by

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About the Author

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**Videos**

The majority of the videos are located at this address: http://vimeopro.com/user20211801/dryland. This video password is 'strong'.

The password for the videos in parts I - IV is ‘CORSMR’.

The password for the videos in parts VI - VII is ‘swim@rio2016’.
Preface for Edition II

Since the first edition of *Dryland for Swimmers* I’ve began working with more clubs of various sizes. With this experience, I’ve slightly revised the programs and structure. In the second edition, I’ve added a detailed flowchart of progressions and regressions for the main body movements. Remember, this flowchart can be created for any exercise. Also, I’ve added great detail in how to present this program and how to work in partners in this edition.

As a coach, it is impossible to watch everyone at once. During dryland, the swimmers can work with one another and provide value feedback and motivation for one another. I can’t encourage you all enough to have your swimmers work in partners and challenge, correct, and motivate one another! This scenario does make more work for the coach, as they must know exercise biomechanics and progressions/regressions for each exercise. This extra time studying for the coach will only benefit the swimmers, the goal of any swimming team.

Lastly, remember most swimmers who are bored with dryland aren’t challenged. Find appropriate exercises, truly pushing and challenging them and I assure you the swimmers will be engaged, stronger, and healthy.

Keep Swimming,

John Mullen
Santa Clara, CA December 13, 2015
Preface for Edition I
Eighty-three - ninety-three percent of swim coaches report using dryland (Krabak 2013). Unfortunately, providing safe, beneficial, and realistic dryland is difficult as the fitness industry complicates the subject. Coaches, particularly biomechanically driven sports, suffer from this excessive promotion. The fitness industry is a multi-billion dollar avenue, as obesity and obesity related diseases rise. This results in many people hopping from one form of exercise to the next. One example, CrossFit is the latest fad sweeping the fitness industry gaining media attention from its CrossFit games to overhead squatting pregnant women. Yet, CrossFit is just the latest fad, as many other exercise prescriptions like it have come and gone, often complicating what aspects of dryland are beneficial for swimming. CrossFit and other training programs use high-intensity training of full body Olympic lifts. Mastery of these techniques takes years of specialized training. Many coaches simply aren’t qualified. Coaches, how would you feel if some weightlifter felt like he could coach your swim team?

Moreover, enthusiastic fitness instructors hop on fitness fads more frequently than not, each time boasting they have the latest and greatest routine for the mother of two or Olympic swimmer. Unfortunately, any program which insists one program fits all is a lie! The principle of individuality is essential from the pool to dryland, which is often dismissed in swimmers. Overall, the dryland for swimming industry has been hindered mostly by the following issues:

1. Conditioning based programs: Most swimming programs focus on improving the swimmers physiological capacities (Stager 2005). Conditioning training attempts to improve the athlete’s work capacity. This has resulted in many programs also utilizing a conditioning strategy outside of the water during dryland. Unfortunately, this emphasis may impair movement biomechanics, as conditioning-based programs impair biomechanics (Frost 2013). Also, if someone is swimming 15 - 20 hours a week, they likely don’t need more conditioning. This is an immeasurable error as swimming success is largely based on biomechanics (Lätt 2002). Also, using non-specific forms of exercise training may impair swimming training and potential biomechanical improvement.

2. Non-swimmers: Now, dryland is a beneficial tool, but prescribing conditioning based dryland programs isn’t necessary for elite, in-shape swimmers. Swimming often gets trainers from other sports [often basketball or football] who don’t understand transference of on-land training to swimming (CrossFit is one example as it does appear beneficial for fat loss, a seldom goal of swimmers). In other words, something may be beneficial in one scenario, but detrimental in another. There are no courses (that I’m aware of) on this subject, yet strength coaches for other sports and general trainers have the audacity to
make sales pitches to swim coaches, telling them they know how to improve their swimmers. Now, a great coach or strength coach doesn’t need to be a swimmer or past swimmer, but understanding the demands and biomechanics of the sport are obvious prerequisites. Also, understanding what can be left out of a program is an important trait for the dryland coach. Inadequate swimming background impairs strength coaches from individualizing and assessing weaknesses.

3. Marketing and viral promotion: As someone in the fitness industry and rehabilitation world, I have a unique view on popular or trendy training methods. The fitness industry is a growing market with many benefits: building community, friendships, and preventing obesity/cardiovascular problems. Unfortunately, these benefits are already addressed in sports. Marketing influences all our decisions ranging from exercise regimens to soda. Just like food, the products with the most marketing and labels screaming their health benefits are likely the least beneficial! I mean, when the last time you saw a healthy sticker on a vegetable was! Make sure you look at the research on any exercise fad, and then use common sense in combination with your knowledge of physiology, psychology, and biomechanics.

4. Strength is cool: Hard bodies, 6-pack abs, and out-of-water strength are commonly sought by many (especially men). Unfortunately, the correlation of these and swimming success is questionable. A “good” physique may enhance a swimmer’s confidence, but mental training and visualization techniques are likely more effective. Understanding the individual weakness of each swimmer is key, and then having an evidence based approach of instructing the swimmer on improvement is essential. Sure, not all will listen at first, but with individualization and improvement their tune will change.

Many strength coaches and other fitness enthusiast will argue against these points, but use your knowledge, research, and commonsense for your practice. Caution all opinions by strength coaches and fitness enthusiast as they often make irrelevant claims from their own fitness experience (often outside of swimming) and use them in their views. This is a massive flaw as the needs of each individual are specific and the needs of any swimmer are far from the needs of non-swimmers. Remember, we are all susceptible to marketing, which the fitness industry has done elegantly.

Hopefully, this book can provide an in-depth analysis of dryland, while providing practical advice for the coach, strength coach, swimmer, and/or parent. Remember, a book contains finite information. Much more information is available on these
subjects and much will change in the upcoming years. Also, there are many roads to success, just don't fall into the many traps of the fitness industry.

John Mullen, DPT, CSCS
July 2014 San Jose, CA
Background of Dryland and Swimmers

Nuances of Swimming

In high school, I swam in a summer swim league. I thought I was cool, I was pretty fast, and liked lifting weights and dryland more than I liked swimming. I was from a suburb in Dayton, Ohio, and no matter how fast you were, a US Open champion or Junior National Champion, you did this summer league. There are two unique items about this league:

1. This summer league competed in short course meter pools.
2. Future NFL players competed in this league.

When I was 15-years old, I swam against future center of the Ohio State University and New York Jets Nick Mangold and sister of Olympic power lifter Holley Mangold, she swam in the same league, but not against me...luckily!

I'll never forget stepping behind the block, hands shaking as it put on my goggles for the 50-free. He was 6’5”, 300 pounds and had a beard like he just escaped from a cave. I thought he would eat me for lunch before the race, but I put my goggles on, squishing them against my face a hundred times, with the mindset of beating this future NFL Pro Bowl lineman!

Take your mark, beep! I dove in, brought my tempo up to as high as possible (probably around 0.8 seconds/stroke) and after my first breath I saw him at my hip. At the turn, he was a body length behind, and at the finish I had won by
over four seconds. Despite the fact he (and even his little sister) could squat 4x my bodyweight I still won!

This short story isn’t meant to boast about my amazing summer league dual meet win, but instead to show that absolute out-of-water strength does not correlate with swimming success [as it was obvious Nick Mangold, his sister, probably his grandpa were stronger than me, as he could have thrown me]. But, he didn’t have the necessary components to beat me in swimming.

Before we continue, let’s get on the same page with a few definitions:
- Relative strength: Ratio of strength considers size. Think of ants, very strong for their size. Elite male sprinters only have a peak force of 50 - 80 pounds and on average 20 - 31 pounds of resultant force, a fraction compared to land athletes (Havrulik 2013, personal communications).
- Absolute strength: Total strength, think elephants.
- Motor control: Ability to coordinate body movements.
- Impairments: Any physical limitation preventing ideal movement.
- Principle of specificity: Performing a specific movement is only enhanced by performing that movement.

The specificity of movement isn’t a novel thought and has tricked many coaches into mimicking swimming movements outside the water [I’ve fallen for this in the past]. This was the likely the rationale behind the swim bench. Ironically this shoulder isolated movement is not sport-specific as it inhibits body rotation (limiting the biomechanical transfer), resulting in a different energetic response and over-stresses vulnerable shoulders (Sexsmith 1992). This stress increases the risk of overuse injuries and time away from the most specific form of training...swimming (Stiff 2000; Vermeil 2004).
The transference of any movement on land is far from the demands in the pool. Despite visual similarities, every swimmer uses unique yet imperceptible micro adjustments in their strokes to optimize balance, force, and deceleration. It is impossible to replicate these movements on land and attempting to be too "sport specific" may lead to confused motor programming (McGuff 2009). Also, similar strength training could impair swimming skill via interference, a phenomenon where one form of training interferes with acquisition of another skill (Reed 2013). This makes dryland extremely difficult for swimming dryland, as nearly every other sport can simply mimic the sports activities on dryland and limit interference. Stay away from specificity to prevent motor program confusion and returning to these resisted patterns when fatigue occurs in the pool.

Now, the lack of correlation between out-of-water strength and swimming does not suggest dryland is not important. Instead, taking a thorough evaluation of the swimmer keeping their short- and long-term goals in mind helps guides a needs assessment for elite swimmers (more on this later). Remember, dryland training is more than just improving strength, especially in sports where the biomechanics are the driving factor for success. Dryland should improve swimming potential by addressing weaknesses

Remember, swimming is a unique sport for many reasons, some including:

1. Prone body orientation
2. Arm and legs used simultaneous
3. Water immersion
4. Unstable medium of water
5. Minimal equipment use
6. Swimmers have brief periods of hypoxia
7. Highly dependent on biomechanics
8. The pool is the avenue for most energy system training
9. Brief breaks during turns
10. Water cools the body
11. Many more

Understanding these subtleties makes swimming vastly different and in need of a different approach. Dryland should enhance a swimmers potential. Dryland is the soil from which the flower grows, but the seed (swimming training) is where the flower comes from! This remark is echoed throughout the book, as swimming success is the end-game of swimming training, not land based.
Dangers of Improper Dryland

Now, at a glance one may not see the harm or mistake of performing incorrect dryland, but as you will see improper dryland can be hazardous, injurious, and wasteful for many swimmers, especially high-skilled swimmers. Remember; use the literature, personal knowledge, and common sense.

