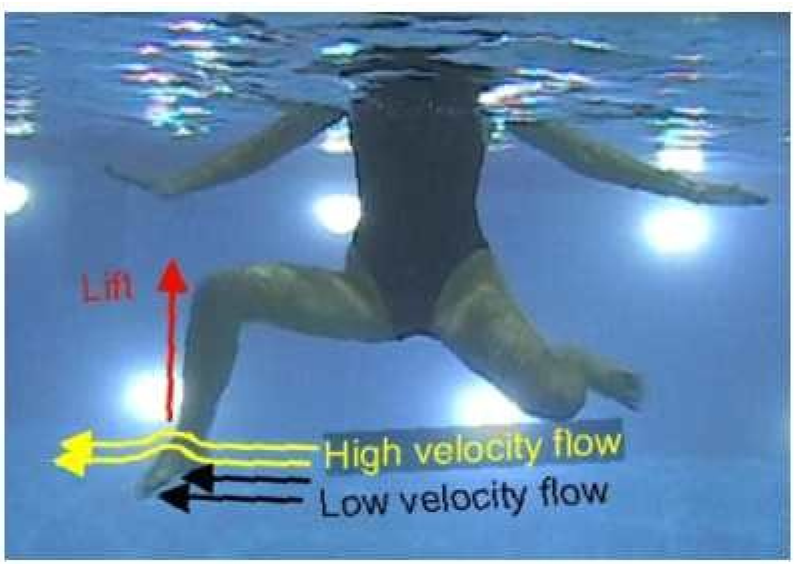

FIGURE 6 : Fluid flow over the top of the foot

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This high velocity flow will produce a lift force component on the top of the foot. This lift force points upwards and inwards and will act upwards to keep the swimmer suspended in the water. The amount of lift is dependent on the angle of the foot, the speed of the foot (Hall 1985), and the range of motion of the foot during the stroke (Sanders 2005). More lift and greater force can be generated when the legs are moved sideways, downward and forward faster to produce additional force to keep the swimmer higher in the water (Sanders 1999). The range of motion of the hip and knee will also determine the speed of the foot, as a greater range of motion over the same time will produce a faster foot speed. The legs should be moved faster, with a more optimal angle of pitch and with a greater range of motion to increase the upward force.
Movement of the feet upward and downward during the eggbeater can produce some drag forces when pushing downward, but these forces are reversed when the feet are again brought upwards. The key to the good eggbeater is the horizontal motions of the foot and keeping the foot in a favorable orientation to the flow to produce lift. This is accomplished by appropriate movements of the hips, knees and ankles (Sanders 1999).

The major force producing portion of the stroke occurs when the foot is brought down, forward and inward while the knee and hip are extending. The foot moves from a high position with the foot near the back of the thigh close to the buttocks to a low position with the knee extended and the foot almost directly below the hip. The foot also starts with a position with the foot behind the buttocks and ends in a position with the toes well in front of the trunk. The movements involved start from the position in which the hips are flexed 90 degrees or more and the hips are abducted 90 degrees as well; the hips are also medially rotated so the toes are pointed outwards and the foot is everted.

