APPROACHING PERFECT SWIMMING:

OPTIMAL FREESTYLE TECHNIQUE

By Rod Havriluk, Ph.D.

SAMPLE VERSION - CHAPTERS 1-6
WITH APPENDICES

This document is part of The Approaching Perfect® series which explores the increasing use of technology to improve performance and enhance competitiveness. Although the series can be used by athletes at any level, swimmers who have already mastered some basic skills may be better suited to apply the principles presented throughout the program.

About the Author

Dr. Rod Havriluk is the president of Swimming Technology Research. Although he specializes in biomechanics, he has also maintained both a research and applied interest in skill learning and injury prevention. He is one of the most widely published authors on swimming technique and has made presentations to coaches and sport scientists in many countries.

Dr. Havriluk earned a Ph.D. in human performance from Indiana University in 1987. While at IU, he specialized in biomechanics under the direction of Dr. John M. Cooper ("the father of modern biomechanics" and inventor of the basketball jump shot) and learned from swimming legend Dr. James "Doc" Counsilman (scientist, oldest swimmer of the English Channel and coach of the most successful US Olympic Swim Team in history).

Rod's research has been published in many swimming publications including the *Journal of Swimming Research*, *Swimming Technique*, and *American Swimming Magazine*, as well as more general scientific publications like the *Research Quarterly for Exercise and Sport* and *Medicine and Science in Sports and Exercise.* He is a frequent conference presenter (FINA, IOC, Biomechanics and Medicine in Swimming, US Swim School Association), and is recognized internationally as an expert on swimming technique. He has lectured to coaches in many countries (e.g. USA, Brazil, Ecuador, Puerto Rico, Aruba, Saudi Arabia, Trinidad, Curacao). His research produced three US patents and prompted the development of software and hardware for instructing and analyzing swimming technique. He has been featured in books on advanced technology (*One Digital Day: How the microchip is changing our lives; Inescapable Data: Harnessing the power of convergence), magazines (PC Magazine; Swimming World Magazine.com)* and on TV (ESPN and "the Score"). His upgraded version of Aquanex+Video was selected as a finalist for *Product Design and Development's* 2003 Product of the Year and featured in *PC Magazine*.

He is a long-time member of the American Alliance of Health, Physical Education, Recreation and Dance; the American College of Sports Medicine; and the American Swimming Coaches Association. He serves on the advisory board of the Counsilman Center for the Science of Swimming at Indiana University; the editorial board of the *Journal of Swimming Research*; and the review board of numerous sport science journals. He is currently the president of the International Society of Swimming Coaching.

Rod has a wide variety of swimming experience, including many years of coaching at the club and college level. He has also competed for most of his life, recently winning titles at a number of open water competitions. As a sport scientist, Rod has worked with thousands of swimmers and triathletes in team, clinic, and private instructional sessions. His client list includes Olympians, world champions, and world record holders.

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PREFACE

This book was prompted, in part, by the many misconceptions about freestyle technique, some of which have become “conventional wisdom.” For example, ineffective arm synchronization (like catch-up stroke), counterproductive drills (like one arm freestyle), and nonscientific analysis procedures (like adopting a technique element of a champion only because he/she swims fast) have contributed to the proliferation of misconceptions. In contrast, all the technique elements presented in this book are based on principles of physics and decades of research, including thousands of trials using Aquanex (the patented force-measurement technology developed by Swimming Technology Research).

Developed with the individual swimmer in mind, this book is based on more than 30 years of research and supported by specific experience in coaching (from age group to college level), consulting with domestic and international swim teams, and the author’s work with individual swimmers at every performance level (from beginners to world record holders).

Although every technique element in this book has a scientific basis, every effort has been made to make each point understandable and easy for a swimmer to apply. As with anything worth doing, however, improving swimming technique is not for the un-motivated. Swimming is a complex skill, requiring many thousands of repetitions to change.

Keep in mind that improving your technique is the ONLY way to reach your full swimming potential and avoid the repetitive motion injuries so common in swimmers. Unfortunately, early success in competition usually results in an increase in training distance at the expense of continuing technique adjustment. (Swimming may be the only sport in which training ***quality*** (a focus on performing with an effective technique) is often sacrificed for ***quantity*** (training distance)! The greater the training distance, the more important it is to emphasize technique – both to avoid injury and reinforce positive technique elements.

At Swimming Technology Research, the science behind every idea is paramount. At the same time, not every swimmer shares that fascination with the underlying biomechanical, physiological, and anatomical foundations. For this reason, effective technique is presented first in this book – much of the scientific basis is saved for the chapter on advanced concepts at the end.

This book includes several icons to help you (swimmer or coach) obtain the information that is most important:

CUE The CUE icon specifies information about the position and motion of body parts that you can see or feel while swimming.

The clipboard symbol indicates information of special interest to coaches.

TIP: The TIP icon alerts you to key information or a special way for controlling a technique element.

The whistle signals a drill or exercise to incorporate into your training.

For those of you interested in the science behind the ideas, the appendix includes summaries of research, as well as links to additional resources and reference material.

STR research is ongoing and your insights/comments about applying the concepts and strategies are always welcome. Contact Dr. Havriluk at havriluk@swimmingtechnology.com.

CHAPTER ONE: INTRODUCTION TO APPROACHING PERFECT

This program will introduce you to the optimal technique of swimming freestyle. The program features a technology-generated biomechanical model (**MONA** or **M**odél **O**ptimál **NA**tación, shown in Figure 1) to demonstrate perfect technique in the freestyle stroke, something not yet found in any "human" swimmer.

Figure 1. MONA – a biomechanical model of optimal swimming technique.

Most programs use a top swimmer as a model. While research clearly shows that faster swimmers have more effective technique than slower swimmers, research also shows that even the fastest swimmers have technique limitations. For this reason, MONA does not model any individual's technique, but instead is a composite of all the most effective elements of technique.

The program:

- Uses MONA to demonstrate optimal technique from above and below the surface;
- Presents visual cues (what the swimmer sees) as well as kinesthetic cues (what the swimmer feels) that will help a swimmer monitor, control, and change technique;
- Provides a checklist for stroke analysis (designed to be used by swimmer, parent, or coach);
- Suggests stroke drills and exercises that focus on specific stroke elements; and
- Gives tips on using equipment to isolate or exaggerate specific stroke elements (to bring them to a level of awareness that the swimmer can recognize, understand, and control).

After completing this program, you will be able to:

- Identify head, arm, and leg cues for each key position within the stroke cycle;
- Determine what changes are needed to improve technique;
- Evaluate technique throughout the entire freestyle stroke cycle;
- Understand how an effective technique will help avoid injury;
- Understand how a more effective technique will improve performance;

- Use a simple feedback form to record current swimming technique and identify needed improvements; and
- Use cue-focused practice to accelerate your technique improvement and swim faster.

Bonus: *Applying* what you learn will help reduce both your effort level and the chance of injury, and ultimately, make you swim faster.

Key Skill-Learning Concepts

Principles of physics, research, and competition have clearly determined the mechanics of an optimal freestyle technique. However, humans must ***learn*** *the skills. A number of skill learning strategies can be used to master these technique elements as quickly as possible.*

Start Slow to Swim Faster

At first glance, swimming slow to get faster doesn't seem to make much sense. But, research in an increasing number of sports and performance activities clearly shows that this is true. Experts insist that mastery of any sport, musical instrument, or movement-based skill requires "deliberate" practice. Swimming strokes must be performed at a speed slow enough to allow focus on individual elements of technique by using cues that specify the position or motion of body parts. It is strongly recommended that swimmers initially swim at a speed where they can be sure they are complying with the cues.

TIP: A general guideline to improve control is to move the hand through the entire stroke cycle as slowly as possible with a continuous motion – i.e. with no hesitations or gliding.

Cue-Focused Practice

It simply is not possible to improve technique by swimming longer workouts. To learn why this is true, let's start with the basics.

To begin with, swimming is difficult. The motions that humans naturally use on land are generally not effective in the water. Because of this, everyone needs to ***learn*** to swim.

That learning process is further complicated because swimming involves continuous motion of both arms, both legs, and the torso - - while the body is submerged.

This makes it all but impossible to gain all the skills needed to optimize technique at one time. Instead, swimming instruction - from basic to advanced skills - is most successful when a swimmer can focus on a limited number of technique elements at a time. This can be done most effectively by using cues - precise information about the orientation of body parts at a specific point in the stroke cycle. Once a swimmer shows the ability to focus on one or two cues (and begins to exhibit both mastery and consistency), additional cues can be introduced.

There are three types of cues – visual, kinesthetic, and auditory.

- A **visual cue** is something you can see - for example, the hand passing beneath the head during the freestyle pull.
- A **kinesthetic cue** is something you can feel - for example, the water level at your hairline.
- An **auditory cue** is something you can hear – for example, the arm entry.

All three types of cues are critical tools for learning any complex movement or skill. Auditory cues, however, play a very minor role in swimming compared to visual and kinesthetic cues.

One of the many benefits of using cues is that you can implement a "standard language for communication" with your team. Cues simplify the information (by explaining a position or motion with a short phrase) and minimize the chances of miscommunications.

Skill-Isolation Drills

Drills can also accelerate skill learning. In particular, drills that isolate a specific technique element (skill-isolation drills) make it easier for the swimmer to process the information that is critical for control. Drills can improve focus on a specific cue. Drills can exaggerate a position or motion so that a technique element rises to the level of the swimmer's awareness. Drills can also push a swimmer to use the full range of motion at a joint.

Movement Control, Permanency, and Automaticity

Focusing on one or two cues at a time by seeing or feeling something specific is a proven way to expedite the learning process. However, it will still require many repetitions (i.e. tens of thousands) of each skill to develop permanency. Once a skill is "permanent," it becomes automatic and does not require the same level of mental involvement. (We have many "permanent" skills already: walking, driving a car, and riding a bicycle are examples.)
Although you won't hear much about it on a pool deck, technique changes require a swimmer to process a great deal of information derived from the principles of physics – specifically, biomechanics and hydrodynamics. This is supported by a substantial body of research that shows how swimmers can best apply these principles.

This program aims to do just that. In addition to accessing volumes of swimming research conducted by experts, Swimming Technology Research has refined technique learning strategies using thousands of trials of synchronized video and force analyses. This research is the basis for the Approaching Perfect program and the performance model it presents.

Skill Development Process

The development of effective swimming technique is an involved process. Fortunately, we have principles of physics (biomechanics and hydrodynamics) and decades of research to guide us in developing an optimal model. Skill-learning acceleration methods (SLAM) are critical to rapidly acquiring the skills exhibited by the model. As more skills are mastered, coach-directed conditioning provides the swimmer with training at faster speeds and with fatigue. Synchronized video and force data feedback show the swimmer how well he/she is complying with the model. Adherence to this scheme produces faster performance times.