1. Injurious Dryland: The number one rule for coaches is “do no harm.” Just as health care professionals swear upon the solemn Hippocratic Oath to do no harm, coaches have an unspoken professional responsibility to their athletes’ well-being. When polled, coaches listed injury prevention as one of the main purposes of dryland (Krabak 2013). An injured athlete will not train up to his or her full potential. Swimmers have improved and will continue improve under many types of programs: high volume, low volume, linear periodization, undulating periodization, and several other variations. Improvement comes in many ways, but never an injured swimmer. A 2009 study from the American Journal of Sports Medicine looked at injury patterns in Division I swimming, analyzing a single program from 2002-2007 (Wolf 2009). Notable findings:
   a. Dryland training and non-training incidents out of the water caused injuries in 38% of the team.
   b. Freshmen were more likely injured than upperclassmen.

These are similar findings from a study more than ten years earlier (MacFarland 1996). This study included only female collegiate swimmers. Notable findings:
   a. On this team, 44% suffered dryland injuries.
   b. Another 11% suffered injuries out of the pool.
   c. Most dryland injuries were from lower body training. Pool injuries were upper body.

Here are two studies over ten years apart with data showing the same thing: lots of swimmers are getting hurt outside the water during dryland training. Whether improvement in upperclassmen injury rates resulted from freshmen adapting to the program or leaving altogether is unclear.

Now, this may sound like a leap, but the possible injury mechanism is two-fold:
   b. High-intensity dryland likely results in a higher degree of soreness. Increased soreness likely impairs biomechanics, which may increase injury risk in and out of the water.
As one can see, the literature and common sense make a strong case against using the ‘traditional’ form of dryland prescribed in college.

2. Excessive Soreness Impairs Swimming Biomechanics and Motor Learning: Many swim coaches are unfamiliar with proper resistance training to maximize relative strength and power. Strength coaches don’t appreciate “feel” or joint biomechanics of the water and the demands of swimming workouts. Now, many claim the success of a few athletes confirms a training program, but this is simply confirmation bias. No matter what program you prescribe, if you work with enough talented swimmers some will succeed! One study suggested performing barbell squats impaired joint biomechanics of the body weight squat (Hooper 2013). Excessive dryland programs result in sore swimmers feeling like wet noodles in the water. Soreness impairs biomechanics and likely prevents improving swimming skills, the main determinant of swimming success (Lätt 2012). If one is continually sore, it is unlikely they are able to make the biomechanical adjustments in the water to facilitate motor learning. Making swimmers sore during dryland also increases one’s injury risk, as soreness alters joint position and recovery.

3. High Volume Out-of-water Conditioning Impairs Conditioning: Another goal of CrossFit and other high-intensity dryland is sneaking in conditioning outside of the pool. Conditioning outside of the pool likely only helps swimmers with poorly designed swimming programs. Most studies find any form of additional training improves novice athletes, but highly skilled swimmers are not novice athletes. Energetics are becoming better understood and the specificity of each system is likely high in swimming. What this means is a 200-yard butterfly swimmer likely improves most from performing their 200-yard fly pace, not 30 minutes of flawed running on the pool deck in jeans and sneakers! Combine this with conditioning dryland programs where a swimmer is continually sore, it is unlikely they can swim at a high enough intensity to illicit the oxidative type II muscle fibers. If a swimmer was able to perform CrossFit and high-intensity swimming, it is more likely they will become overtrained, increasing the likelihood of becoming sick (Morgado 2012). Another concern with overtraining is the potential of impairing skeletal muscle growth (Xiao 2012). Lastly, overtraining increases the physiological and psychological burden of the athlete, a common corollary with burnout for the season, or worse their entire career (Theriault 1997).

The dangers of improper dryland are immense, yet many coaches continually perform these practices. Perhaps this is why the “burnout” rate and injury rates are so high in
the sport. Remember, the work a swimmer does in and out of the water as a young swimmer influences their later swimming. Also, young and novice swimmers improve with nearly all forms of training. Therefore, if a swimmer becomes injured or “burns out” the efficacy of the swimmers entire career is questionable.
Benefits of Proper Dryland

A proper dryland program provides numerous benefits for the coach, swimmer, club, and swimming community. Many simply think dryland improves strength, but this is only one facet. A proper dryland program provides a multitude of benefits, here are 10 of the benefits of a proper dryland:

1. **Improved strength**: Progressive strength training can improve their strength. Whether they are 10 years old or 18 years old, progressively challenging the swimmer with APPROPRIATE INTENSITY is key! Programs must use a sliding scale to enhance swimming dryland experience!

2. **Improved group camaraderie**: When swimmers begin monitoring and enhancing each other’s technique, they learn how to motivate one another and build a stronger team. Research demonstrates peer feedback is much more valuable than coaching feedback... Use the swimmers!

3. **Better team environment**: If the team is on a systematic program, the younger kids can see what the older kids are doing and see the connection. This connection builds a great team environment where the older kids can help the younger swimmers! Also, when you have a systematic dryland program, the kids are doing dryland with the team, building a great team environment.

4. **Improved parent and board environment**: Having the parents view dryland and see the team working together, monitoring each other’s form, and getting stronger shows them the value of a systematic dryland program.

5. **Reduced mental stress**: If all the coaches are on the same page, then there is less mental stress for the coaches! They have the dryland program and can simply work on coaching (at dryland), but also in the water!

6. **Reduction of Injuries**: Building strength, monitoring form, correcting form...all these items help reduce injuries with a systematic team dryland approach.

7. **Improved confidence**: Mastering a new exercise and progressing to a harder skill builds self-confidence, something lacking in many swimmers. If all you do is have your swimmers run, are they able to see themselves improve? If you give too hard or too easy of exercises, improvement won’t occur or be noticed!!! Make sure you are providing effective exercises for improved confidence!

8. **Improved body awareness**: When swimmers are monitoring each other, they are capable of helping each other with form and learn how to control their body in space.

9. **Improved posture**: Postural strength is a term I learned from legendary strength coach Vern Gambetta. If a swimmer has improved postural strength, their streamline will improve and their skills will greatly improve!

10. **Improved swimming**: All of these above reasons build to this point, the main point for swim coaches! A systematic dryland helps improve swimming performance! Make sure you are giving them what they deserve!
Research on Dryland

Once again, most coaches (80 - 93%) incorporate some dryland training (Krabak 2013). Yet, many questions exist in regards to dryland training. This is the current state of the literature of the exercise-intervention studies (Aspenes 2012):

1. Dryland Strength Training: Overall, the studies indicate there may be a positive association between maximal dryland strength training and swimming performance. However, due to a low number of studies, lack of information, variety between the interventions, subjective characteristics and effects, low numbers of study participants, combined intervention design and lack of randomized study designs, the effects are questionable.
2. Swim-Like Resistance Training: No evidence of the effect of training on the biokinetic swim bench on swimming performance. In-water resistance training may provide positive effects on competitive swimming performance. No evidence of improved performance by increasing the relative volume of swimming training with hand paddles.
3. Training the swimmer's Legs: It seems increased relative amounts of leg training do not seem to improve whole-stroke swimming performance. However, no randomized controlled studies have looked at the correlation of leg strength and swimming performance.
4. Respiratory Training: The studies are overall inconclusive as many different protocols have been used. However, initial studies are correlating forced expiratory volume over one second with sprint performance.
5. Exercise Training and the Energy Delivery System: Only one randomized study was reviewed in this category, but this concept is adapted from other sports. Since this is barely studied, more research needs to be done to suggest this form of training.
6. Impacts on Drag and Stroke Mechanics: Strength training may have positive effects of stroke characteristic, but so far the evidence is inconclusive.
7. Plyometrics: Conflicting research implies moderately trained swimmers improve sprint performance with plyometric training. However, the benefits of adding plyometric training compared to more swimming seem unimpressive. However, these studies are small and poorly randomized/controlled, so minimal these conclusions are mostly speculative.
8. Static Stretching: Overwhelming evidence suggests long, greater than 60 seconds, of static stretching impairs strength, power, and balance directly before an activity. However, static stretching may aide recovery and decrease sympathetic nervous system activity in immobile individuals.
9. Dynamic Stretching: Conclusive evidence suggests dynamic stretching is beneficial before exercise.
10. PNF Stretching: The research suggests PNF stretching increases range of motion more than static stretching, yet its effects on strength, power, and endurance are not well known. More research is needed on this subject.
11. Core Training: Of the numerous sports studies on core training, few have
addressed swimmers. One small study had beneficial effects of core training and swimming, but more research and more subjects are needed on this subject.

12. Injury Prevention Training: Despite the high injury rate, the few studies of prevention programs in swimmers suggest swimmer’s practices and beliefs need re-evaluating. On top of this, the traditional programs may not even be effective!
**Strength Training**

Not many studies have analyzed strength training interventions in swimmers.

Strass (1986) found a 7.3% improvement in 50m freestyle in the intervention group after a heavy, explosive strength training regimen (three repetitions per three sets at 90% resistance of one-repetition maximum (1RM), two repetitions per two sets at 95% of 1RM, one repetition at 100% of 1RM and one repetition attempted at 100% of 1RM+1kg) of the elbow extensors for four sessions per week across 6 weeks.

In addition, Strass (1986) did not supply any control group data from pre- or post-tests in numbers. He did, however, report a small, but possibly significant age difference between the groups (mean age 16.6 years in the intervention group and mean age 17.8 years in the control group, not reporting whether the difference was significant). Furthermore, the measurements of isometric force may limit the data interpretation, as swimming is a dynamic exercise and isometric tests may not always be an accurate measure of dynamic muscular capacity (Wilson 1996).