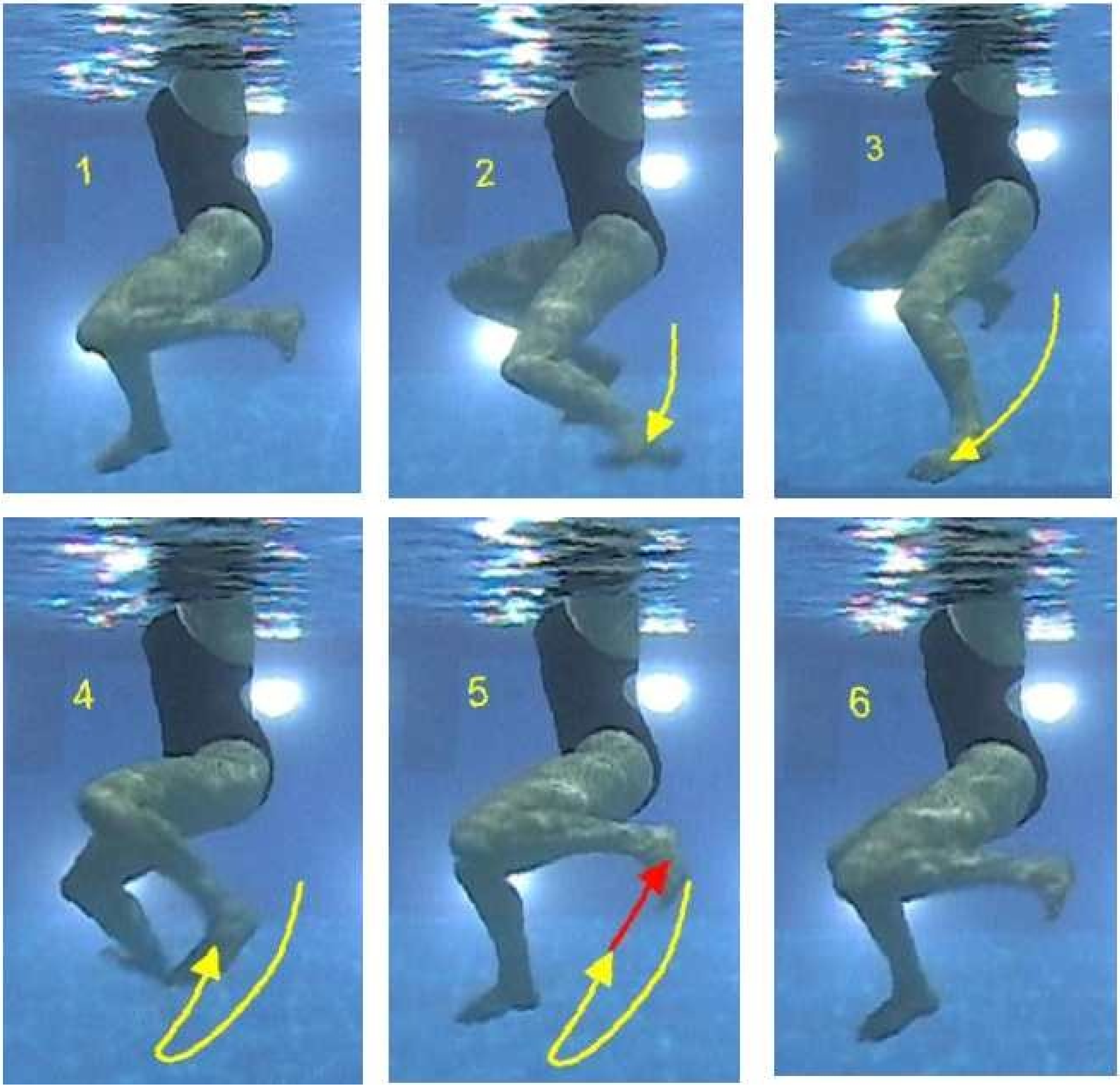

FIGURE 7 : Excursion of foot from highest to lowest point of stroke and back to the beginning of the next force producing phase.

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The knees are flexed up to 20 degrees and the lower leg is also laterally rotated. The foot starts in a high position almost touching the back of the thigh during maximal knee flexion; and finishes in a low position almost under the hip with the knee almost extended. This vertical excursion of the foot may be related to the amount of lift force produced during the stroke --dependent on both the distance and speed of the movement. It has been suggested that better performers use more anterioposterior movements of the foot (Figure 7), while poorer performers use more up and down movements of the feet (Sanders 2005).