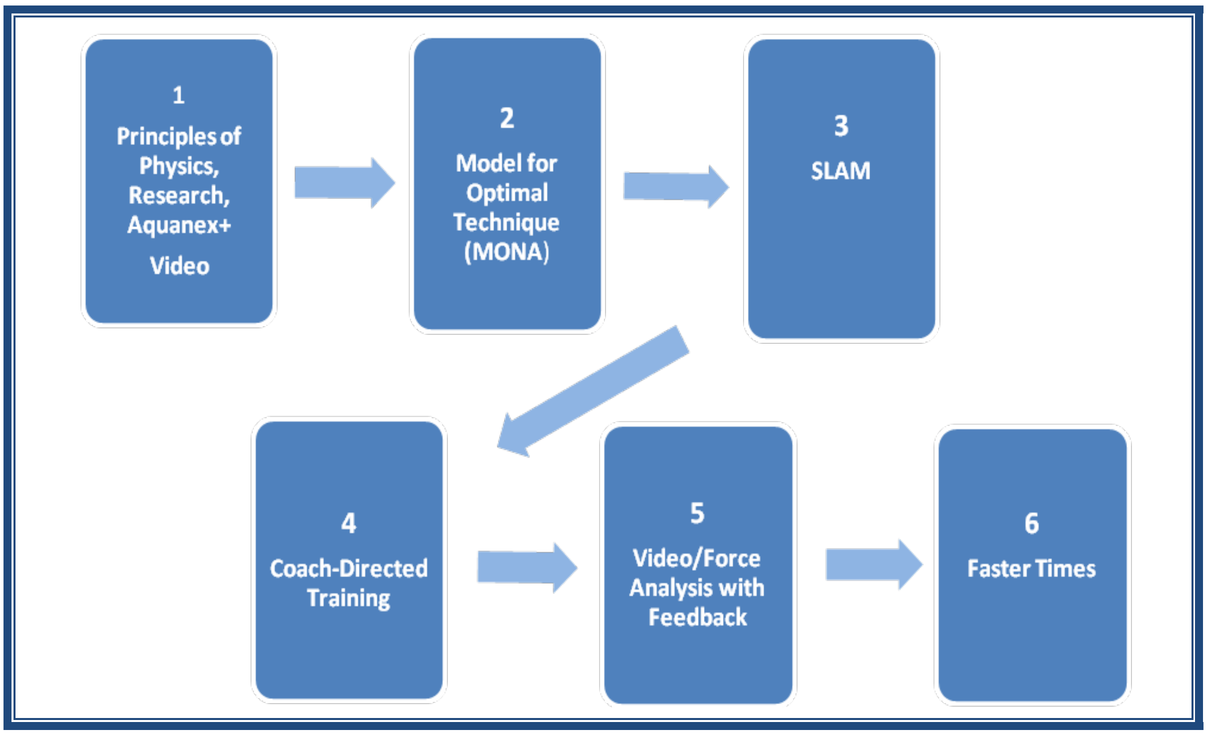


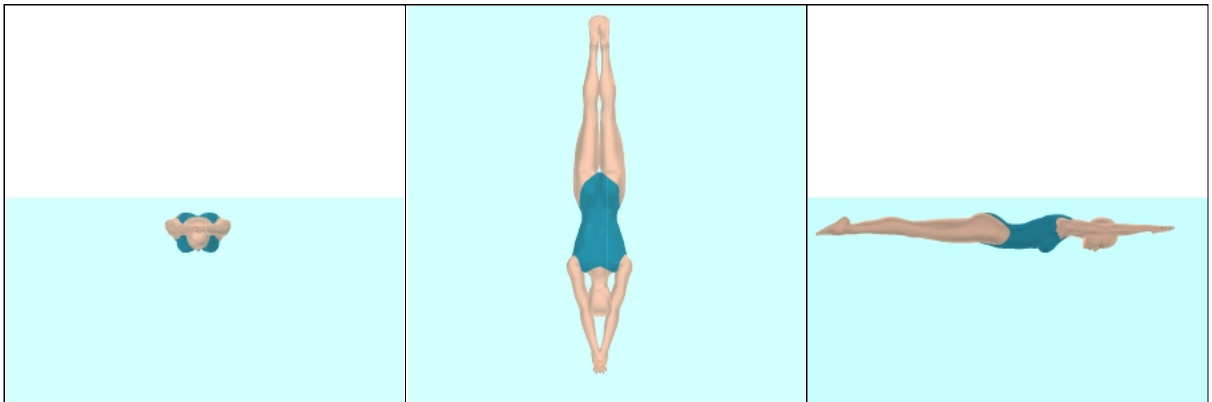
Figure 2. A scheme for skill development.

Having a model for optimal technique is vital, but learning strategies that allow for skill development are just as important. With effective strategies, swimmers make technique adjustments to conform to the model, using cue-focused practice. Using the cues for feedback, individual swimmers make technique changes permanent when they can maintain the technique changes throughout a routine or coach-directed workout (i.e. at faster speeds and with fatigue). A video/force analysis reinforces the changes and identifies additional limiting factors. The change cycle can then begin again with cues for new skills.

Once the new skills are mastered (that is, when the changes become permanent), faster swimming will result.

CHAPTER TWO: HEAD, BODY, AND LEG POSITION

The most basic goal for optimizing technique is to swim as fast as possible with as little effort as possible. Minimizing resistance and maximizing propulsion help to achieve this goal. First, consider the body position that minimizes resistance – the streamline, as shown in Figure 3 below.



Front View	Top View	Side View

Figure 3. The most basic position for swimming – the streamline.

One way to evaluate the streamline is to draw an oval around the shoulders (in the front view image). If all the body parts are within the oval, the cross-section of the body (the area that is perpendicular to the horizontal direction of motion) will be minimal, and so will the resistance.

A second way to evaluate the streamline is to note how well the orientation of all body parts makes the water flow around the body with minimal turbulence. The more the body is shaped like a spear, the better the water will flow.

An effective streamline exhibits compliance with nine cues. Only one cue is visual (body part orientations you can see) while eight cues are kinesthetic (body part orientations that you can feel).

CUE

For an optimal streamline position:

- The ***visual cue*** is to see the bottom of the pool directly beneath the head.
- The ***kinesthetic cues*** are to feel:
  1) one hand on top of the other
  2) fingertips pointing horizontally at the pool wall
  3) elbows locked
  4) upper arms squeezing the ears
  5) back arched
  6) legs straight
  7) feet together
  8) toes pointed

A subset of these cues is sufficient for most swimmers. For example, kinesthetic cues 1, 4, and 8 are adequate for many swimmers. However, some individuals may require attention to all nine cues.

TIP: Initially, focus on two cues for the streamline – one hand on top of the other and upper arms squeezing the ears. The hands can be positioned before pushing off from the wall so after the push-off it is only necessary to position the upper arms.

While the streamline is optimal for minimizing resistance, a swimmer cannot maintain this position and generate any propulsion. It is helpful to keep in mind that as limbs move to generate propulsion, maintaining a position as close to streamline as possible will help to get the best of both worlds – maximum propulsion and minimal resistance.

This ***does not*** mean that the body is ever in a streamline at any point in the freestyle stroke cycle. This ***does*** mean that a swimmer will benefit when swimming with a body orientation that is relatively close to a streamline.

The best way to reinforce the streamline is on every push-off from the wall. Assume the streamline as soon as the feet separate from the wall. It is best to maintain a motionless position as you check compliance with all the cues for the streamline. Initially, checking nine cues (or a subset of cues that works for you) may require several seconds. With practice, that time will decrease. When mastery occurs, you will be in compliance with all nine cues as the feet leave the wall.

Swimmers often get lazy (or at least inconsistent) about hitting all the cues of an optimal streamline on every push-off. Constant reminders before each push-off and feedback after each push-off are necessary to achieve consistency. Remember, this is the most basic position for successful competitive swimming. A swimmer who ***has not*** mastered the streamline is likely to struggle with more advanced skills. A swimmer who ***has*** mastered the streamline shows the body control necessary to progress to more advanced skills.

Flexibility is an issue in achieving an optimal streamline. Some swimmers, particularly adults, lack the range of motion at the shoulder to make the upper arms squeeze the ears. A lack of flexibility may be a reason to not be compliant with certain cues. However, realize that every time you get into the streamline you are performing a flexibility exercise that can increase the range of motion. A sufficient number of repetitions (and it could be many thousands!) will help you achieve an optimal streamline.

In the following series of images, you'll be introduced to "perfect technique" that incorporates optimal head and body positions throughout each arm and leg phase of the freestyle stroke. (There's a lot happening in each second – just like it does in the water.) You will also be introduced to specific cues to check your own technique and receive several tips to help you perfect your technique.

In the next few chapters, we'll show you exactly what MONA is doing with her head, body, arms and legs in each phase of the stroke. Continue by carefully reviewing the images that follow. Note that this information is organized by **key positions** (for the head, legs, body, and arms), **stroke phases** (exit, entry, pull, and push), and **breathing motion**.

Key Freestyle Positions

To say that the following positions are "key" is an understatement. A swimmer, who masters the cues for the head, arm, and leg positions below, will have (at the least) a relatively effective technique.

Non-breathing Head Position

The non-breathing head position is critical, and not just for the sake of the head. If the head is optimally positioned (and motionless), other skills will be easier to evaluate and control.

CUE

For an optimal non-breathing head position:

- The ***visual cue*** is to look forward at a 45^{o} angle so that both the wall at the end of the pool and the bottom of the pool are within your view.
- The ***kinesthetic cue*** is to feel the water level at your hairline.

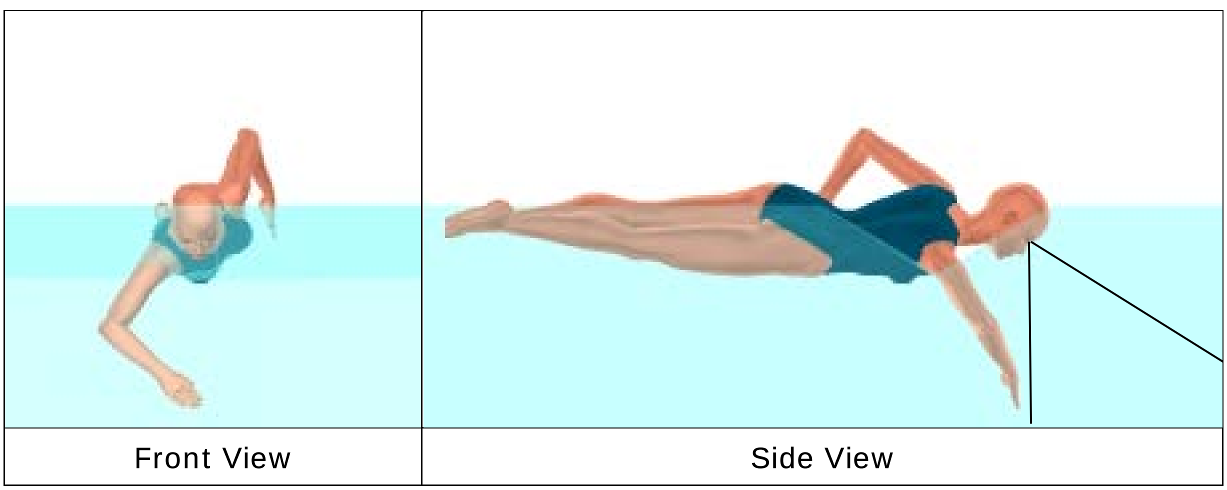


Figure 4. The non-breathing head position with lines showing the boundaries of a typical field of view (side view).

Key Points:

- The exact position of the water level on the forehead primarily depends on two factors: body composition and swimming speed. Very slight adjustments may be necessary.

- Swimmers with a lower proportion of body fat or a lower swimming speed may need to lower the head slightly (by flexing at the neck) so that the water level is slightly above the hairline.