These findings were supported by Girold et al. (2007) who reported a ~2.8% improvement in 50m freestyle performance after 12 weeks of biweekly sessions of explosive dryland strength training (six different exercises with three times six repetitions of explosive-type strength training at 80-90% of 1RM). This trial compared strength training (S), resisted swimming (RS), and a control group (C; biking). The strength and resisted swimming groups had significant improvement in a 50-meter time trial. The strength group improved 2.8%, resisted swimming 2.3% and control 0.9%. There was no significant difference between the improvement of S and RS. Stroke depth was significantly decreased in the S and RS group. Stroke rate was significantly increased in RS and C, but not S. Isometric strength of the elbow flexors was significantly increased in S and RS, but not C.

Now, this study appears quite positive for resistance training, but the swimmers were intermediate in speed, and the type of control training may have inhibited performance. Moreover, only a 50-m was assessed and keeps in mind the resistance training protocol, low volume of repetitions (Girold 2007). Both studies also found improvements within the respective strength parameters, and concluded that their strength-training interventions were successful. However, data from small study groups are scientifically fragile compared with larger study groups, and like many of the other studies included in this review the findings of these studies may be limited by the low number of subjects (on average 4.5 and 7).

Girold (2012) more recently looked at twenty-four national-level competitive swimmers (M=12, F=12; ~21.8 years; 27.8 ± 1.8 seconds top 50 m time) who averaged 20 hours of swim training per week. These swimmers were split into dryland (S), electrical stimulation (ES), and control (C) groups. The strength sessions were 15 minutes long, preceded by a 10-minute warm-up which was performed 3 times per week before swimming. The program included 3 sets of 3 exercises with 2 minutes
rest between each set. Each set consisted of a maximum of 6 repetitions of pull-ups and draws with pulleys. “The swimmers were instructed to pull on the bar until it reached the level of the chest when performing pull-ups and first draw exercises. For the second draw exercise, swimmers were instructed to pull on the handle until it reached the level of the hips.”

The exercises were performed between 80 - 90% of 1RM and each participant was instructed to perform the concentric phase as fast as possible, followed by a 3 second isometric phase and a slow eccentric phase. The ES program performed the same 10-minute warm-up as the S group followed by electrical stimulation to the latissimisdorsi. A significant improvement was noted at week 4 in the S and ES group. S and ES both showed improvement at 8 weeks, but were not significant from one another. After 4 weeks stroke length was significantly increased in the S, but not the ES or C group. Peak torque significantly increased at moderate and fast speeds for the S and ES group. ES also improved in strength for isometric and eccentric contractions. No differences were noted between men and women.

Again, these results seem quite positive for resistance training, but keep in mind; it only looked at a 50-m velocity, no longer distances. Moreover, the volume of resistance training was quite low. For ES, it is likely this low volume may have increased strength.

Aspenes et al. (2009) observed improvements in 400m freestyle swimming performance, which was suggested to be related to a strength training regimen. In the study, a combined intervention of strength (~two weekly sessions of an explosive pull-down strength training regimen of five repetitions with maximal load relative to the number of repetitions over three sets) and endurance training (two weekly sessions of 4 times 4 minutes of high-intensity interval training), was compared with a control group that only performed regular swimming training. Mean age in the intervention group was 17.5 years (n = 11, 6 males), and in the control group 15.9 years (n = 9, 2 males).

Although the latter paper (Aspenes 2009) partly agrees with the aforementioned trials, indicating that dryland strength training may benefit swimming performance, a
crossover effect from the endurance intervention may potentially have influenced the findings (Aspenes 2009). The latter study (Aspenes 2009) may also be limited by the lack of a RCT design, like many other studies in this review. In addition, the intervention group and the control group were not similar with respect to sex (7 of 9 subjects were female in the control group, 5 of 11 subjects were female in the intervention group).

Recently, Burd and colleagues (2010) observed a prolonged myofibrillar protein synthesis after three-set strength training compared with one-set training. That finding may possibly explain the mechanisms behind improved swim performance after combined maximal strength and endurance training.

In contrast to the earlier studies, Tanaka and colleagues (1993) found no significant improvements in either 22.9 or 365.8m swimming performances after 8 weeks of dryland strength training. Tanaka et al. (1993) compared an intervention group
The combined strength training and swim group (combo) declined maximal swimming velocity between week 2 and 8 of the study. The decline was not significant compared with the control group. The combo group had improvements ~25% during dryland tests, while the swimming only group did not have improvements in this area. The decline coincided with attendance at seven competitions within the 6-week study period, and may thus possibly be a sign of overreaching or overtraining, and may subsequently eliminate possible benefits from the strength training intervention.

This hypothesis was also discussed by the authors, but rejected, since stable serum cortisol concentrations were observed in the swimmers. The healthy range of normal cortisol levels and its relation to overreaching are, however, debated, and an overreaching effect can therefore not be completely ruled out. The strength intervention in the study from Tanaka et al. (1993) involved a higher number of repetitions of the strength training exercises than the previously discussed papers. It has been suggested that one needs to lift or move more than \( \approx 70\% \) of 1RM for the strength training to be beneficial, (MacDonald 1984) and the strength training intervention applied by Tanaka and colleagues may not have the appropriate load (three sets of 8-12 repetitions, load not stated but training was supervised) to cause increased muscular strength. In their paper, the authors suggested that the strength training regimen may not have been sufficiently specific to affect swimming performance.

A study from Trappe and Pearson (1994) compared weight-assisted training (three sets of dips and pull-ups with no assistance until volitional fatigue, 13.6 kg assistance and 22.7 kg assistance, respectively) to dryland strength training (six exercises with three sets of 8-12 repetitions with progressive maximal load until exhaustion) in addition to common swim practice, and found no differences in 22.9 or 365.8m swimming performance between the groups. However, the possible effects were inadequately controlled, as the strength training intervention was carried out during the first 6 weeks of a 12-week observation, and performance tested in weeks 4 and 12 in both groups, which makes it challenging to draw inferences.

Correlating dryland strength, power, and swimming performance is also commonly performed. In 65 collegiate swimmers, strength measures which included 1 RM of the bench press, latissimus pull down, and triceps press were assessed. Dryland power was assessed using a seated chest press and a two-arm supine overhead throw for distance using a 6-lb medicine ball. Swimming power was assessed by performing a 30-s, maximal effort, tethered, crawl stroke swim. Competitive times for 50 and 100-m crawl strokes were used as measures of swimming performance. For the whole group, all relationships were significant. For women, the three strength measures
were related to dryland and swimming power. Only the 1 RM latissimus pull down was related to performance. For the men, muscular strength was related to dryland and swimming power but not to performance (Crowe 1999).

More recently, twenty-three females (~18.9 years, non-swimmers) were taught the swimming start and split into a control or resistance training group (Breed 2003). The resistance training lasted 9 weeks and was performed three times per week (clean pull, barbell press, parallel squat, back extension and many more at varying training volume). Starting styles were correlated with jumping test, but not isokinetic squat tests. Also, resistance training improved the dryland test. However, alterations did occur in certain start variables. Importantly, the take-off velocity significantly improved in the track start. However, flight distance did not improve in the resistance training group. Horizontal impulse and hand impulse significantly improved for the resistance training group for the track start. Lastly, the flight angle significantly improved, likely due to the improvements in impulse. This suggests in untrained swimmers, resistance training can likely increase impulse and velocity for the track start (Breed 2003).

Sadowski (2012) randomly assigned twenty six male swimmers (mean age 14) to either a swimming or dryland power training (experimental) or swimming only (control) group. Then the subjects were tested with hydroisokinetic ergometer. The swimming training consisted of six weeks of doubles every day except Sunday and one training session on Saturday. All subjects swam 273.50 km during the whole experiment. The power training consisted of circuit training, of 6 sets of 50 seconds of work and 10 seconds of rest on the ergometer (Sadowski 2012). The experimental group had significant improvements in tethered swimming force, but both groups noted non-statistically differences in 25-m performance. This suggests extra ergogenic swimming does not improve performance.

**Summary:**
The reviewed studies of dryland strength training on swimming performance indicate that there may be positive associations between maximal dryland strength training and swimming performance. However, due to a low number of eligible studies, lack of information, variety between the interventions, subject characteristics and effects, low numbers of study participants, combined intervention design and lack of randomized study designs, further randomized controlled trials (RCTs) on the effects of dryland strength training should be carried out in competitive swimmers.
**Swim-Like Resistance Training**

A swimmer’s success is determined by the ability to generate propulsive forces while reducing resistance towards forward motion, i.e. drag (Toussaint 1992; Pedergrast 2005). The majority of propulsive forces in swimming are gained from the use of the arms (Smith 2002; Toussaint 1992; Hollander 1988). In freestyle swimming, more than 85% of the thrust is gained from the arms (Toussaint 1992). Holmer (1974) observed that the maximal freestyle velocity of flume swimming with only the arms can be at ~98% of the whole stroke. Arm power or arm strength is strongly correlated to maximal swimming velocity (Sharp 1982; Hawley 1991; Tanaka 1998). This correlation is stronger in the short swim distances (25-100 m), but also significantly correlated to performance in longer events (200-400 m) (Tanaka 1998). In an observational study on international swimmers across four seasons, it was observed that the moments of peak performance were associated with peaks in tethered swimming force (Gullstrand 1983).

A biokinetic swim bench mimics the prone position of competitive swimming (swimmer lying on top, facilitates the upper-body musculature used for freestyle and butterfly propulsion) (Sharp 1982). In a cross-sectional study it has previously been found that maximal power produced on the swim bench can be associated with competitive swimming performance in events ranging from 45.7 to 457 - m freestyle in a linear fashion. The latter study group consisted of 40 competitive swimmers (mean age 15.2 years) (Sharp 1982). It has also been found that swim bench power correlated with maximal swimming velocity, (Sharp 1982; Shimonagata 2003) and with swimming power in water measured under semi-tethered conditions (Shimonagata 2003).