As the power stroke starts the hips are adducted, extended and medially rotated; the movement of the thigh occurs first. The total range of motion of the thigh at the hip joint is only about 45 degrees of extension, but the key movements are the medial to lateral hip rotation that brings the foot in close to the midline. The knees are also extended and medially rotated and the feet moved towards inversion. This rapid movement of the lower leg and foot medially and inferiorly causes water to flow at a higher speed over the top of the foot than the sole, and a lift force is created that helps to keep the swimmer suspended.

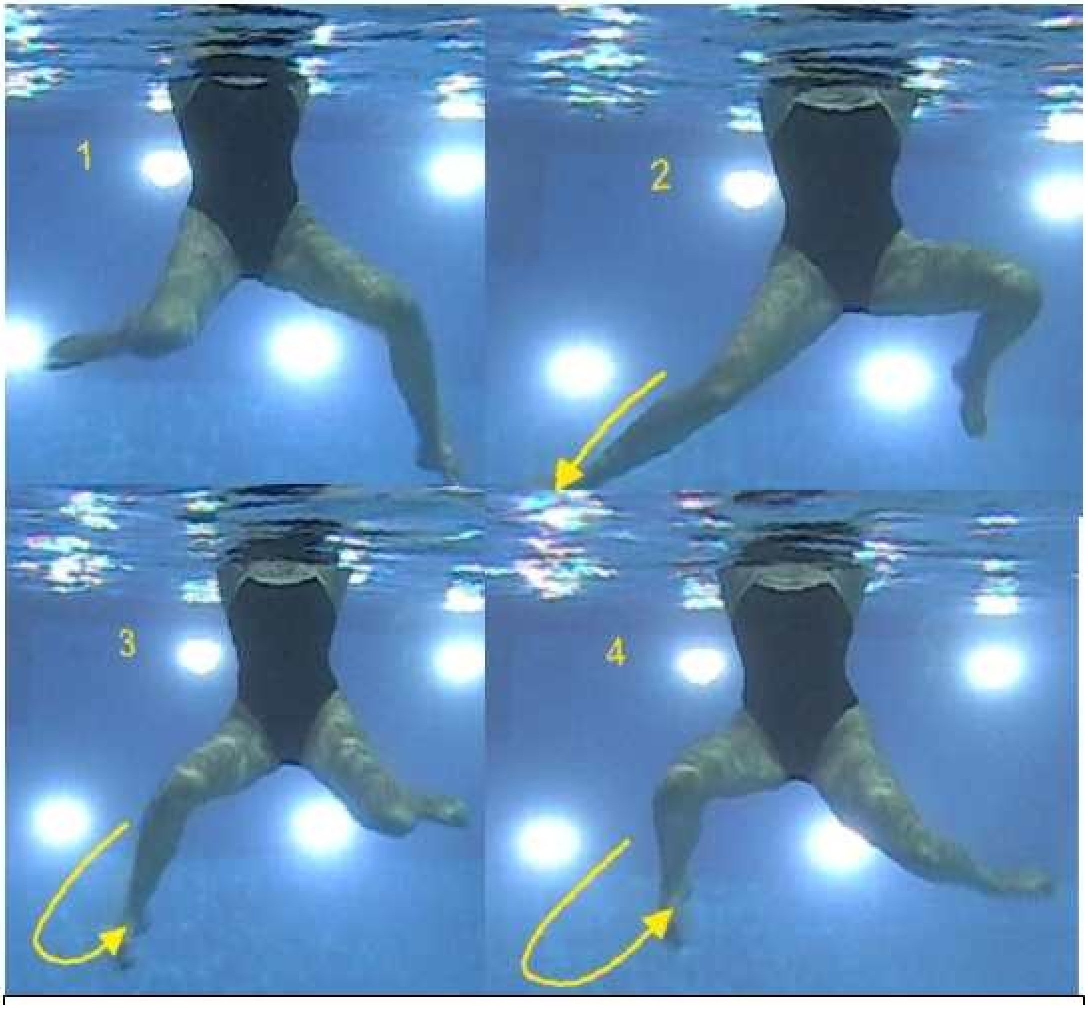

FIGURE .8: Frames 1-4 show the path of the power stroke

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When the power stroke is over, the hip has been extended, adducted and laterally rotated; while the knee has been extended, adducted and medially rotated; and the foot has moved from eversion to inversion. Recovery consists of hip flexion, medial rotation and abduction; and knee flexion and lateral rotation to place the leg back into the power position; along with ankle dorsiflexion and subtalar eversion to cock the foot for the power phase. The trunk is held erect and the arms are often out of the water to remove the effects of sculling on the eggbeater kick.