- Swimmers with a higher proportion of body fat or a faster swimming speed may find they can breathe more easily by raising the head slightly (by extending at the neck) so that the water level is just below the hairline.

- The head position remains fixed throughout the non-breathing stroke cycle and there is no vertical, lateral, or rotational movement.

One of the many misconceptions about swimming technique is that the head must be submerged for the legs to stay behind the shoulders. Although lowering the head may help to raise the legs, breathing then requires excessive head motion that distorts the body position and increases the body cross-section. Since the spine is closer than the head to the legs, ***arching the back*** is a much more effective way to control the leg position.

Even many experienced swimmers have minor head motion during non-breathing stroke cycles. Very often, head rotation is synchronized with torso rotation. While a slight amount of head motion will not have a major impact on swimming speed, it is vital to control because of the impact on tracking other skills. A swimmer can be much more certain of what he/she sees and feels if the head (the primary frame of reference) is motionless. It is also very common for swimmers to synchronize downward head motion with the arm entry. This is natural, but counterproductive.

Leg Position

Once the head is in an optimal position, it is much easier to orient the rest of the body. Arching the lower back lifts the legs to bring the heels to the surface. If the legs stay behind the torso (as in the front view of Figure 4), resistance is minimal. The smaller the swimmer maintains the area of the body perpendicular to the direction of motion (the body cross-section), the lower the resistance.

CUE For an optimal leg position:

- the ***kinesthetic cues*** are to feel:
  1) the legs straight
  2) the toes point
  3) the back arch so that the heels break the surface on every kick upbeat.

TIP: Every time you push-off from the wall, maintain the streamline position until you feel the heels at the surface. (Arch the back, if necessary.) Then, it is only necessary to maintain that leg position to feel the heels break the surface on every upbeat. Note how MONA's heel breaks the surface in the side view of Figure 4 above.

Key Points:

- Even if the head and body are optimally positioned, there is no guarantee that the legs will stay in line with the torso to minimize the cross-section.

- Very often, the legs will drop below the torso and generate excess resistance. This is fairly common in adult males.

- If necessary, arch the back so the heels rise to the surface. This will keep the legs behind the torso to minimize the cross-section and, therefore, resistance.

- Avoiding excess knee bend and foot separation are critical cues for maintaining a leg position with minimum resistance.

Body Position

If the swimmer has an optimal head and leg position, the body (torso) position will probably be effective. A front underwater video can confirm that the cross-section is minimal. If there is an issue with the torso, adjustment of the head or legs will usually make the necessary correction. Note the front view image of MONA in Figure 4.

An optimal body position and optimal use of energy depends on using less muscular effort rather than more. Research shows that contraction of abdominal muscles can have a negative impact on performance. Research also shows that more skilled swimmers only use the muscles that are critical for a movement, while less skilled swimmers also activate unessential muscles.

Key Points:

- If the head is motionless, it is much easier to maintain an effective body position throughout the entire stroke cycle.

- To minimize resistance, the body must present a minimal cross-section in the direction of motion.

- To minimize the cross-section, rotate the shoulders and hips together.

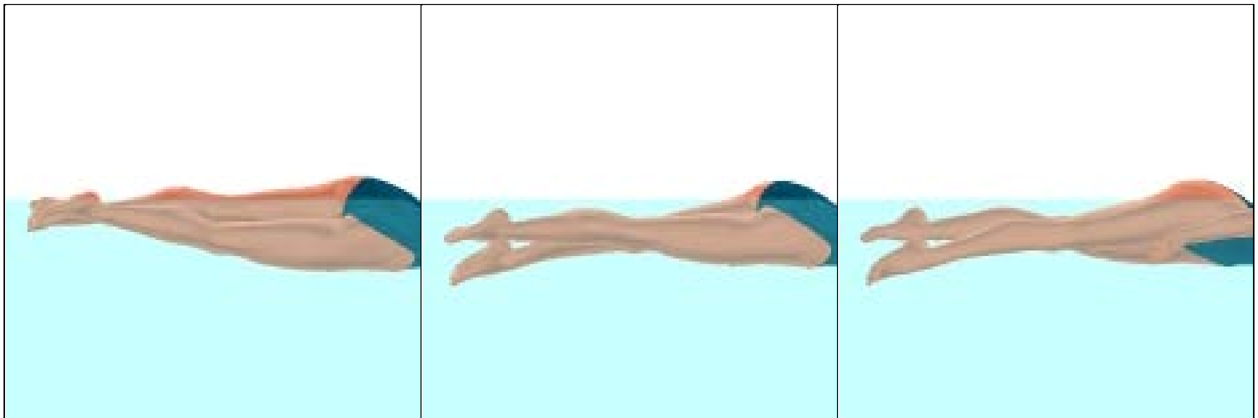
- Torso rotation is best synchronized with the arm entry – i.e. as the arm enters, the torso rotates downward.

TIP: There are many references to “body length” in the literature. It is true that a longer body has a lower drag coefficient and will, consequently, go faster (all other factors being equal). However, ***trying*** to make the body longer by stretching the arm in front of the body can twist the torso, stress the shoulder, and slow the stroke rate.) Body length is determined by body height. A swimmer will make the best use of his/her height by complying with the cues for the head, arms, and legs.

CHAPTER 3: LEG MOTION

There are two phases to the kick: a downbeat and an upbeat.

The downbeat is initiated with downward motion of the upper leg, followed by the lower leg and foot. (While this order of limb motion is identical to a land-based kicking motion, the range of motion at each joint is drastically less – i.e. there is much less change in the angles at both the hip and knee.)



Beginning of downbeat		Completion of downbeat

Figure 5. Right leg downbeat

CUE For an optimal kick downbeat:

- the ***kinesthetic cues*** are to feel:
  1) the knee flex slightly
  2) the foot accelerate downward

At the completion of the downbeat, the leg is straight. The straight leg moves upward during the upbeat to return to the position to begin another downbeat.

Most swimmers bend the knee too much. It is often helpful to point the toes and make the leg feel completely straight. Another cue is to feel the legs stay behind the torso. As you practice your kick, it is best to feel that the leg position is not very different from the streamline.

TIP: If it feels like there is any more than a slight amount of knee bend, there is probably excess knee bend.

Kick Effort Level

It is important to monitor the effort level of the kick. While the frequency may be appropriate, swimmers typically put excessive effort into a kick. Particularly when working on technique (especially head, body, and leg position), it is beneficial to maintain a kick effort level that is only sufficient to synchronize the legs with the arm motion (whether that's a 2-, 4-, or 6-beat kick), but not to generate propulsion.

Kick Frequency

Most swimmers naturally synchronize a 6-beat kick with their arm motion. A 6-beat kick has 3 downbeats for each leg per arm cycle. A 2-beat kick synchronizes best if there is a kick downbeat with the arm entry on the opposite side. A 4-beat kick is the least popular. When first beginning to work on technique, the kick frequency is not an immediate concern like either the effort level or maintaining the legs in position behind the torso.

Kick Amplitude

The amplitude or maximum distance between the feet during the kick is another key technique element. Many swimmers have an appropriate amplitude when their body is flat on the front (i.e. not rotating). When the body is rotated, many swimmers increase the kick amplitude so that the feet are outside the body cross-section causing extra resistance.

Key Points:

- Feel like the feet kick with a small amplitude (i.e. the feet never move very far apart).
- When the torso rotates, it is natural for the feet to separate more than when the torso is not rotating (i.e. when the torso is flat on the front). This is natural, but not effective.

TIP: Maintain the same kick amplitude throughout the stroke cycle – whether the torso is flat on the front or rotated on the side.

> When training distance swimmers or triathletes, keep in mind that the legs generate only about 10% of total propulsion. Particularly with triathletes swimming long distances, it is beneficial to only put sufficient effort into the kick to stay synchronized with the arm motion, but not to actually try to generate propulsion.

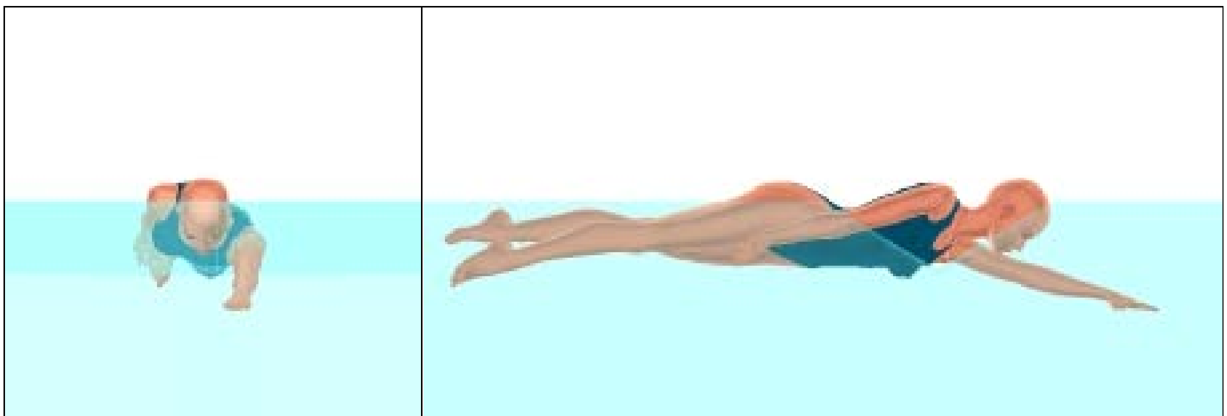
If the feet break the surface on the upbeat, this is not necessarily a problem. At faster swimming velocities, this is usually desirable. However, when learning an effective kick, it is best to use the surface of the water as the upper limit for the range of motion.

CHAPTER 4: CRITICAL ARM POSITIONS – FOUR CHECKPOINTS

Because the arms move continuously throughout each stroke cycle, it is necessary to master multiple arm positions. To simplify the learning process, freestyle is presented using four key arm positions (These positions can be considered “checkpoints”). These key positions are not very far apart in time (approximately .2 sec) or distance (approximately .5 m). A swimmer in compliance with these four positions cannot get too far off track in between these positions. Consequently, mastery of these four key arm positions will insure that a swimmer has at least a fairly effective technique.

Checkpoint #1

Before working on checkpoint #1 during the swimming stroke, simulate the position while standing. Stand with your feet flat on the deck (or the bottom of the pool) and make your body straight. Then, straighten your arms along your sides (with your elbows touching your ribs). Stick out your thumbs and touch the front of your thighs. Feel exactly where your thumbs are making contact with your legs. This is checkpoint #1. You will want to feel the same orientation of your hand and leg at the end of each stroke.



Front view	Side view

Figure 6. The right arm at checkpoint #1.

The first key position in the freestyle arm motion is at the completion of the push phase. The arm straightens until the elbow locks and the thumb brushes the front of the thigh.

CUE For an optimal arm position at checkpoint #1:

- The ***kinesthetic cues*** are to feel:
  1) the arm straighten
  2) the elbow lock
  3) the thumb touch the middle of the front of the thigh

This position is critical to master before working on additional arm skills. No matter what a swimmer has done throughout the rest of the stroke cycle, getting the arm in position to comply with the cues of checkpoint #1 is relatively straightforward. Swimmers can generally comply with the cues for this position easier and with greater accuracy than the other three. Compliance with this position also gives the swimmer a fresh starting point for the next stroke.