**Summary:**

*Swim-like resistance training mimics swimming*

**Biokinetic Swim Bench Training**

Roberts and colleagues (1991) studied the effects of training on the biokinetic swim bench on a 91.4 m freestyle swimming performance. Conclusions were based on the comparison of a single intervention group to a control group (overall mean age was 19.1 years, group-specific information not given). The intervention group trained 3 times per week using 4 times 10-second intervals interspersed with three 10-second rest periods between the intervals on the swim bench in addition to regular swimming training. The control group only carried out regular swim training. No significant improvements in the 91.4-m swimming performance were observed after the Intervention period in either group in this study, but more studies are needed to conclude on the effect of training.

The finding that swim bench training does not improve swimming performance may contrast the previously described association between peak power on the biokinetic
swim bench and swimming performance (Sharp 1982). Since Sharp (1982) is cross-sectional and not prospective, it might indicate that it only describes an association and not a cause-and-effect relationship. In a small, uncontrolled substudy (four subjects) from Sharp et al. (1982) that was not included among the review papers, the authors found that a training regimen of five sets of ten maximal pulls 5 times a week on the biokinetic swim bench increased sprint velocity (Sharp 1982). Although the swim bench is suggested to reproduce some elements of regular swimming, (Roberts 1991; Sharp 1982) it cannot adopt the biomechanical aspects related to the athletes feel for the water (i.e. the drag propulsion relationship (Toussaint 1994) or circumstances related to water immersion (controlled respiration, (Cordain 1988) hydrostatic pressure (Pendergast 2009) and the antigravity effect (Pendergast 2009).

Summary:
There is currently no evidence of the effect of training on the biokinetic swim bench on swimming performance. There is a lack of RCT studies documenting the effect of swim bench training. It would be interesting to study whether swim bench training can improve other swimming events (Roberts 1999).
In-water Resistance Training

In-water resistance training can take many forms, ranging from buckets to swim racks. This is the literature on the topic:

Toussaint and Vervoorn (1990) used a ladder-like system of fixed rungs for measuring active drag (MAD) to investigate the effects of resistance against each stroke on performance. The MAD system is immersed in water at a depth where the swimmers can pull and push against the ladders during swimming. In an RCT the authors (Toussaint 1990) found improvements in 50m and 200m freestyle performance after 10 weeks of 1.8 weekly sessions of 30-minutes of freestyle sprints in the intervention group (11 subjects, 8 males, mean age 18.4 years, national competition level). The control group (11 subjects, 8 males, mean age 18.5 years, national competition level) performed ordinary sprints in parallel, but with less progress.

The main differential effects in favor of the intervention group were improved maximal swimming force power and swimming velocity on the MAD system. In addition, the intervention group had a significantly decreased number of strokes with maintained maximal velocity in both the 25m and 50m freestyle (Toussaint 1990). The intervention group was also faster at a post intervention competition in both the 50m freestyle (mean 0.6 seconds) and 200m freestyle (mean 2.5 seconds) and the control group were not. Although the latter findings are encouraging, it should be noted that the compliance of the study seemed poor.

According to the paper, the intervention group attended 48.3% of the training sessions, while the control group attended 46.8% of the training sessions. Furthermore, the intervention group attended 59.3% of the training sessions on the MAD system. Thus, both groups attained a low number of the available training sessions, but the intervention group attended a larger portion of the MAD sessions than the other training-sessions. This could subsequently result in an improved effect compared with the control group. Since the time of the post-test time-trial was not clear, the observed effects may also come from other efforts (for instance tapering or dietary effects). However, the swimmers were skilled (mean 50m freestyle time 27.5 seconds overall) before entering the study, which may limit the potential for improvement. However, the results of MAD training are encouraging for swimming improvement.

Instead of overloading stroke mechanics to fixed points, Mavridis et al. (2006) overloaded free swimming by dragging a perforated bowl for 3 weekly sprint sessions (n = 82, 53 subjects in the intervention group). The authors reported that the groups were balanced for sex, swimming style and competitive performance. Mean age in the intervention group was 14.7 years and in the control group 15.0 years. The researchers found that the intervention group improved both 100m and 200m best style swimming performance, compared with a control group that brought out equal sprint training without the bowl (Mavridis 2006). Although the study was not clear on when the post-test was carried out and why 65% of participants were placed in the
intervention group, the findings of Mavridis et al. (2006) are interesting in that they have a large population, and report positive findings from all four strokes.

In comparison, a study from Girold et al. (2006) compared one group that performed tethered swimming training with elastic bands with another group that trained with assisted training from elastic bands, and a control group. Although there were several weaknesses with the study (large initial differences in performance level, and only 3 weeks of intervention) and the findings were not overall consistent (strength increased significantly in control group), the researchers concluded that the tethered training group was more efficient in improving strength and 100m performance.

Based on the weaknesses, the conclusion of the latter study does not appear well founded. In a later more robust study, the same group of researchers (Girld 2007) found that a combination of assisted and resisted swimming training had the same, positive impact on 50m freestyle swimming performance as dryland strength training, and they were both superior to a control group. From that study, stepwise regression analyses indicated that the improved performance found in the dryland strength training group was associated with improvements in crude strength, while the performance improvements observed in the assisted- and resisted-swimming training group were primarily related to enhance technical parameters (i.e. increased stroke rate and decreased stroke depth).

Gourgoulis (2013) had eight female swimmers (mean age 16; mean top 100-meter time 63.91 seconds) perform four 25-meter sprints with and without added resistance. The resistance was: “[a] bowl with a diameter of 23 cm and capacity of 2.2 L, a bowl with a diameter of 26 cm and capacity of 4 L and a bowl with a diameter of 32 cm and capacity of 6 L were used as low, moderate and high added resistance, respectively [similar to buckets] (Gourgoulis 2013)”.

Participants did not breathe during the trial. Trials were performed in a random order and video recorded. “Resisted swimming did not significantly alter the velocity and the orientation of the hand. Although the mean resultant velocity of the hand during the pull and the push phases was decreased during resisted swimming, in comparison with free swimming, these reductions were not statistically significant. Moreover, no significant differences were found in the pitch and sweepback angles of the hand during both the pull and the push phases, between the experimental conditions (Gourgoulis 2013)”.

However, the stroke length, stroke rate, and velocity were significantly lower in the resistance training group. These results suggest swimming parameters do change with added resistance, but the biomechanical adjustments are not significantly different. These results oppose previous studies, potentially due to the level of these athletes, since elite swimmers have a pitch back angle of 50 - 60 degrees, but in this study the pitch back angle was 26 degrees. Also, the kinematics of the hands were estimated in this study. This study indicates resistance swimming does not significantly alter swimming kinematics. However, the method of analysis, amount of swimmers, and
level of swimmers must be considered. Also, the distance of 25-meters is not a competitive distance. Lastly, not breathing is also uncommon in swimming races >50-meters, suggesting this may apply to sprint (25 - 50-meter swimming), but more research is necessary on greater distances.

Parachute training is also common in swimming and a recent study by Schnitzler (2011) suggests this form of training is similar to regular swimming when performed at a high velocity.

**Summary:**

*In-water resistance training may provide positive effects on competitive swimming performance. However, the findings of Toussaint and Vervoorn (1990) need confirmation in an RCT with higher compliance, and it would be interesting to apply a similar intervention on butterfly swimmers. It is surprising that after more than 20 years, no other intervention studies from the MAD system were eligible for the present review. In addition, we also encourage researchers interested in competitive swimming to pursue the promising findings from Mavridis et al. (2006) further.*

*More common in-water resistance training appears beneficial and mimics in-water biomechanics when performed at high-velocity.*
Swim Training with Hand Paddles

Another method for overloading the arm stroke is the use of hand paddles. The method was studied by Konstantaki and colleagues across two trials (Konstantaki 2008; Konstantaki 2007).

In one study (Konstantaki 2008) they compared a group that applied arms-only training with hand paddles in 20% of every swimming session with a control group where ~6% of the training was arms-only training with hand paddles. The authors found no significant impact on the 372m freestyle swimming performance (testing was performed in a 21m pool) from increasing the relative volume covered with hand paddles.

In another study Konstantaki and colleagues (1998) compared arms-to-legs-only training (i.e. 20% of the total training distance of every training session was dedicated to limb-specific training), and found that the two regimens induced limb-specific improvements, while 400m freestyle swimming performance did not change in any group. However, the paper did not investigate whether arms or legs-only training may be better than regular swimming training.

Barbosa (2013) had fourteen well-trained male swimmers (~20.0 years; 87.4% of 100m world record) perform a standardized warm-up consisting of 10-minutes of self-stretching, 10 minutes of free swimming and four 15-m sprints 90 seconds apart. Five minutes was then given before the swimmers performed two sessions:

1) Propulsive force was tested during a 10-second maximal tethered swim
2) Swimming, velocity, stroke rate and stroke length were analyzed in 25-m maximal sprints. Five minutes rest was provided between the following conditions:
   a. Free swimming
   b. Small paddles (280 cm2)
   c. Medium paddles (353 cm2)
   d. Large paddles (462 cm2)
   e. Extra-large paddles (552 cm2)

The participants were asked not to breathe during the trials, but were allowed to kick in attempt to keep the whole stroke technique. The size of the paddles had a significant effect on

Figure 2. Shape and sizes of the hand paddles tested.
peak force, average force, minimum force, time to peak force, stroke duration, rate of force development and impulse. Swimming velocity was also significantly faster with the paddle size, while stroke length decreased with greater paddle size.

Stroke duration likely increased due to the increase in drag from the paddles. The significant increases of peak force suggest that the effect of hand enlargement compensated the decreases hand velocity; even those hand velocities have greater effect due to its quadratic relationship. With small paddles, no significant changes in peak force were noted, likely due to not a large enough increase in surface. Although peak force increased the most with the largest paddles, it also caused the greatest increase and change in stroke duration. Paddles likely provide an environment for improving swimming-specific arm strength, but the conditions are not exactly the conditions of free swimming. Since paddles do alter strokes by increase force production and drag, they must be individualized according to every single swimmer.