Skill in the eggbeater is likely related to the range of motion occurring in the legs and the speed of movement of the lower leg and foot in the power phase. The time for one complete cycle of the legs from the high point of the foot to the high point of the foot again is between .5 sec and .65 sec. Less skilled athletes will tend to have a smaller range of motion of the hips and knees and slower foot motion during the stroke. Less skilled athletes also have less range of lateral rotation of the hip and knee.

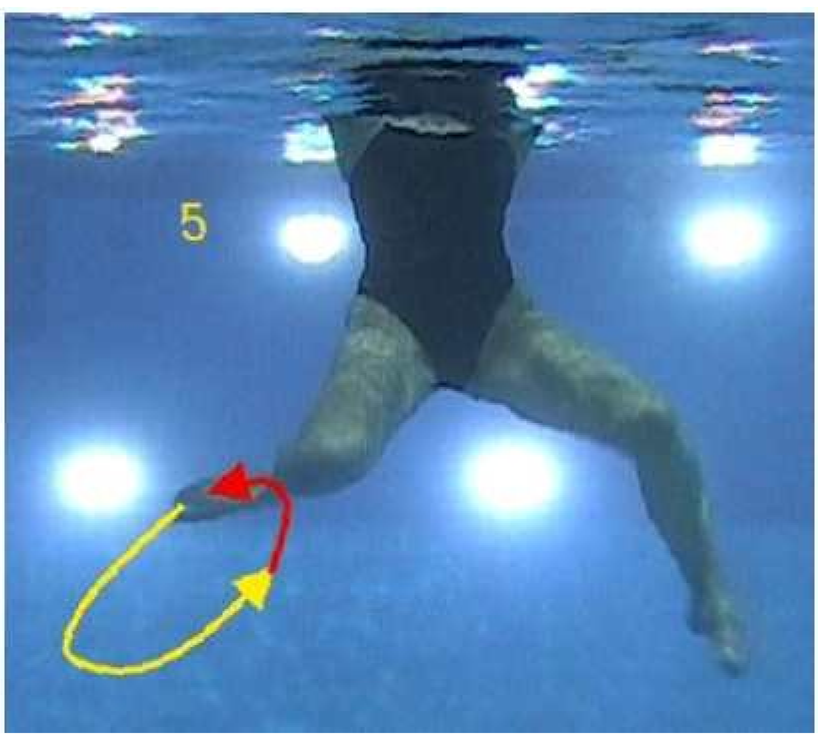

FIGURE 9 : The red arrow is the path of foot recovery

The key to the skilled eggbeater is the angle of the foot and lower leg during the power phase of the stroke. The foot must be dorsiflexed and the ankle everted to start the stroke, to provide a large surface area for the foil created by the foot. As the foot is brought down and in, the foot is plantarflexed and everted to improve the airfoil shape of the foot. The shape of the foot must be carefully controlled by the swimmer to ensure that the airfoil shape is maintained during the power portion of the stroke. This position may be altered by excessive plantarflexion of the foot during the stroke, which would decrease the effectiveness of the foot as a foil.