It sometimes takes a considerable number of repetitions to develop consistency in complying with checkpoint #1. Mastering this skill is easier if you focus on maintaining backward hand motion until your elbow locks. Make the hand control the arm motion to push back to checkpoint #1. (Since the upper arm is rotating around the shoulder, the natural tendency is for the elbow to move toward the surface and take the hand with it. Because of this tendency, most swimmers never optimize the finish of the push.) You should feel that your arm is completely straight when your thumb touches your thigh.

Swimmers often have difficulty with this checkpoint if the hand is moving too fast. (Even a moderate hand speed may be *too* fast.) Ask swimmers to push the hand back slowly (as opposed to letting it move upward toward the surface) with hitting checkpoint #1 as a priority. A slow, but continuous, hand speed usually helps a swimmer comply with this skill.

TIP: Most of the cues presented in this book will work for any swimming speed. However, checkpoint #1 is an exception. While it is still important to benefit from the push phase at the fastest swimming speeds, locking the elbow and touching the thigh may interfere with maximizing the stroke rate. If you practice enough repetitions at a fast speed complying with the cues for checkpoint #1, it will not be necessary to focus on them when racing.

Checkpoint #2

Once consistency in complying with the cues for checkpoint #1 is achieved, you can progress to checkpoint #2. After you make the thumb touch the thigh, shift control of the arm to the elbow. Lift the elbow until the upper arm is in the same vertical plane with the shoulders (perpendicular to the surface of the water), keeping the hand close to the body. When the arm is in position at checkpoint #2, it will feel like the full range of motion is being used at both the shoulder and elbow joints.

	
Front view	Side view

Figure 7. The right arm at checkpoint #2.

CUE For an optimal arm position at checkpoint #2:
- The ***kinesthetic cues*** are to feel:
  1) the elbow pointing straight up
  2) the hand alongside the body
  3) the fingertips pointing toward the surface of the water
  4) the back of the hand facing forward

As you lift the elbow to move your arm from checkpoint #1 to checkpoint #2, relax the lower arm and hand. The elbow should feel like it is the only part of the arm that you are lifting. The back of the hand faces forward, and the fingertips point diagonally toward the surface.

> Many swimmers get the idea of lifting the elbow to take the arm out of the water. Few swimmers, however, lift the elbow for a long enough time. From the side view, it is usually obvious when a swimmer only lifts the elbow long enough to get the arm out of the water. The elbow lift must continue until the arm is in the same vertical plane as the shoulders (i.e. checkpoint #2).

As you work on this skill, make sure to hold the head in position. There is a natural tendency to lower the head as you lift the elbow. An effective strategy is to focus on rotating the torso as you lift the elbow, as opposed to lowering the head. As long as the head stays motionless in position, the torso is not rotating too much.

In Figure 7 (front view), the angle at MONA's shoulder may look abnormal. However, most age group swimmers have the flexibility to achieve this position. Adults without a swimming background - or experience in other activities that worked the full range of motion at the shoulder - may not be able to replicate the model. If that is the case, consider each swimming stroke as a flexibility exercise, where you use the full range of motion at the shoulder joint (whatever that range may be).

Checkpoint #3

From the second checkpoint, make the fingertips enter the water directly in front of the shoulder. As the arm enters the water, the arm straightens and the elbow locks. At the completion of the entry, the arm is straight and directly in front of the shoulder. At checkpoint #3, the hand will be the deepest part of the arm.

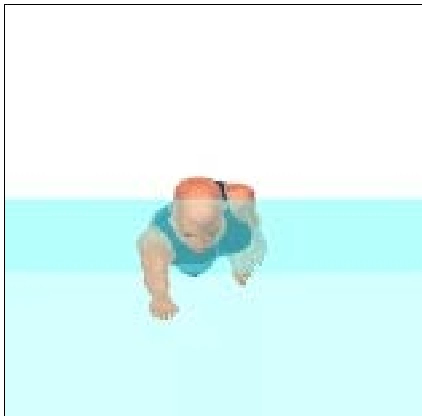
	
Front view	Side view

Figure 8. The right arm at checkpoint #3.

CUE

For an optimal arm position at checkpoint #3:

- The ***visual cues*** are to see:
  1) the arm straight
  2) the hand directly in front of the shoulder
  3) the hand below the shoulder.
- The ***kinesthetic*** cues are to feel the arm straight in front of the shoulder.

Note that the arms are in opposite positions from Figure 6. This arm synchronization provides a more continuous source of propulsion for a more constant horizontal body velocity, a more efficient use of energy, and therefore, faster swimming.

As the arm passes the shoulder, a swimmer’s hand is usually further away from the body than as illustrated for checkpoint #2. Typically, the hand moves in a lateral arc above the surface from alongside the shoulder to the entry point in front of the shoulder. When there is angular hand motion in the air, the hand usually continues to move sideways underwater. When the entry is complete, the hand is often directly in front of the head. This technique limitation indicates that the swimmer needs more work on checkpoint #2. The closer the arm position to checkpoint #2, the more likely the arm gets to checkpoint #3.

If the head is in an effective non-breathing position, the arm entry is within the swimmer’s view. Since research shows that humans are generally better at processing visual information, it is vital to evaluate checkpoint #3 visually.

TIP: It is important to make the arm straight at checkpoint #3. However, it is also important not to stretch the arm (i.e. continue to move the arm forward beyond checkpoint #3) so that the torso moves sideways and generates extra resistance. Stop the forward arm motion as soon as the elbow locks.

Checkpoint #4

The arm must begin to move from checkpoint #3 by flexing the elbow. The hand then follows a path from directly in front of the shoulder to directly beneath the head. At checkpoint #4, the hand is beneath the head with a 90^o angle at the elbow.

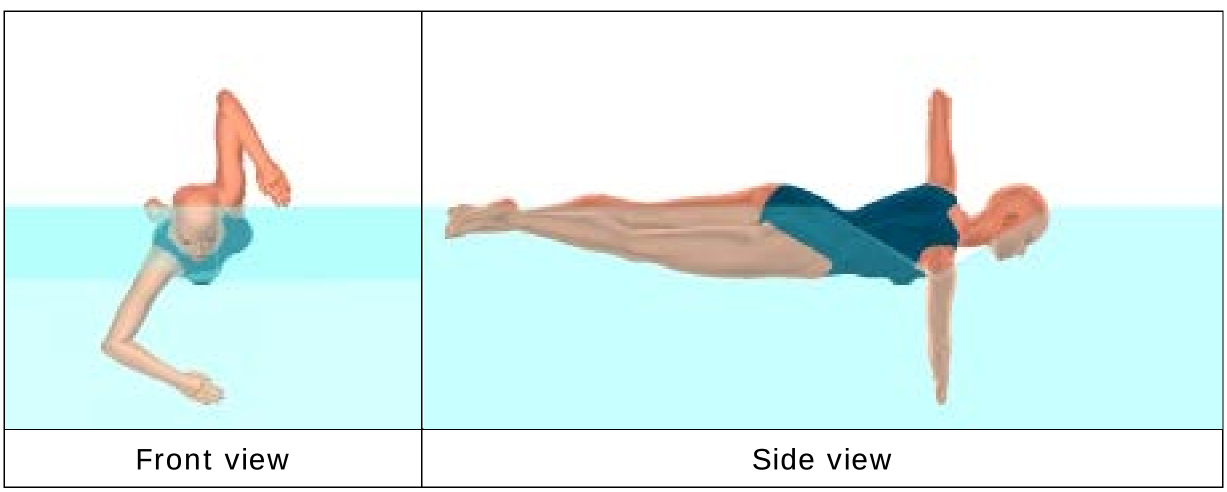


Figure 9. The right arm at checkpoint #4.

CUE For an optimal arm position at checkpoint #4:

- The ***visual cues*** are to see:
  1) the elbow bent to 90°
  2) the hand directly beneath the head
  3) the elbow to the outside of the shoulder
- The ***kinesthetic*** cues are to feel:
  1) the elbow bent
  2) the elbow pointing toward the pool wall on the same side

Like checkpoint #3, checkpoint #4 is also within the visual field of the swimmer. It is important to focus on the visual information from checkpoint #3 to #4. If the elbow does not begin flexing as soon as the arm begins moving back from checkpoint #3, there will be wasted motion and less propulsive force. As soon as the arm straightens to hit checkpoint #3, it must immediately begin bending to move to checkpoint #4.

Progressing through the Checkpoints

While it is possible to begin working on any of the four checkpoints, the presented order (from 1 to 4) can produce the fastest changes. Most swimmers develop consistency with checkpoint #1 fairly fast. If the arm is kept close to the body, moving from checkpoint #1 to #2 (and even #3) is simplified. As a swimmer gets consistent with checkpoint #2, he/she may find that the entry phase and movement to checkpoint #3 has improved before actually focusing on the cues for the entry. Finally, as a swimmer becomes consistent with checkpoint #3, the arm is in a stronger position to begin the pull phase with elbow flexion and move to checkpoint #4. The presented order has a distinct advantage in best preparing the swimmer for each successive arm position (i.e. checkpoint).

CHAPTER 5: ARM PHASES AND TRANSITION POINTS

Most of the information about the arms that has been presented so far has been positional – i.e. cues for specific arm positions within the stroke cycle. This chapter presents information about the arm phases – i.e. cues for moving from one position to another position. This chapter also includes the transition points between phases.

Arm Phases

There are four phases of the freestyle arm movement:

- Exit Phase
- Entry Phase
- Pull Phase
- Push Phase

There is also a transition point between each pair of phases.

- Exit to Entry
- Entry to Pull – also called the "Catch"
- Pull to Push
- Push to Exit – also called the "Release"

Understanding the phases and transition points makes it easier to progress through the critical skills.

Exit Phase

The sequence in Figure 10 shows the exit phase for the right arm. The exit phase begins as the arm changes horizontal direction (from backward to forward at checkpoint #1), continues as the arm surfaces, and ends when the arm reaches the vertical plane of the shoulders (at checkpoint #2).

To help you with the optimal arm motion during the Exit phase, feel that you are lifting the elbow in synchronization with the upward rotation of the torso on the same side of the body. Relax the lower arm and hand so the hand is alongside the body. Feel the hand move forward, as opposed to swinging to the side and away from the body.