**Summary:**
There is no current evidence of improved performance by increasing the relative volume of swimming training with hand paddles. The training method should be subject to further RCT studies in all strokes. If using paddles, one must consider the biomechanical changes and prescribe individually.
**Training the Legs**

Konstantaki and Winter (2007) randomly assigned 15 male subjects to an intervention group (n = 8) or a control group (n = 7) with no anthropometrical differences at baseline, and found that increasing the relative volume of legs-only training (20% of total daily distance) compared with regular swimming training (on average 4% leg kicking) did not benefit 400m swimming performance. The groups had equal training volumes (in meters) throughout the study.

In a cross-sectional study, Ogita et al. (1996) observed that the summarized oxygen consumption (VO2) during arms-only swimming or leg-kicks only was higher than the VO2 during whole-body swimming (≈40.8% higher sum). In addition, the summarized anaerobic capacity of arms-only plus leg-kicking swimming was also higher than for whole-body swimming (≈56.2% higher sum). An unknown part of the surplus energy production may be a result of recruitment of the same stabilizing and respiratory muscle groups during both measurements. However, the observation could also indicate that there is a large unattained potential for energy release in whole-stroke swimming, or that the muscles of the arms and the legs are competing for the cardiac output (Secher 2006). It can also mean that the role of the legs in whole-stroke swimming acts more as a stabilizing factor to reduce drag rather than increase propulsion.

In a cross-sectional study on international-level swimmers, Gullstrand and Holmer (1982) observed that the performance in tethered leg kicking was not associated with overall swimming performance.

Another observational study observed that maximal leg strength was associated with diving distance (Miyashita 1990) but may also influence reaction time in the start, entry velocity from the dive, turn time or kick-off velocity after the turns. Those hypotheses have not been properly tested (Potdevin 2011) and there is thus a potential for future research.

**Summary:**

*Increased relative amounts of leg training do not seem to improve whole-stroke swimming performance. However, we found only one RCT, and studies designed to improve strength or power parameters in the legs will be of great interest. Relevant parameters might be maximal strength and the rate of force development in quadriceps and hamstrings from a starting position and in water when kicking away from the wall.*
**Dryland and Stroke Biomechanics**

As stated in the Introduction, biomechanics are the main factor for swimming success. A possible explanation for this might lie in the nature of swimming; forces being applied against a fluctuate element with the posture of the human body being the most important vector against propulsion. Swimming performance is thus determined by the athletes’ ability to produce forward motion while reducing water friction, or drag (Toussaint 1990; Pate 1984). The possible biomechanical effects (propulsive abilities and drag) from dryland must also be considered. Unfortunately, all the studies do not compare biomechanics, making the results of each study impossible to extrapolate the biomechanical results of training. Four studies observed improvements in stroke mechanics, specifically increased stroke length, (Toussaint 1990; Strass 1986), increased stroke rate (Girold 2006) and decreased stroke depth (Girold 2007) after strength training. None of the included studies investigated whether there was a possible training effect on active or passive drag.

Girold et al. (2006) found that improved swimming performance was positively associated with an increased stroke rate of the last 50m of a 100m freestyle time trial after 3 weeks of in-water resistance training (tethered to an elastic tube). Swimming velocity is the product of stroke rate and stroke length, (Craig 1985) and both factors should be optimized for maximal performance. Although stroke rate has been associated with maximal swimming velocity, (Wakayoshi 1995) stroke length is likely more important (Wakayoshi 1993).

For instance Craig and colleagues (1985) observed that stroke length was the factor that differentiated finalists from non-finalists during the US Olympic trials in 1984, and another study suggested that increased maximal velocity was an effect of increased stroke length (Wakayoshi 1993).

Girold et al. (2006) found decreased stroke depth after both combined resisted- and assisted-sprint swim training (tethered to an elastic tube pulling against or towards swimming direction), and dryland strength training. The researchers found increased stroke rate both in the combined resisted- and assisted-sprint group and in the control group, but not in the strength training group. Although the findings were not fully consistent, the authors concluded that the decreased stroke depth was a consequence of maintained stroke length when stroke rate was increased. However, if body rotation remains stable, decreased stroke depth may reduce the biomechanical momentum of the propulsive muscles, and thus decrease the potential for propulsion.

In the study from Toussaint and Vervoorn, (1990) they observed increased stroke lengths at equal maximal swimming velocities after resistance training on the MAD system. The observed change was suggested to come from increased maximal swimming power, although maximal swimming velocity was unchanged. Similar observations were also made after dryland maximal strength training in the study from Strass, (1986) but not in the studies from Aspenes et al., (2009) Trappe and Pearson, (1994) Tanaka et al. (1999) or Roberts et al. (1991). Faude et al. (2008)
compared the effects of low volume training with high-intensity versus high-volume training with low intensity, and observed no differential effects on mean stroke rates in either 100m or 400m maximal freestyle. High volume, low-intensity training is sometimes recommended for improving swimming economy, but none of the studies included in this review support that notion. However, the hypothesis needs more studies before any conclusion can be drawn.

Summary:
Strength training may have positive effects on stroke characteristics, but so far the evidence is inconclusive. Future RCT studies can probably be designed to study the effect of, or preservation of, stroke characteristics with strength training.
Plyometrics

Plyometric training is popular in many dryland programs, especially age-group swimmers. Although an area with most research studies, still many questions exist.

Cressor (1999) compared thirty-eight adolescent swimmers (-11.7 years) and split into an experimental (PG) or control (SG) group. Before and after the training, two hand-timed, push-start, maximal effort 50-m swims as well as vertical jump height were performed by each swimmer.

The SG performed three times per week for 1.5 hours and the PG group swam three times a week for 1.25 hours and performed plyometric training for 30 minutes before each session. The 30 minutes of plyometric were split into a warm-up, exercise period (15-minutes), and a cool-down. The main exercise period consisted of two sets of 10 - 15 repetitions completed. This volume was chosen to be approximately the same amount of tumble turns performed in the SG. Cressor notes no significant differences between the groups after 20-weeks of training.

Now, both groups improved, but there were no significant differences between these intermediate adolescent swimmers. Plyometric training volume equal to SG volume does not improve jump height or swimming parameters in intermediate level adolescent swimmers.

Bishop in 2009 took twenty-two trained swimmers (-13.1 years; minimum of 8 hours/week; best 50-m freestyle ~35 s) and split them into a plyometric training (PT) or habitual training (HT) group. The PT group was given an additional 2 hours per week of specific plyometric exercises for 8-weeks. Land and water testing was performed before and after the 8-weeks. The PT group had significantly greater change in time to 5.5 m, take-off to water contact, distance to head contact, and time to head contact. No significant changes were noted in angle out of blocks and angle of entry into water. The swim time to 5.5 was improved on average by 0.59 seconds or 15%.

PT improves starting power, subsequently improving swimming velocity when compared to no additional training in intermediate adolescent swimmers.

In 2011, Potdevin took thirty-three adolescent swimmers (M=10, F=13) who swam 5.5 hours/week and split them split into a control (C) or plyometric group (PG) for 6-weeks. The PG performed 2 training sessions/week and a total of 2,146 jumps were performed. The PG was systematic and progressive using a variety of double and single limb jumps. Swimming and land performance tests were performed before and after the 6-weeks. The PG had significant increases in the countermovement jump (CMJ) and squat jump (SJ). The PG had significant improvements in maximal glide speed. Swimming velocity during a 400- and 50-meter significantly increased in the PG.
Plyometric training improves power and swimming performance compared to no additional training in intermediate adolescent swimmers.

The effects of aquatic plyometrics on the performance of elite age-group swimmers’ freestyle turn time, 50-yd freestyle time, and vertical jump were evaluated. Ss were divided into an 8-week aquatic plyometric training group (N = 8) and a control group (N = 8). Land and aquatic vertical jump were measured five times during the study.

There was no significant difference between the groups in 50-yd time, flip-turn time, and both vertical jumps. Most of the factors measured were significantly related with each other.

Summary:
More RCTs with more subjects of elite caliber are needed for plyometrics. However, it seems plyometrics are beneficial, but potentially no more than extra swim training.
**Respiratory Training**

The relationship between breathing and swimming is unique in the sport world, as land-based sports do not require breath holding. Swimmers have a high respiratory capacity mainly related to elevated lung volumes and enhanced pulmonary diffusion capacity, compared with both nonathletic peers (similar sex, age and health status) and athletic peers from other sports (Cordain 1988; Magel 1969). These differences may partly express genetic advantages and partly come from swim training (Cordain 1988) where restricted breathing, water immersion and the prone position of swimming are suggested to be conditions that can explain the high-respiratory capacity. From other sports (rowing, cycling and running) the impact of respiratory training on competitive performance is unclear (Sheel 2002; Riganas 2008; Volianitis 2001) but if respiratory capacity is a modifiable ability seen in swimmers, it might also be adaptable to proper stimuli.

Three studies have investigated the impact of respiratory training on swimming performance in athletes at equal performance-levels (Kilding 2010; Wells 2005; Lemaitre 2013) but with contradictory findings.

Kilding et al. (2010) found significant improvements in both 100m and freestyle performance from 30 repetitions of maximal intensity inspirations, Wells et al. (2005) did not find any change in 200m freestyle performance. The intervention in the latter study was inspiratory and expiratory muscle training for 30 repetitions at 50-80% of maximal inspiratory and expiratory pressure before every swim training session across 12 weeks (ten sessions per week). Lemaitre (2013) had two homogenous groups of ten swimmers (M=13, F=7; between 13 - 18 years) were split into a RMET or non-RMET group over an eight week period. During this time period, the swimmers had the same training sessions 5 - 6 times/week. Respiratory muscle strength and endurance, performances on 50- and 200-trials, effort...