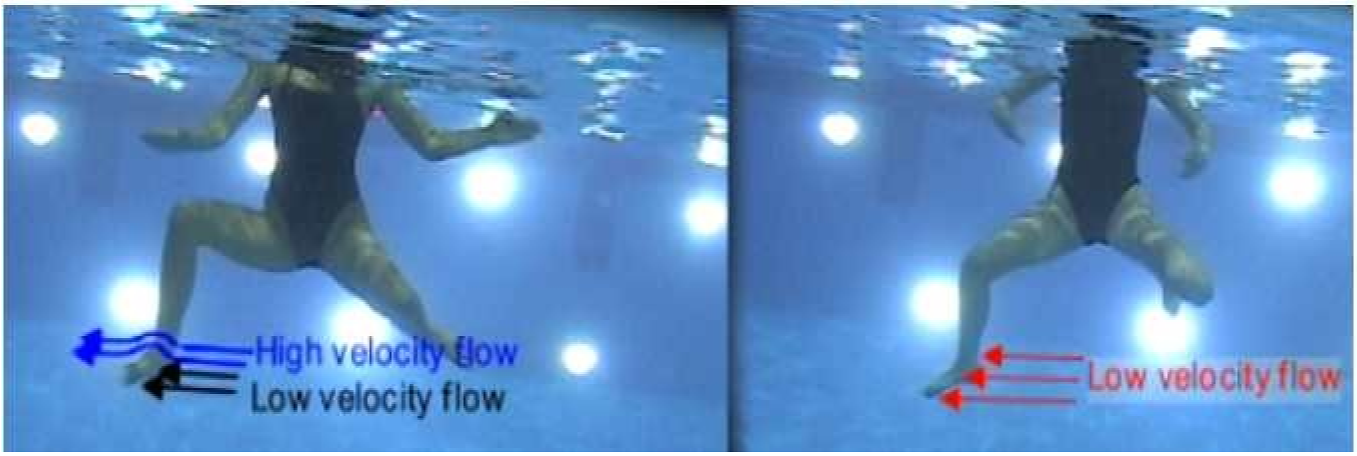

FIGURE 10 : The athlete on the left demonstrates a good foil, while the athlete on the right demonstrates a poor foil

It has been suggested that performance is maximized in players that scull with their feet with large horizontal components rather than merely pushing downward. Although pushing downward can generate force, much of this advantage would be lost when the foot is pushed upward to begin the next cycle (Sanders 1999).

Athletes often want to rise further out of the water using the eggbeater, as seen in the water polo shot or a boost in synchronized swimming. This additional height is attained by the use of trunk extension and rapid knee extension of each of the legs in rapid succession (Sanders 1999). This rapid knee extension allows the athlete to maintain higher foot speed and apply greater forces to the water.

FIGURE 11: Circular path of the foot and FIGURE 12: Path of knee and ankle (side view). Note the anterior movement of the foot during the stroke.

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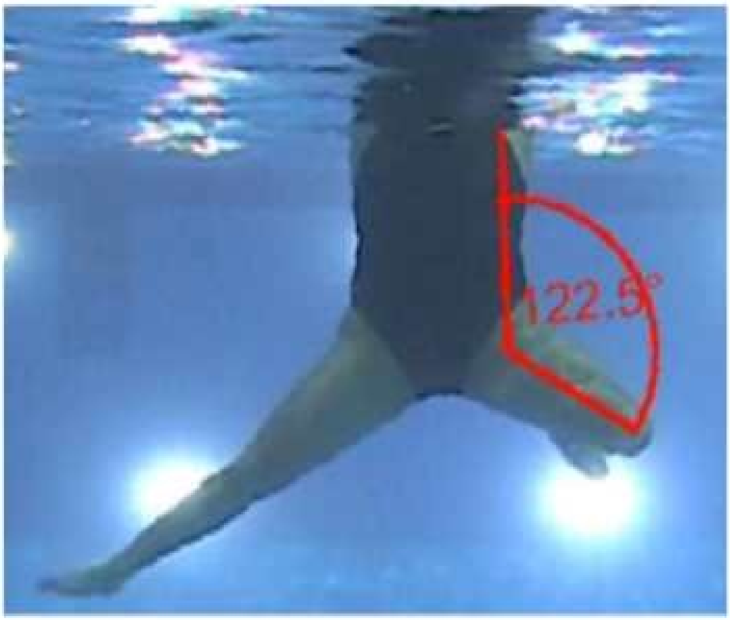
Common errors in the eggbeater:

- Not enough hip abduction so the power stroke into adduction is too short
- Not enough flexion of the hip (should be past 90 degrees) so the hip extension range is limited.
- Not enough extension of the hip so the power phase is limited.
- Not enough hip medial rotation to cock the foot and lower leg to create an airfoil.
- Not enough hip lateral rotation to bring the foot back to the hip line, so stroke is shortened.
- Not enough knee lateral rotation, dorsiflexion and eversion so the foot is not cocked at the correct angle to obtain lift-might be due just to the poor medial hip rotation.
- Too small a range of motion in knee flexion and extension, so the vertical excursion of the foot is limited.
- Keeping the hips too flexed throughout the stroke; rather than forcefully extending during the power stroke.
- Not enough of a circular motion of the lower legs-too much up and down motion which does not produce as much lift as movement forward and back and sideways (left and right)
- Not as much anterior posterior and lateral motion.
- Too much bouncing or lack of stability, where swimmers do not maintain a steady height and vertical posture (Berg 2004).



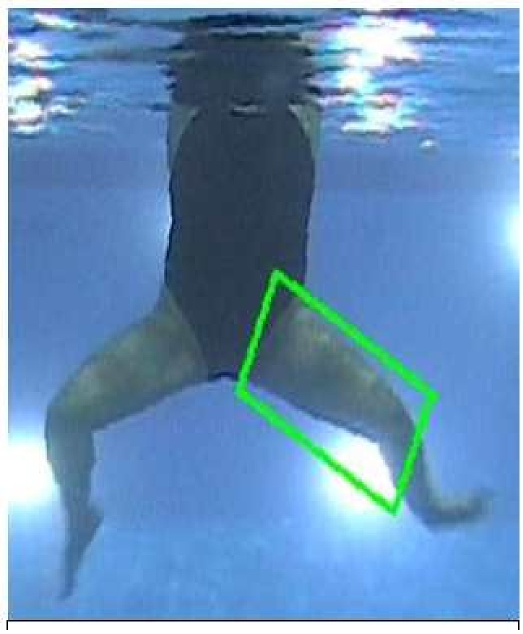


FIGURE 13: Inadequate hip abduction FIGURE 14: Inadequate hip flexion FIGURE 15 : Inadequate hip rotation

Useful variables to measure in the eggbeater

HIP:

Range of flexion-extension during the stroke; position of maximum flexion and position of maximum extension (from the side view)

- Range of adduction/abduction during the stroke; position from maximum abduction to maximum adduction (from the front view)
- Range of medial to lateral rotation of the hip- difficult to measure but could estimate.

KNEE:

Range of flexion extension during the stroke; position of maximum flexion and maximum extension; also the vertical excursion of the knee, from maximum height to minimum height in the pool.

- Range of medial to lateral rotation of the knee; position of maximum medial and lateral rotation.

ANKLE:

- Range of motion at the ankle; from maximum dorsiflexion to maximum plantarflexion.

SUBTALAR JOINT:

- Estimate range of motion from eversion to inversion; when movements occur during the stroke.

Other variables:

- The circular movement of the foot during one complete cycle- look at shape of the circular pathway for each foot.
- Shape of the pathway of the knee during stroke
- Change in elevation of the foot during the stroke, from maximum hip flexion/knee flexion to maximum knee extension/hip extension
- Distance subject drops into the water when arms are extended above the water- the legs only kick
- Time for one complete cycle of each legs: propulsive phase and recovery phase- how symmetrical is the kick? (Many athletes lack symmetry in the kick, with a larger range of motion in the right leg than the left leg in many of the athletes we have examined).

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