CUE For an optimal exit phase:

- The ***kinesthetic cues*** are to feel:
  1) the elbow point straight up
  2) the fingertips point down
  3) the hand close to the side of the body

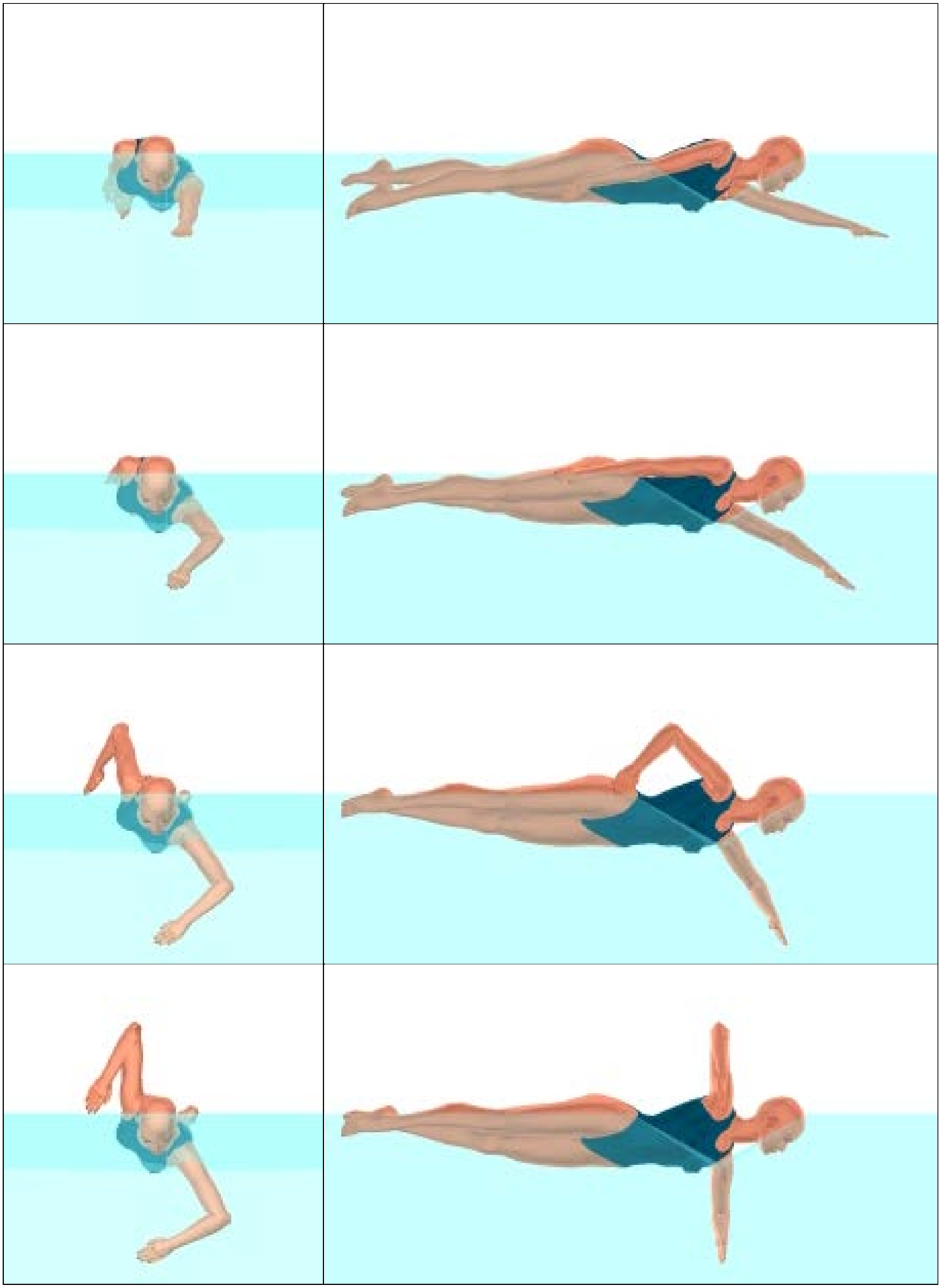


Figure 10. The exit phase for the right arm.

The elbow is the highest part of the arm throughout the exit phase. The fingertips are barely above the surface. It should feel like the full range of motion at the shoulder is being used, but this should not cause pain. It might feel uncomfortable, however, if this is different from your normal technique.

Exit to Entry Transition

The exit to entry transition occurs when the arm is above the surface and in the same vertical plane as the shoulders. This transition position is checkpoint #2 as explained above.

Entry Phase

The following sequence (Figure 11) shows the entry phase for the right arm. The entry phase begins above the surface as the arm moves forward from the vertical plane of the shoulders (checkpoint #2), continues as the arm submerges, and ends when the arm is no longer moving forward (checkpoint #3).

To control the arm on the Entry phase, poke the fingertips into the water directly in front of the shoulder. Angle the hand downward as it submerges. As you complete the entry, the arm straightens so that the hand is below the elbow and the elbow is below the shoulder.

CUE

For an optimal entry phase:

- The ***visual cues*** are to see:
  1) the hand enter directly in front of the shoulder with a downward angle
  2) the arm straighten
- The ***kinesthetic cues*** are to feel:
  1) the fingertips poke a hole in the surface
  2) the arm straighten

If the elbow is the highest part of the arm as the fingertips enter the water, and you maintain a downward angle with the fingers, there should be very few bubbles dragged down by the arm. By the time the arm straightens, any bubbles should be gone.

In addition to the performance benefit of a downward entry angle, this action also helps to avoid injury. When the arm completes the entry with hand below the shoulder, there is less stress on the shoulder and less chance of injury.

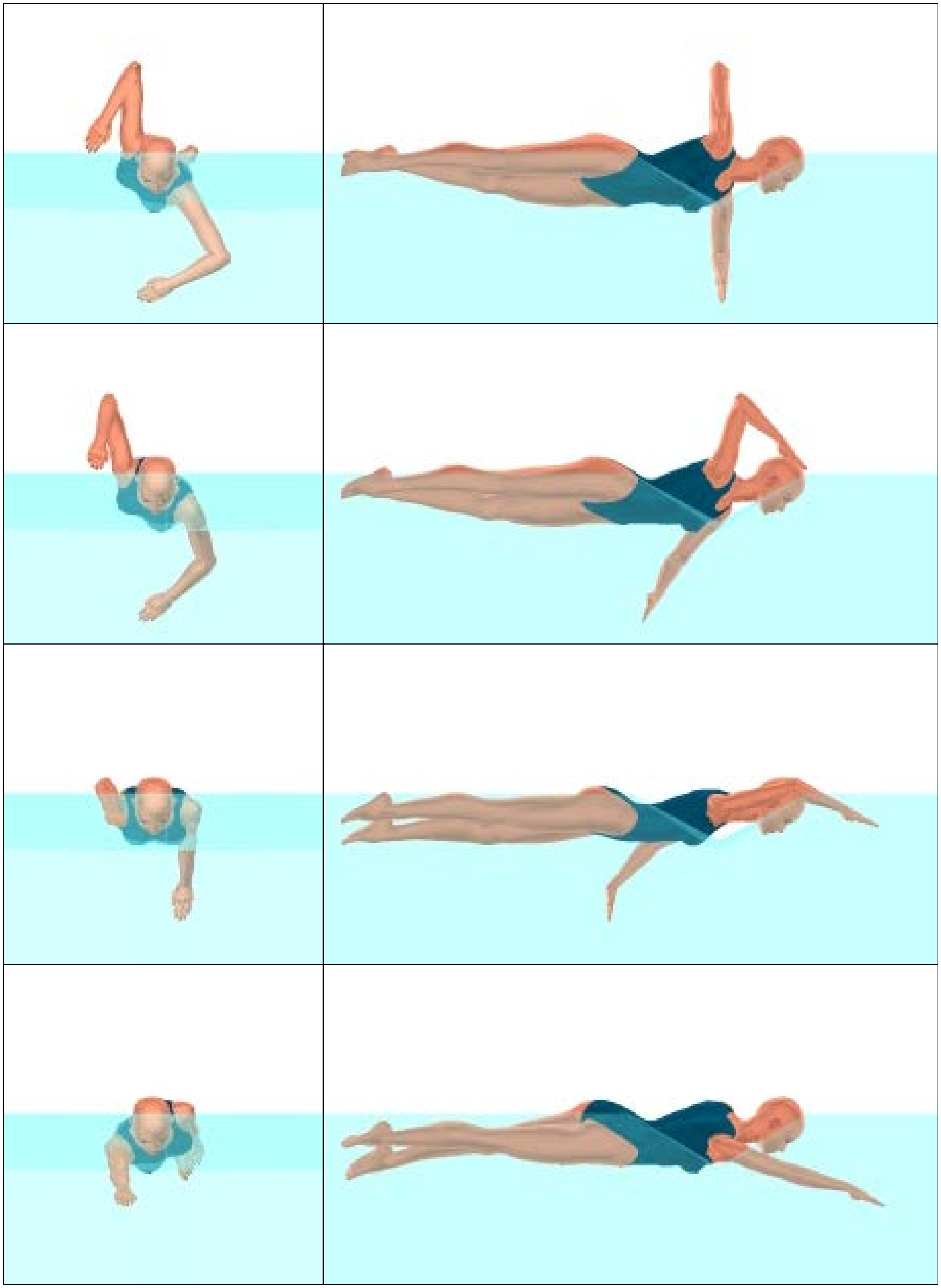


Figure 11. The entry phase of the right arm.

There are two classic ways that a swimmer loses the downward hand angle on the entry – by leveling off the entire arm (by dropping the elbow) or by extending the wrist. If the elbow drops on the entry, it is very common for the fingertips to lose the downward angle and change direction to point straight ahead so that the arm is parallel to the surface at the completion of the arm entry. It is also common for a swimmer to extend at the wrist as soon as the hand is submerged. The natural tendency is then for the hand to move upward towards the surface. When the wrist extends, the palm often faces forward causing a "braking" force (which is counterproductive as it decelerates the body).

There are many references in the literature that encourage entering the arm parallel to the surface. This position is counterproductive for at least three reasons. First, very little propulsive force can be generated when the arm is parallel to the surface. Second, when the arm is parallel to the surface, it requires at least .1 sec before the hand can be submerged to a position below the shoulder where substantial propulsive force can be generated. (That time is completely "wasted" motion and slows the stroke rate.) Third, the arm is in a position that reduces space for the rotator cuff and if the torso rotates down while the arm maintains this position, it is likely to further stress the shoulder joint.

TIP: Synchronization of torso rotation with the arm entry can help both technique elements. As the arm enters with a downward angle, downwardly rotate the same side of the torso.

Entry to Pull Transition – "Catch"

During the entry, the arm moves forward and downward. During the pull, the arm moves downward and backward. The point of transition from forward movement during the entry to backward movement during the pull is the "entry to pull transition" or the "catch."

TIP: Make sure you consider the "catch" a transition point – i.e. a split second during which the hand changes direction from forward (on the entry) to backward (on the pull). Remember that the hand continues downward as it passes through the catch point so the hand does not stop moving. If you consider the "catch" a phase, it is likely that you will have wasted lateral motion that slows your stroke rate.

The familiar meaning of the word "catch" is a ***phase*** between the entry and pull. Attempting to add a phase in between the entry and pull is a formula for wasted motion. Thousands of Aquanex analyses have shown as much as .2 sec of lateral hand motion after the swimmer completes the entry, but before the backward hand motion begins the pull. This wasted motion slows the stroke rate and keeps the arm in a weak and awkward position.

TIP: As you work on the downward angle on the arm entry, make sure the head remains motionless. There is a natural tendency to submerge the head in synchronization with the arm entry. This is natural, but not effective.

Pull Phase

The sequence below shows the pull phase for the right arm. The pull phase begins as the arm begins to move backward and ends when the arm reaches the vertical plane of the shoulders.

If you begin the pull by flexing your elbow, the hand will begin to move backward and force will increase rapidly. If you begin the pull by moving your hand, it is unlikely that elbow flexion will begin until after you have wasted at least .1 sec. During the wasted motion, only a minimal amount of force will be generated.

CUE For an optimal pull phase:

- The ***visual cues*** are to see:
    1) the elbow begin to bend as soon as the hand begins to move backward
    2) the hand move backward from directly in front of the shoulder to directly beneath the head.
- The ***kinesthetic cue*** is to feel the elbow point to the side of the pool.