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**Figure 2.** Effects of respiratory muscle endurance training (RMET) on change in international point scores (IPS) during the actual competitions. Data are means (± standard deviation). * denote sp < 0.05.
perception, and dyspnea were assessed before and after. The RMET consisted of the use of a SpiroTiger, which helps prevent hypocapnia despite hyperventilation. The training consisted of 30-min of TS per day, five days per week. The results showed that ventilator function parameters, chest expansion, respiratory muscle strength and endurance, and performances were improved only in the RMET group. Moreover, perceived exertion and dyspnea were lower in the RMET after both the 50- and 200-m. Performance improved 3–4%.

More recently, 100-m performance was predicted by forced inspiratory volume over 1 second (Noriega-Sánchez 2014). This is the first study to demonstrate the influence of FIV1 in 100 m performance. FIV1 likely aids performance by allowing the swimmer to inhale air quicker and increase the amount of air they can inhale in a limited time. Swimmers with high FIV1 may need less respiratory frequency, produce less inspiratory muscle fatigue, increasing active limbs blood flow and reducing fatigue in these limbs, and consequently may improve performance.

Two dissimilarities can possibly explain this contrast as follows:

1) Differences in training intensity. Training intensity seems to be important for the adaptations in other physiological parameters, (MacDonagh 1984; Helgerud 2007) and will probably also be central for respiratory muscle adaptation. Inspiratory exercises are most likely to affect inspiratory parameters (Sheel 2002; Volianitis 2001; Mickleborough 2008; Clanton 1987; Griffiths 2007) and among different parameters. The study from Kilding et al. (2010) observed a highly significant intervention-specific increase in the maximal inspiratory pressure (9.1% in intervention group vs 0.3% in control group), while Wells et al. (2005) only observed this improvement among the female intervention participants (6.9% in the intervention group and 7.3% in the control group). In the latter study, (2005) it was discussed whether there was a threshold in respiratory training intensity that needed to be exceeded to have an effect beyond swimming training alone, but this hypothesis needs further clarification.

2) Inspiration versus alternating inspiratory and expiratory resistance training. In competitive swimming, respiration can be a critical point, since the athlete is immersed in water. The expiratory phase can essentially be done at any time in the stroke cycle, while proper inspiratory timing and velocity (inspiration must be performed within 0.3–0.5 seconds (Wells 2005) can affect swimming performance and must adhere to the stroke cycle as a whole (Cordain 1988; Lomax 2003). The elevated lung volumes observed in swimmers have been suggested to be related to elevated inspiratory muscle strength (Cordain 1988) and, in a study on competitive rowers, it was found that inspiratory muscle training improved performance while expiratory muscle training, and combined inspiratory and expiratory muscle training did not (Griffiths 2007).
A similar comparison has not been done in swimming but, empirically, expiratory training may seem redundant, and the efforts spent in the expiratory phase may possibly limit the quality and intensity of the inspiratory phase in an alternating inspiratory plus expiratory training regimen. In competitive rowing, the importance of ventilation and locomotion coupling (entrainment) on rowing performance has been studied (Siegmund 1999). In this review there were no studies included on entrainment for competitive swimmers, but the element is interesting and might be highly relevant for improving swimming performance.

Another avenue for respiratory training is for recovery. Deep breathing was shown to activate the sympathetic nervous system greater than in professional swimmers after five minutes of controlled 5 second inhalation and 5 second exhalation breathing (Palak 2013).

Summary:
The findings are overall inconclusive. The effect of intensity of training and effect of inspiration versus alternating inspiratory and expiratory resistance training deserves further attention.
**Energy System Training**

Highly developed lactic and alactic capabilities are assumed to be essential for a peak swimming performance (Lavoie 1986). Avalos and colleagues (2003) reported that in a group of elite swimmers ~90% of the weekly training volume was brought out at intensity with a lactate accumulation of less than 4 mmol/L. Other studies state that the emphasis in swim training is on high-training loads, (Mujika 1996) often with medium intensity, (Houston 1981; Costill 1999) although it does not harmonize with the energetic demands of races that in most cases last less than 2.5 minutes (Costill 1991). Laursen (2010) found that the equilibrium between lactic and alactic energy production may be reached even at 75 seconds of near maximal exercise. Beneficial alactic and lactic adaptations in swimmers can be induced from overloading training frequency, duration or intensity, (Wenger 1986) and studies in both competitive swimming (Mujika 1996; Mujika 1995; Chatard 1999) and other sports (Helgerud 2007; Wenger 1986) have suggested that overall training intensity may be more important than training volume (i.e. frequency and duration combined) for improving performance. Three of the studies included in this review investigated the interactions between training intensity and training volume by comparing one swimming training regimen with another, with approximately doubled training volume (in meters) (Faude 2008; Costill 1991; Houston 1981).

Aspennes (2009) investigated regular competitive swimming training compared with a combined strength and endurance training regimen. The study reported that 2 weekly sessions of high intensity interval training combined with 2 weekly sessions of maximal dryland resistance training improved 400m freestyle performance, but concluded that only strength training influenced performance. The endurance training regimen was considered insufficient to influence endurance performance because no indications of improved endurance capacity (unaltered VO2max and work economy) were observed, except for improved 400m freestyle.

**Summary:**

*It may seem that overall training intensity may compensate for high-training volumes in swimmers. For this section of the review we found only one RCT study. Although several aspects can probably be deducted from other sports, the pathways of intensity- or volume induced adaptations should be addressed in future RCTs on swimming, specifically since competitive swimming may differ from other sports. High training volumes are often chosen by coaches in the early periods of seasonal preparation to build a strong aerobic basis for high-swim performance. Since this organization of training is not yet scientifically investigated, the relevance of high-training volumes, as a base for more intense training in swimming, needs to be investigated in the future.*
**Range of Motion Training**

Sport specific range of motion is required for ideal biomechanics. In swimming, the shoulders, ankles, and hips are the most common area of extreme range of motion. However, the effects of this range of motion are not well documented in the literature.

**Shoulders**

Glenohumeral internal rotation is required for an early vertical catch in swimming. Yet, internal rotation deficits do occur in swimmers, likely from the volume of training.

Torres (2009) assessed shoulder rotation in groups of swimmers, tennis, players and controls. Overall, there was a gross internal rotation deficit of 12 degrees in swimmers, compared to only 4.9 degrees in the control group.

Bak (1997) compared swimmers with shoulder pain and without shoulder pain and noted increased shoulder external range of motion and decreased shoulder internal range of motion compared to normalized data.

**Summary:**

Swimmers with and without shoulder pain exhibit a lack of shoulder internal rotation which may decrease force production potential. However, future studies must see if interventions at improving internal rotation motion improve swimming velocity.

**Ankles**

Wilems (2014) had twenty-six healthy competitive swimmers (M=15, F=11; ~16.4 years; minimum 500 FINA score) undergo a passive plantar flexion range of motion test, bilateral active and passive internal rotation ROM, isometric strength, and an underwater dolphin kicking analysis. The swimmers also underwent a trial using a tape, preventing ankle range of motion.

Ankle dorsiflexion and internal rotation muscle strength were positively correlated with dolphin kick velocity. There was no correlation between plantar flexion and external rotation strength and dolphin kick velocity. Despite popular belief, active and passive plantar flexion and internal rotation ROM were not significantly correlated with the dolphin kick velocity. During the kick condition, ankle flexibility and dolphin kick velocity were significantly impaired. Ankle flexibility doesn’t correlate with dolphin kick velocity, yet research must assess if improved ankle range
of motion further improves dolphin kicking. Also, research on flutter kicking is also essential before completely ruling out ankle flexibility programs.

Another study comparing flutter kick speed in collegiate swimmers \( (n = 10) \) compared to recreational swimmers \( (n = 10) \) noted significant moderate correlations between plantar flexion and flutter kicking speed (McCullough 2009).

Summary:
Ankle mobility is a necessity for swimmers, but it doesn’t appear the most beneficial aspect for dolphin kicking. Future studies must assess the importance of ankle mobility and swimming speed for each stroke. Then, intervention studies must see if more ankle range of motion improves performance.

Hips
Unfortunately, there are no studies on hip range of motion and breaststroke performance. Future studies are needed on this subject as it seems obvious hip internal range of motion is paramount for elite breaststroke.

Summary:
Future studies must see if a correlation exists between breaststroke kicking velocity, breaststroke velocity and hip range of motion.
Core Training

Many believe core training is beneficial for swimmers, yet the research is lacking on this notion. Other studies and sports have found positive associates with core training on throwing accuracy and proprioception (Lust 2009). In fact, studies have suggested throwing velocity can improve ~4.9% in handball players (Saeterbakken 2011). Balance has also been suggested to improve with core training (Sandrey 2013). Only one study has trialed core strength and swimmers:

One study by Weston (2014) assessed core training in swimming. Of this study, twenty national-level junior swimmers (~16 years) were split into either an intervention or control group. The intervention group completed core training, which included lumbo-pelvic complex and upper region extending to the scapula three times per week for 12 weeks. The core training group had a significant improvement in the 50-m swim (~2%) as well as on land tests. Peak EMG activity also increased.

Summary:
Many more questions exist regarding core training, but it seems core training does improve core strength which may improve sprint swimming compared to no control. Future studies must assess more subjects and compare different forms of training.
Injury Prevention

Although coaches report injury prevention as the main role of dryland, injuries still occur (Krabak 2013). Injuries are multi-factorial, but unsafe practices and perceptions likely aide the high rate.

Hibberd (2013) surveyed one hundred two swimmers (between 13 – 18 years) from seven swim clubs were given a survey with questions regarding swimming practice and shoulder pain. Mild pain was 0 – 4/10, moderate was 5 – 7/10, and severe was 8 – 10/10. Seventy percent of those surveyed responded (M=39, F=63; ~15.1 years). Participants completed an average of 6.98 practice/week of 6,000 – 7,000 yards/practice. On average, 4.21 dryland sessions were performed per week. The majority of swimmers believed that mild and moderate shoulder pain is normal and should be tolerated. Seventy three percent report using pain medication to manage their shoulder pain and 47% used it regularly - one or more times per week. Overall, 85% of high school-aged clubs swimmers reported mild shoulder pain in the past year, 61% reported moderate shoulder pain, and 21% reported severe shoulder pain. Of these, only 14% had been to a physician.