It is critical that elbow flexion begin the pull phase. If the elbow begins to bend, the hand will begin to move backward. However, the converse is not true. If the hand begins to move backward, there is no guarantee that elbow flexion will begin.

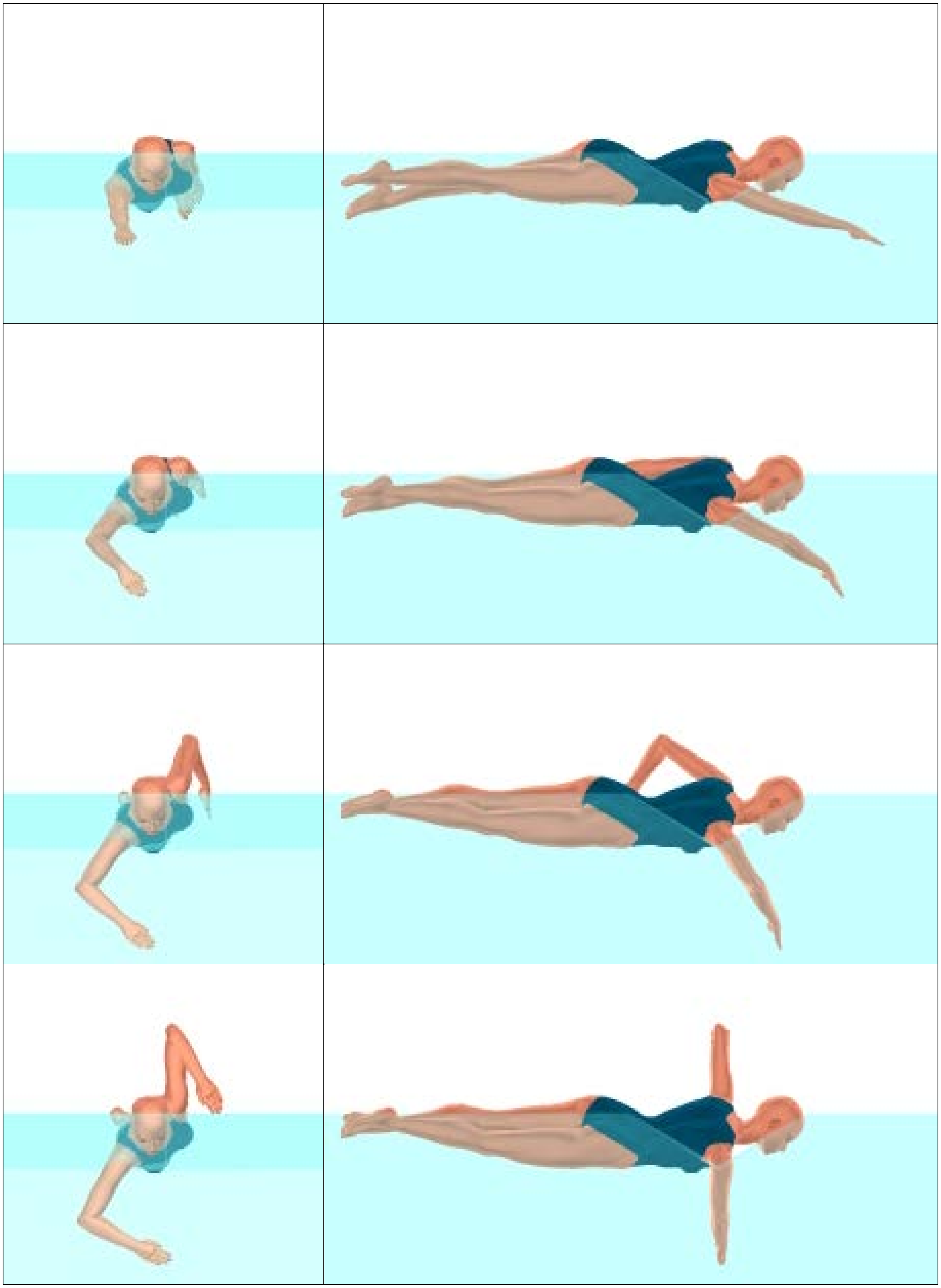


Figure 12. The pull phase of the right arm.

Pull to Push Transition

The pull-push transition occurs when the arm is underwater and in the same vertical plane as the shoulders. It is important to increase the hand speed from the pull to the push. The natural tendency is to lose force (by slowing the hand speed) during the transition.

> Hand force analysis shows that even some of the world's fastest swimmers lose force as they make the pull to push transition. Optimizing technique requires a "seamless" transition by increasing the hand speed from pull to push.

Typically, the entire time that the arm is submerged is referred to as the "pull." This is biomechanically inaccurate (because once the arm passes below the shoulders, it is a pushing motion) and more importantly, counterproductive (because the arm is in position to generate greater force during the push phase). Realizing that the arm is pushing after it passes the shoulders can help make the entire underwater motion more productive.

Push Phase

The sequence in Figure 13 shows the push phase for the right arm. The push phase begins as the arm moves backward from the vertical plane of the shoulders, continues as the arm moves upward, and ends when the arm is no longer moving backward.

CUE

For an optimal push phase:

- The ***kinesthetic cues*** are to feel:
  1) the palm push back under the thigh
  2) the arm straighten
  3) the thumb brush the front of the thigh

Keep in mind that while the hand is moving backward on the push, the torso is rotating upward. It is very natural to let the hand move upward in synchronization with the torso motion. While this synchronization is natural, it is counterproductive. The hand must primarily move backward on the push to generate maximum propulsion.

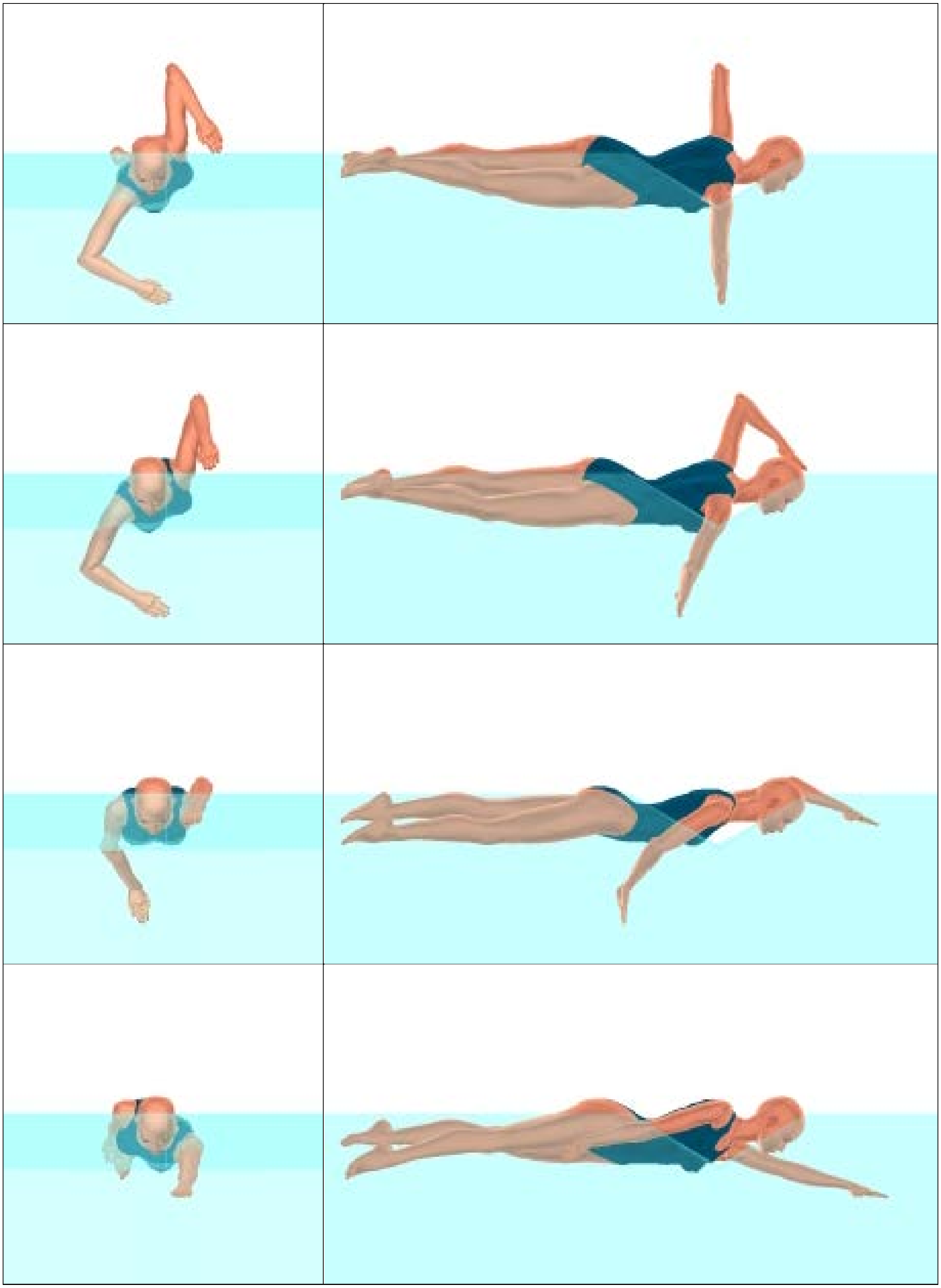


Figure 13. The push phase of the right arm.

TIP: Be aware of the simultaneous actions of torso rotation and push phase. As the torso rotates, keep the hand on a backward track to finish the push below the thigh. Avoid the natural tendency to let the hand move upward with the torso.

If a swimmer is pushing back (as opposed to letting the elbow take the arm to the surface), the elbow will be submerged throughout the push phase. From a side view of the swimmer from the pool deck, this skill can be evaluated. During the push, many swimmers have excess upward motion of the elbow. Consequently, at the completion of the push, most of the arm is at or above the surface.

Push to Exit Transition – "Release"

During the push phase, the arm moves backward and upward. During the exit phase, the arm moves upward and forward. The point of transition from backward movement during the push to forward movement during the exit is called the push to exit transition or the "release."

Phase Review with Primary Body Parts

One strategy for controlling the arm motion on each phase is by emphasizing a primary (or "leading") body part. A primary body part and an action for that part simplifies the cues for each phase.

For the **exit**, lifting the elbow moves the hand forward and upward.
For the **entry**, poking the fingertips in the water moves the hand forward and downward.
For the **pull**, flexing the elbow moves the hand backward and downward.
For the **push**, pushing the palm backward beneath the leg moves the hand backward and upward.

Phase	Direction of Hand Motion	Primary Body Part	Body Part Action
Exit	Forward and upward	Elbow	Lift
Entry	Forward and downward	Fingertips	Poke
Pull	Backward and downward	Elbow	Flex
Push	Backward and upward	Palm	Push

CHAPTER 6: BREATHING

A breathing stroke cycle in freestyle is identical to a non-breathing cycle with one exception. A breathing cycle includes enough head rotation to position the mouth just above the surface to allow breathing.

Rotating the head to breathe synchronizes best with the push phase of the arm on the breathing side. Inhalation occurs during the exit phase. Breathing is completed by the time the arm is in the same vertical plane of the shoulders (at the end of the exit phase). As the arm moves past the shoulders (and begins the entry phase), the head rotates back to the non-breathing position. The swimmer can exhale the entire time the head is in the non-breathing position.