The training program, swimming technique, and physical characteristics are thought to influence shoulder stress and the development of swimmer’s shoulder. The attitude and acceptance of shoulder pain in the sport is disconcerting. This pain likely impairs swimming performance and continuance in the sport. Proper shoulder pain education for swimmers is mandatory at all levels, as one can suspect these values are higher in older swimmers.

In other work by Hibberd and colleagues (Virag 2014), clear biomechanical faults do exist, even in collegiate swimmers. Thirty-one collegiate swimmers (~10 years; ~179.17 cm; ~75.43 kg) from the University of North Carolina participated in this study. Swimmers who could not complete entire practices due to pain were excluded in this study.
Each swimmer swam freestyle for 1 length of the swimming pool at a pace of 50 - 75% of their maximal speed. Each swimmer was recorded for two trials. Of the trials, one stroke cycle was selected for analysis. The following parameters were used in the study:

<table>
<thead>
<tr>
<th>Stroke Phase</th>
<th>Correct Freestyle Biomechanics</th>
<th>Incorrect Freestyle Biomechanics</th>
<th>Relevance of Incorrect Biomechanics to Shoulder Pain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand entry</td>
<td>Hand enters water forward and lateral to the head, medial to the shoulder. Figure 2a</td>
<td>Hand enters further away from or crosses the midline of the long axis of the body. Figure 2b</td>
<td>Increases impingement to the anterior shoulder. Mimics Neer impingement testing position.</td>
</tr>
<tr>
<td>Little finger or fingers-first hand entry. Figure 3a</td>
<td>Thumb-first hand entry. Figure 3b</td>
<td>Stresses the biceps attachment to the anterior labrum.</td>
<td></td>
</tr>
<tr>
<td>Pull-through</td>
<td>Elbow kept higher than hand and points laterally throughout pull. Figure 4a</td>
<td>Dropped elbow during pull-through. Figure 4b</td>
<td>Increases external rotation, placing muscles of propulsion at mechanical disadvantage.</td>
</tr>
<tr>
<td>Swimmer should use a straight back pull-through. Figure 5a</td>
<td>S-shaped pull through or excessive horizontal adduction past body midline during pulling. Figure 5b</td>
<td>Increases time spent in the impingement position. Mimics Hawkins Kennedy impingement testing position of horizontal adduction, flexion, and internal rotation.</td>
<td></td>
</tr>
<tr>
<td>Recovery</td>
<td>Elbow kept higher than the wrist throughout the recovery phase. Figure 6a</td>
<td>Dropped elbow during recovery phase. Figure 6b</td>
<td>Leads to an improper entry position with the elbow entering the water before the hand. The water will cause an upward force on the dropped humerus, leading to its superior translation and subacromial impingement in the shoulder.</td>
</tr>
<tr>
<td></td>
<td>Body roll of ~45° along the longitudinal axis of the body. Figure 7a</td>
<td>Body roll that is greater or less than 45°. Figure 7b</td>
<td>Excessive roll can lead to crossover entry position during the hand entry and/or pull-through phase. A lack of roll during recovery can increase mechanical stress on the shoulder and lead to improper hand entry position.</td>
</tr>
<tr>
<td>All phases</td>
<td>Head in neutral position. Imagine line through center of head and extending length of the spine. Figure 8a</td>
<td>Head carriage is in eyes-forward position. Figure 8b</td>
<td>Eyes-forward head position increases impingement by impeding normal scapulothoracic motion.</td>
</tr>
</tbody>
</table>

Two swim coaches and a certified athletic trainer examined the swimming strokes of the swimmers.

The most common biomechanical errors were a dropped elbow during the pull-through phase (61.3%) and a dropped elbow during the recovery phase (53.2%). Incorrect head position and hand entry during the hand entry phase occurred at 46.8% and 45.2%. Incorrect hand entry angles and pull-through patterns occurred at 38.7% and 32.3%.
There were significant associations between a dropped elbow during the recovery phase and a thumb-first hand entry. An incorrect hand entry and dropped elbow during the recovery phase, and eyes-forward head and an incorrect pull-through pattern.

Incorrect biomechanics are common in elite swimmers. These errors feed into other errors, potentially increasing shoulder stress and injury.

Although most of the swimming literature reports on shoulder injuries, understanding other types of injuries and possible prevention programs are also important.

**Shoulder Injuries**

Swimming is a unique sport, especially when compared to land-based sports. To excel at swimming requires countless hours of practicing in the water. Water is a unique medium when compared to running on ground or throwing through the air. Swimming also requires a high volume of overhead movements. In fact, there are a staggering large number of overhead movements in swimming when compared to baseball or tennis. Additionally, there is no limit, or stroke count, to protect the shoulders of a swimmer like there is for baseball pitchers. According to the numbers, swimmers perform approximately sixteen times the volume of overhead movements when compared to baseball pitchers (Wilk 2008). This high volume undoubtedly increases fatigue, a prerequisite for many shoulder injuries (Stocker 1996). However, the exact prevalence of shoulder pain in swimmers was 3% in a study published in 1974 and has increased in recent publications: 42% in 1980 (Richardson 1980; Neer 1983), 68% in 1986 (McMaster 1987), 73% in 1993 (McMaster 1993), 40 - 60% in 1994 (Allegrucci 1994), 5 - 65% in 1996 (Bak 1996), 38% (Walker 2012). This may be from an increase in diagnosis or training volume, nonetheless an injury risk around 40 - 60% hinders the sport of swimming, as any missed time from the water or altered biomechanics impede motor learning. This conundrum is unsettling at first, but considered essential to developing sport-specific “feel” in an unnatural medium, which is a necessity for competitive swimmers.

Only one study has analyzed the effects of the commonly prescribed shoulder injury prevention program in swimmers (Hibberd 2012). This study monitored the effectiveness of a 6-week strengthening and stretching program in 44 collegiate swimmers. The program consisted of resistance tubing Ts, Ys, Ws, shoulder flexion, low rows, throwing acceleration and deceleration, scapular punches, shoulder internal rotation and shoulder external rotation combined with a pectoralis and external rotator cuff stretch. This routine was performed 3 times per week. The results showed in differences in strength between groups, as both groups had improved shoulder extension and internal rotation strength regardless of group. Also, scapular motion was not significant after the training.
Summary:
Traditional shoulder rehabilitation programs are not effective for combating the strength imbalances and altered scapular movement associated with swimming training.

Low Back Injuries
The low back is the second most commonly injured body part in swimmers. Unfortunately, the exact cause of low back pain and use of injury prevention programs has not been studied.

Hangai (2009) had 308 well-trained university athletes (baseball, basketball, kendo, runners, soccer players, and swimmer) and 71 nonathlete university students. Disc degeneration was evaluated with a T2-weighted magnetic resonance image (MRI). A questionnaire concerning low back pain was also performed. This study found a higher rate of disc degeneration in swimmers and baseball players. There was an association between low back pain and degeneration and the degree of severity of low back pain with disc degeneration. Repetitive sports such as baseball and swimming appear to increase incidence of disc degeneration. These sports also have greater rotation than the others studied one possible mechanism of degeneration.

Kaneoka (2007) had fifty-six elite swimmers (M=35, F=21, ~19.6 years) and a control group (38 recreational swimmers; M=24, F=14; ~21.1 years) undergo a magnetic resonance image (MRI). Disc degeneration was compared between groups.

Participants also completed a questionnaire about their main strokes as well as their low back pain history.

Thirty-eight (68%) elite swimmers and 11 (29%) controls had generated discs at various levels. Disc level L5-S1 was more frequently degenerated in the elite swimming group. However, there was no significant relationship of low back pain symptoms associated with this increase in disc degeneration. Swimmers had a lower rate of low back pain, but back pain was more debilitating.

The L5-S1 segment undergoes greater degeneration in elite swimmers. However, the lack of associating symptoms brings to light the lack of correlation between defects in imaging and symptoms.

Summary:
Low back pain degeneration is higher in swimmers and is likely the reason for the higher injury rate compared to most other athletes. Unfortunately, prevention programs in swimmers have not been studied.

Part I References:


Part II: Dryland Overview

Team Dryland Overview
The *Dryland for Swimmers* Program, which you’re about to start, is based off the research previously discussed and years of practical experience. It is a complete dryland program with specific overload and rest phases for the taper of the swimmers. Remember, start in the appropriate phase based on your age, dryland experience and training. This training will create a complete athlete, strengthening all the muscles in all the planes of motion, while focusing on the subtitles of swimmers. If you follow this program or implement this program for your swimmers for the entire career, then a healthy, powerful, and well developed swimmer will develop. This type of training is very different from - and more effective than - the type of training you would do if your only goal were to “get bigger” or “get ripped”. This program is based on a meaningful, measurable goal and enables continual progress-monitoring along the way and between years. It also encourages a competitive, performance-oriented mind-set that enhances motivation and training enjoyment and makes it easy to work hard, guaranteeing you even better results.

Program Structure
The structure of the program varies on the age of the group. Also, there are two guides for determining where to start:

1) Team Dryland Program
2) Individual Dryland Program

Both of these structures provide benefit, depending on the goal of the swimmer and/or team. For example, if a team is looking for a cohesive, systematic program, then the group plans are the best method. If a swimmer is elite or wishes individualization, the self-assessment is mandatory. No matter if you’re working as a team or individual, the program structure is similar, as many swimmers have similar needs.

Overall, there are four macrocycles in the *Dryland for Swimmers* which is not accidental. This is meant as a complete guide for swimmers year, building up to four total tapers. Some of the weeks may seem minimal, but this is purposeful, as periods of rest are essential for maximal enhancement.
The weekly training schedule includes two to six sessions per week. This does not include the dynamic warm-up which is suggested each day. Not all of these days are demanding, as during taper “mobility” days and visualization/deep breathing are methods for recovery.

I know many people who have had success with varying dryland frequency, but this schedule fits best with majority of swimmers. Training less frequently has proven beneficial to some, but training more frequently in dryland is rarely more effective for the elite swimmer. This is because it gases the central nervous system (CNS) – impairing recovery and gains.