Some swimmers will hold their breath and when they rotate their head they will exhale and inhale. This can usually be evaluated by the coach from a side view during the breathing motion. If the swimmer exhales completely when the head is in the non-breathing position, he/she will be able to inhale more quickly and efficiently.

It would be awkward to rotate the head during the entry or pull phase. It is most comfortable to breathe when the least amount of head rotation (with respect to the body) is necessary – which is when the torso is rotated the most (during the exit phase).

During the **pull phase** of a breathing cycle, the arm, leg, and body positions are the same as during a non-breathing cycle. The swimmer should focus on the hand of the breathing side during the pull phase. This prepares the swimmer for timing the start of head rotation.

During the **push phase** of the freestyle breathing cycle, the swimmer must be ready to rotate the head as the hand on the same side passes beneath the head. The head begins to rotate as the hand on the same side completes the push phase.

During the **exit phase** of the freestyle breathing cycle, the head is in a position so that the swimmer's mouth is above the surface. The swimmer has the exit phase (about .2 sec) to inhale.

CUE

For an optimal breathing position:

- The ***visual cue*** is to rotate the head until you can see the surface of the water.
- The ***kinesthetic cue*** is to rotate the head until your mouth is barely above the surface and you feel the corner of your mouth touching the surface of the water.

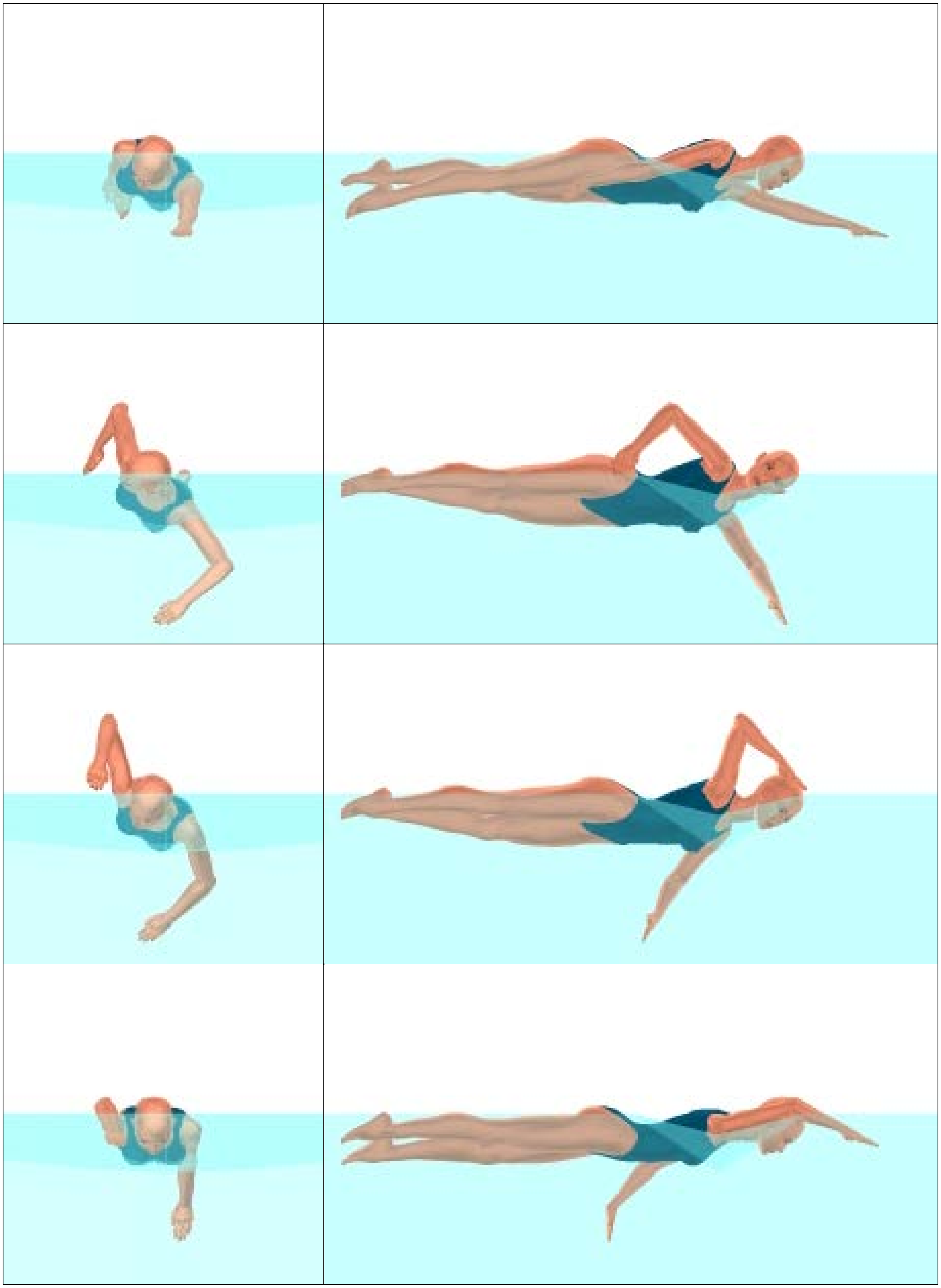


Figure 14. The head motion for breathing.

Many (actually, most) swimmers rotate their heads too much. As you rotate your head to the side to breathe, look for the surface of the water to come into view. As soon as you can see the surface, stop rotating your head and check if the lower corner of your mouth is touching the surface. If so, you should be able to breathe without inhaling any water. If not, you need to rotate your head slightly more, while staying visually focused on the surface.

It is important to only rotate the head to breathe. Many swimmers will drop their head, and some will slightly lift their head. If a swimmer only rotates the head, he/she will be looking to the side at a point directly opposite the position of the head. If the head is raised (neck extended) during rotation, the swimmer will see a point slightly in front of the head position. If the head is dropped (neck flexed) during rotation, the swimmer will see a point slightly behind the head position. Asking a swimmer about the exact point they see when they breathe is an effective way to help them breathe by only rotating their head and not lifting or dropping it.

Other visual cues can help with the head position for breathing. You are looking underwater through both goggles in the non-breathing head position. As the head rotates to breathe, check that you are looking underwater through one goggle and above the surface through the other goggle.

TIP: When breathing, the hand on the side opposite the breathing side often moves laterally (away from the body) to stabilize the body. While this motion is natural, it is not effective. It is important to practice numerous non-breathing repetitions focusing on both the visual and kinesthetic cues of the arm entry and pull, so that on a breathing stroke you can comply with effective motions by only relying on the kinesthetic cues.

If a swimmer develops a fast and efficient breathing motion, the body position will not be distorted and there will no reason not to breathe when necessary. Breathing every right arm or every left arm should not generate extra resistance and negatively impact performance.

A common misconception is that breathing every third stroke (i.e. alternating sides) will “balance” the stroke. While breathing on both sides can improve perception and help a swimmer to gain symmetry, there is no guarantee. It is still important to check the cues to assure a symmetrical stroke.

Chapters 7-10 are not included in this sample.

APPENDIX A: TECHNIQUE FAQS

1. How do swimmers with obvious technique problems still swim very fast?

Fast swimming is determined by a number of factors - physiological, psychological, biomechanical, etc. A swimmer may be so gifted in one attribute (e.g. strength, lung function, pain tolerance) that it offsets his/her technique limitations. A swimmer with a high maximum oxygen uptake (75 ml/kg/min) or a high peak hand force (60 lbs) can have substantial technique limitations and still swim very fast.

2. Which fast swimmer has perfect technique?

Our research shows that faster swimmers have more effective technique than slower swimmers. However, our research also shows that even the fastest swimmers have limiting factors. If you copy the technique of an Olympian, you risk adopting their limiting factors as well as their positive technique elements.

3. What about the _________ (characteristic technique element) of ___________ (Olympic champion)?

A characteristic technique element of an Olympian may be obvious, but not necessarily helping him/her swim faster. It's vital to differentiate between characteristic technique and effective technique, especially in Olympians.

4. What is the most important factor in swimming propulsion?

Hand force is the single most important factor in swimming propulsion. Research shows that hand force is directly related to swimming speed - the greater your hand force, the faster you swim. Research also shows that faster swimmers generate more hand force than slower swimmers. While most swimmers have peak hand force values of less than 50 lbs (220 N), Olympians generate as much as 80 lbs (350 N). The arms account for about 80% of total propulsion and hand force accounts for about 80% of arm propulsion, so learning how to position your arms to generate maximum hand force throughout the stroke cycle is essential to swimming your fastest.

5. How do you increase hand force?

Most swimmers can increase hand force by increasing hand speed throughout the stroke cycle. Improving bilateral symmetry, minimizing wasted motion, and decreasing force losses will help to increase the average force on each stroke.

6. How do hand force values vary within a stroke cycle?

The arm can move into stronger and stronger positions at faster and faster speeds throughout the stroke cycle. Hand force peaks about halfway into the push phase (after the arm passes the shoulders) for freestyle, butterfly and backstroke. For a swimmer with effective technique, the force value on the push phase is typically twice as much as on the pull phase.

7. What is the most important part of the freestyle stroke?

The entire stroke cycle is important. Most swimmers don't take full advantage of the push phase because the arm exits prematurely. Maintaining the elbow below the surface can increase the force and time of the push. A swimmer who does not double the force from the pull to the push has a major technique limitation.

8. What causes shoulder injuries?

Three contributing factors to shoulder injuries are: overuse (excessive training distance), ineffective technique, and inadequate strength training. Any single factor can cause injury, but a combination is often responsible. A decrease in training distance, a change in technique to decrease stress on the shoulder, and strength training that targets muscular imbalances are all necessary to recover from a shoulder injury.

9. Can hip rotation increase hand force in freestyle?

No. In freestyle, the torso rotates about the polar axis (a reference axis through the center of the body from head to feet). Summation of forces requires that successive body segments (e.g. torso, upper arm, lower arm, hand) rotate in the same direction (as in throwing). The freestyle arm motion is perpendicular to the torso rotation and the hand force cannot be increased by the force of hip rotation. Although the timing of the push phase in freestyle is usually simultaneous with torso rotation, rotating the hips harder or faster will not increase hand force. Exaggerated torso rotation can even produce counterproductive motions.

10. When is gliding recommended?

It is appropriate to glide when the body is moving faster than swimming speed. For example, when the body enters the water after a start or leaves the wall after a turn, it is moving faster than swimming speed and gliding is appropriate. There is one other time when gliding may be appropriate. During breaststroke, for a fraction of a second after the kick, the body may be moving faster than swimming speed. When this is the case, it is counterproductive to immediately begin the arm motion.

11. Is there a glide phase in freestyle?

No. Gliding in freestyle (usually associated with "catch-up stroke") is counterproductive. During a glide phase, there is no propulsion from either hand. The body slows down and requires considerable energy to speed up. The energy cost of speeding up on every stroke is greater than maintaining a relatively constant speed. Gliding in freestyle is biomechanically ineffective, physiologically inefficient, and anatomically stressful.

12. What is the most important factor in swimming resistance?

Reducing the body cross-section (the area perpendicular to the direction of body motion) is the most important factor in swimming resistance. Keeping the hips and legs directly behind the shoulders minimizes the cross-section.

13. What's the best measure of swimming technique?

Counting strokes is the easiest way to measure technique, but not the best. A decrease in stroke count does not always indicate a more effective technique. An increase in stroke count does not always indicate a less effective technique. The active drag coefficient is the most accurate measure of swimming technique.

14. What's the best way to control technique changes?
Skills must be learned at a slow swimming speed. Once a swimmer has learned to control his/her movements at a slow speed, gradually increasing the stroke rate will help a swimmer maintain control at faster speeds. Individual instructional sessions and regular analysis sessions expedite the learning process.

15. Is the head completely submerged in freestyle?
No. One of the many misconceptions about swimming technique is that the head must be submerged for the legs to stay behind the shoulders and minimize resistance. A more effective way to minimize the body cross-section is to arch the lower back to bring the heels to the surface. Maintaining the water level just above the hairline puts the head in an optimal non-breathing position that also minimizes the head motion necessary to breathe.

16. As the elbow flexes at the beginning of the freestyle pull, does the forearm become vertical?
If the elbow is flexed and the forearm is vertical, the hand must be lateral (to the outside of) the shoulder. As force is applied during this motion, torque is generated and the body twists about the antero-posterior (front to back) axis. Twisting the torso increases resistance and slows swimming velocity. It is more effective to diagonally orient the forearm during the pull phase, so that the hand passes beneath the head. The swimmer will benefit from the improved mechanical advantage of the elbow angle and have the arm in a stronger position to generate force on the push phase.

17. Do hand paddles cause shoulder injuries?
While it's possible for paddles to cause an overload on the shoulder joint, it is far more likely that an ineffective technique is to blame for a shoulder injury. For example, if the arm entry on freestyle is parallel to the surface, the arm is in a weak and awkward position that can stress the shoulder when the pull begins. Swimmers often continue torso rotation after the entry is complete, which further stresses the shoulder. If additional stress is added with paddles, the combination of these three factors is equivalent to a "perfect storm" for the shoulder.

18. Should I stop wearing hand paddles if I have a shoulder injury?
If hand paddles cause shoulder pain, it is advisable to stop wearing them during conditioning. Paddles can serve a very important purpose, however, during technique work. Paddles slow the hand speed and make it easier to track the hand path that is within the swimmer's field of view. Paddles also make the orientation of the hand on entry and exit more obvious. The enhanced feedback is vital to improving technique to overcome the injury.

19. Can hand paddles improve technique?
In spite of advertising claims, improving technique is far more complicated than just wearing a piece of plastic on your hands. There is no research that supports an improvement in technique by simply training with a specific paddle design. The paddle goes where the hand takes it, not the other way around. The strength training benefit of paddle design, however, has been documented.

20. Why don't swimmers get more technique instruction during team practices?

If you do the math, it's easy to understand why there's not more time for instruction during a team practice. On a typical team, a coach will have 30 swimmers for a 2 hour workout. If only 30 minutes of the coach's time is taken up by explaining sets, fixing goggles, checking performance times, etc, he/she has 90 minutes left. If the coach uses all of the remaining 90 minutes for technique instruction, each swimmer gets 3 minutes of individual attention per workout. On the average, 3 minutes is only enough time for a coach to evaluate and interact with a swimmer about a single technique element.

21. Will 10,000 hours of practice make a swimmer an expert?

The 10,000 hour guideline is probably sufficient to make a swimmer an expert with respect to training, but not technique. Many swimmers have trained for 10,000 hours by the time they finish high school. Very often they have considerable expertise in training (effort level, intervals, etc), yet still have not mastered technique. Swimmers must practice with cue-focused strategies for the hours to count towards making them an expert.

22. Are strokes "driven" by the shoulders, core, hips, torso or body?

In attempts to get swimmers to maximize effort, care must be taken to avoid counterproductive actions. For example, Aquanex testing shows that swimmers emphasizing hip rotation in freestyle often slide their hand sideways and upwards on the push phase in the same direction as the hips, resulting in a sudden loss in hand force. Recent research by Dr. Tim Henrich (presented at BMS 2010 in Norway) found that contracting abdominal muscles decreases pulmonary function. Pioneering work by Dr. Jan Clarys (one of the world's leading biomechanists for over three decades) showed that more skilled swimmers only used muscles critical for an activity, while less skilled swimmers also activated nonessential muscles. An increased effort is more likely to improve performance if there no negative aspects from actions that increase resistance or fatigue.

23. Is a straight arm recovery in freestyle beneficial?

There are at least three reasons not to use a straight arm recovery in freestyle. 1) If the arm is straight as it exits the water, the upward arm motion will force the body further underwater and cause needless fatigue. 2) If the arm is straight as it recovers through the air, it is more likely to stress the shoulder. 3) If the arm is straight on entry, misdirected force will waste time and energy. While some swimmers may benefit from improving their push phase in an effort to straighten the arm for recovery, it is far better to improve the push phase independently of the arm recovery.

24. Is it more important to decrease resistance or increase propulsion?

It depends on the individual. If a swimmer's legs are below the torso causing an increase in the body cross-section, decreasing resistance could make a sudden improvement in performance. A swimmer who has .2 sec of wasted arm motion at the beginning of each stroke cycle, would see a dramatic time drop from adjusting the arm motion to generate more propulsion.

25. Is a different freestyle technique used for short course and long course?

There are data that shows that some swimmers use a different technique for short course and long course. However, an optimal technique is identical for short course or long course. Minor differences in stroke rate and stroke length would be related to the distance of the swim, as opposed to the distance of the course.

APPENDIX B: CUE CHECKLIST

FREESTYLE	Y/N
When not breathing, is the head motionless throughout the entire stroke cycle?	
When not breathing, is the water level at the hairline?	
When not breathing, is the vision directed ahead at a 45^{o} angle?	
On the kick upbeat, do the heels break the surface?	
During the kick, do the toes point back toward the pool wall?	
Does the hand enter the water directly in front of the shoulder?	
At completion of the arm entry, does the arm straighten completely?	
At completion of the arm entry, is the hand directly in front of the shoulder?	
At completion of the arm entry, is the hand below the elbow?	
At completion of the arm entry, is the elbow below the shoulder?	
At completion of the arm entry, have all the bubbles dissipated?	
As the arm pulls back, does the elbow begin to bend?	
As the arm pulls back, does the hand pass beneath the head?	
At the completion of the push phase, does the thumb touch the thigh?	
At the completion of the push phase, does the arm straighten completely?	
At the completion of the push phase, is the arm completely submerged?	
At the beginning of the arm exit phase, does the elbow break the surface first?	
As the arm passes the shoulder on the recovery, does the elbow point up?	
During the arm recovery, is the hand close to the side of the body?	
During the arm recovery, is the elbow the highest part of the arm?	
At the completion of the push phase, does the head rotate for breathing?	
When breathing, is the vision directed across the water surface?	
When breathing, is one corner of the mouth at the water level?	

APPENDIX C: INTERNET RESOURCES

Freestyle Cue Checklist -
http://www.swimmingtechnology.com/Papers/Cue%20Checklist.pdf

Technique FAQs – http://www.swimmingtechnology.com/index.php/faqs/

Technique Tips – http://www.swimmingtechnology.com/index.php/technique-tips/

Technique Misconceptions -
http://www.swimmingtechnology.com/index.php/misconceptions/

The effect of technique on performance -
http://www.swimmingtechnology.com/index.php/resistance-research/instruction-improves-drag-coefficient/

Propulsion - http://www.swimmingtechnology.com/index.php/propulsion-research/

Resistance - http://www.swimmingtechnology.com/index.php/resistance-research/

Injury Prevention - http://www.swimmingtechnology.com/index.php/injury-prevention/

Freestyle Breathing - http://www.active.com/swimming/Articles/Perfect-Your-Breathing-With-a-Better-Body-Position.htm

Advanced Technology -
http://www.coachesinfo.com/index.php?option=com_content&view=article&id=10086:analysis-of-swimming-performance-using-advanced-technology&catid=41:swimming-assessment&Itemid=85

Focused Practice - http://www.swimmingcoach.org/wsca/pdf/WSCAnl2011-02.pdf

Arm Synchronization -
http://www.swimmingtechnology.com/index.php/research/arm-synchronization/

APPENDIX D: SELECTED STR TECHNIQUE RESEARCH SUMMARY

1. Hand force is directly related to swimming velocity.

As swimmers increased their hand force, they swam faster. Swimmers with higher hand force values swam faster than swimmers with lower values. There was a quadratic relationship between hand force and swimming velocity that was consistent with theory.

Havriluk, R. (2004). *Hand force and swimming velocity*. Paper presented at the XVth FINA World Sports Medicine Congress, Indianapolis, IN, October.

2. Faster swimmers have more effective technique than slower swimmers.

Aquanex clearly found that faster swimmers have a more effective technique than slower swimmers, as indicated by a lower active drag coefficient. The results also showed an improvement in technique with age. The coefficient of active drag was found to be a valid measure for the effectiveness of swimming technique.

Havriluk, R. (2003). *Performance level differences in swimming drag coefficient*. Paper presented at the VIIth IOC Olympic World Congress on Sport Sciences, Athens, Greece, October.

3. Even the fastest swimmers do not have an optimal technique.

Reviews of thousands of trials of Aquanex+Video revealed three typical limiting factors: 1) bilateral differences, 2) force losses, and 3) wasted motion. Each of these factors has been observed in some of the fastest swimmers in the world.

Havriluk, R. (2006). Analyzing hand force in swimming: three typical limiting factors. *American Swimming Magazine*, *2006*(3), 14-18.

4. Swimming velocity and drag coefficient improve with instruction.

Aquanex results demonstrate that even a relatively short period of carefully targeted instruction can make a meaningful improvement in technique (as measured by the active drag coefficient) and performance (as measured by swimming velocity).

Havriluk, R. (2006). *Magnitude of the effect of an instructional intervention on swimming technique and performance*. Paper presented at the Xth International Symposium on Biomechanics and Medicine in Swimming, Porto, Portugal, June.

5. Aquanex research findings are reliable and valid.

The initial research on Aquanex showed that the system was reliable and valid. A series of three experiments found a greater force value for competitive swimmers than for recreational swimmers; for swimmers treated with an instructional intervention than without the intervention; and for swimmers after being coached than before coaching.

Havriluk, R. (1987). *Validation of a criterion measure for swimming technique.* Paper presented at the VIIth FINA World Medical Congress, Orlando, December.

APPENDIX E: SELECTED REFERENCES

Havriluk, R. (2012). Do Expert Swimmers have Expert Technique? - Comment on *Arm Coordination and Performance Level in the 400-m Front Crawl* by Schnitzler, Seifert, and Chollet (2011). *Research Quarterly for Exercise and Sport*, 83(2), 359-362.

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Havriluk, R. (2007). Variability in measurement of swimming forces: A meta-analysis of passive and active drag. *Research Quarterly for Exercise and Sport*, *78*(2), 32-39.

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Becker, T., & Havriluk, R. (2006). Bilateral and anterior-posterior muscular imbalances in swimmers. In J. P. Vilas-Boas, F. Alves, A. Marques (Eds.), Biomechanics and Medicine in Swimming X. *Portuguese Journal of Sport Sciences*, *6*(Suppl. 2), 327-328.

Havriluk, R. (2006). Analyzing hand force in swimming: Three typical limiting factors. *American Swimming Magazine*, *2006*(3), 14-18.

Havriluk, R. (2005). Performance level differences in swimming: A meta-analysis of passive drag force. *Research Quarterly for Exercise and Sport*, *76*(2), 112-118.