**Dryland Days**
Dryland days are what you’d expect, dryland! This includes a mix of mobility, strengthening, and motor control training on land. Overall, it minimally stresses the metabolic system, as the system doesn’t require metabolic stress if the swimmer is receiving it in the water.

**Mobility Days**
Mobility days are restorative, helping an athlete relax their central nervous system and feel as good as possible for training. These days occur on off-days and are more frequent during taper. Deep breathing and visualization also occur in this day, for psychological benefits.

**Energy Days**
Most traditional swim programs lack maximal anaerobic stress. This is likely why some programs greatly benefit from high-intensity dryland, despite the notions above. Therefore, energy days are beneficial for some teams, depending on the training approach and style. These days are short and intense, maximally stressing the anaerobic system, while creating minimal soreness.

These energy days can also help reduce body fat stores for the select swimmers needing this adjustment. These are the endomorphs who struggle to lose weight and require more intense sessions.

**Technique Days**
Having proper technique is crucial in and out of the water. Unfortunately, many swim coaches neglect biomechanics in dryland, assuming the athletes know what they’re doing. Just like swimming, dryland is a skill and practicing precise form is essential for health and long-term gains. Instead of focusing on just strength or energy system training, biomechanics and skill development are also essential for dryland for swimmers.
Testing Days
Monitoring improvements is essential for motivation and assessment of the program. Too often coaches provide sporadic dryland, without monitoring or assessments. This is like only performing swimming practice without meets! Checking improvements is a key aspect for teams or individuals, as gains let you know if the program requirements enhancement or adjusting. Testing days are for the end of each macrocycle.

Program Structure
Each session varies in length depending on the age of the swimmer and if they performed the dryland before or after practice. Nonetheless, dryland for swimmer entails a 10-minute dynamic warm-up before each session (swimming or dryland). This includes muscle activation, rehabilitation, mobility drills, and soft tissue work. If a team does dryland before swimming, then the dryland session will begin. If a team swims first, then the team will hit the water, and then go straight to dryland after swimming. Despite the breath of information of dynamic warm-up and soft tissue work, it is still underutilized in all levels of swimmers. Please resist any temptation to shorten or skip these warm-ups. Although many of these warm-ups are silly and goofy, they have a purpose. Exercise novelty is essential for developing motor control and skill. This is the one goal of these exercises. The dynamic warm-up exercises also prepare your body for better performance and reduce injury risk by raising body temperature. It also increases joint mobility at key spots for swimmers.

The warm-up exercises for the lower body emphasize mobility, especially at the hips and ankles. Many swimmers lack mobility in these regions, impairing performance. The warm-up also builds stability at the lumbar spine and shoulder, helping prevent injuries.

Another difference between this program and many others is the intensity of the training. When performing low repetition training, it is essential to find an exercise which challenges the swimmer. For this, we provide many progressions and regressions for body weight training. When performing these exercises, ensure enough rest between sets, as the CNS requires long rest for maximal effort.

Workload Modulation
Overall, the training varies from week to week within each four-week phase. This is meant to de-load the swimmer and help make gains. It also helps coaches manipulate the program, so the low workload days coincide with meets. Now, most swim teams do not taper for each meet, but the swimmer should receive a lower work volume in dryland competition weeks. This program helps the coach manipulate this schedule around swim meets. For taper meets, individuality is king. Nonetheless, most
swimmers taper ~2 weeks. Therefore, a low workout for the week before taper, followed by only optional Mobility days, visualization, and deep breathing for the entire two weeks of taper.

**First Week:** High workload  
**Second Week:** Medium workload  
**Third Week:** Very high workload  
**Fourth Week:** Low workload

One problem with common dryland programs is training at more or less the same workload each week. Just like swimming, varying the workload from week to week is far more effective for building strength in the long term. Cutting the volume helps peak at meets and make great gains by allowing you to train at higher intensity levels.

**Phases**  
The program is also built into different phases, helping create a safe and effective dryland program.

**Phase I**  
Phase I, introduces the swimmer to the dryland for swimmers training. This transitions any swimmer from either their current dryland or no dryland and the new form of training ahead.

This training emphasizes high-intensity training through performing more challenging lifts. The goal is to get the body accustomed to harder exercises. The areas addressed are the typical “weak links”, such as the trapezius, glutes, hamstrings and low back. This routine also uses a lot of single-leg exercises for functional carryover and lower-extremity health.

Some higher-speed exercises are introduced in this phase. This can help develop efficient technique and teach force production. Most dryland programs lift either slow or fast. This combination teaches athletes both methods. There are also core exercises in this phase, which are basic stability exercises which will lay a foundation for more advanced core training in later phases.

**Phase II**  
Phase II challenges exercise selection and the higher intensity level builds on phase I. The exercises progress in difficulty during this phase.
This form of training using “cluster training” which is for example a set of 3 repetitions, take a brief rest (10 seconds), then perform 1 - 2 more repetitions before you rest. Ideally, having the correct difficulty of each exercise is key for cluster training. This brief rest should allow just the right amount of rest for completing the set.

This form of training is quite difficult, but doable for many swimmers. It subjects the muscles to high levels of hypoxia (oxygen deprivation) and mechanical stress - two mechanisms for muscle growth.

Phase I will have increased your neuromuscular efficiency, therefore varying the exercises is important for continual gains. The training is progressed from Phase I.

**Phase III**
Phase III adds a bit more volume than the previous two phases. This phase will continually push the swimmer, helping the swimmer develop more intense training. This phase uses a low-rep range for the initial sets, followed by a slightly high repetition range for the next sets. For example, you might perform three sets of three reps, followed by two sets of five repetitions.

**Phase IV**
Phase IV truly maximizes strength and power gains, as it is focused on extremely low volume repetitions. Maximizing strength is likely the biggest benefit of dryland training for swimmers. This phase epitomizes this phase, while minimizing soreness and overall fatigue.

**Equipment**

**Tennis Balls** or **baseballs**
Tennis balls are used to perform self-soft tissue mobilizations to improve the tone and length of the muscle. These can be replaced with lacrosse balls or baseballs if tennis balls are unavailable or a harder surface is desired.

**Resistance Bands**
These functional training devices provide a simple way to add resistance to any exercise. Start with lighter bands and progress to higher tension bands. We will use these to improve muscle strength and timing.
**Foam Rolls**
A foam roll is an excellent method to relax the sympathetic system and back muscles (deep thoracic rotators). I prefer the white, less aggressive foam rolls, but the black, high-density foam rolls also work.

**Swiss Balls**
A Swiss ball is an excellent tool to implement the horizontal position, forcing balance and core stability. This improves strength in a swimming-specific manner.

**Weighted Vests**
Weighted vests are used to increase body weight and increase the difficulty of many movements, especially explosive movements (plyometrics). A heavy rope is a simple replacement if weighted vests are unavailable.

**Chains**
Chains are another method for increasing body weight resistance for exercises. This added resistance is more variable than a weighted vest and changes throughout the movement. A heavy rope is a simple replacement if chains are unavailable.

**Mobility Stick**
Mobility sticks are the rolling pins of mobility. Unfortunately, these devices are commonly used incorrectly, as many muscles are too aggressively rolled.

**What to Expect**
How long until I see results? I know this question is in the back of your mind - if not in the front! In all honesty, I don’t know the exact time for improvement, all I know is it does take time. Some swimmers see significant gains in 3 - 4 weeks, while others take 3 - 4 months! Nonetheless, gains will occur. Nonetheless, here are some of the typical results I’ve seen when working with swimmers on this program.

The one thing that I guarantee is that if you follow the program as it is written and work hard, you will make gains. How much improvement depends on many factors, including your past dryland experience, as beginners with a lot of natural strength will experience the biggest relative improvements. If you have a swimmer who doesn’t increase weight easily, then it is likely they’ll see the slowest improvements.

Type of dryland in the past is also a factor for improvement. If past dryland included a lot of long duration running, higher-repetition sets, and little or no mobility work, then you may see huge improvements, even if you’re an elite swimmer. If sore spots or injuries have plagued progress over the years - be ready for large gains!
Here are the results from one of my past clients. Michelle, a 15-year-old female, Junior National qualifier made these gains in a few months:

<table>
<thead>
<tr>
<th></th>
<th>Day 1</th>
<th>Day 60</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plank</td>
<td>0:45</td>
<td>2:00</td>
</tr>
<tr>
<td>Push-up</td>
<td>3</td>
<td>18</td>
</tr>
<tr>
<td>Single Limb Squat</td>
<td>2 Right/ 4 Left</td>
<td>12 Right/ 13 Left</td>
</tr>
<tr>
<td>Inverted Row</td>
<td>4</td>
<td>19</td>
</tr>
</tbody>
</table>

The most impressive thing about these improvements is that Michelle also made large gains in the water, dropping nearly 2% in her 500-yard freestyle. Now, these results can’t all be attributed to dryland, but there is a positive correlation between her dryland and swimming improvement. More markedly, she had a decrease in shoulder pain, something which plagued her for nearly a year.

Another athlete who did the *Dryland for Swimmers* program was Paul, a 20-year-old male 50-yard freestyle swimmer. Paul had been doing a lot of resistance training at his school, focusing on Olympic lifts, notably cleans and jerks. After a summer on the program, Paul made great improvements:

<table>
<thead>
<tr>
<th></th>
<th>Day 1</th>
<th>Day 90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plank</td>
<td>1:30</td>
<td>3:34</td>
</tr>
<tr>
<td>Single Arm Push-up</td>
<td>2 Right/ 6 Left</td>
<td>8 Right/10 Left</td>
</tr>
<tr>
<td>Single Limb Squat</td>
<td>8 Right/11 Left</td>
<td>19 Right/19 Left</td>
</tr>
<tr>
<td>Pull-up</td>
<td>12</td>
<td>29</td>
</tr>
</tbody>
</table>

Now, this is only the case of a few swimmers, but the results were impressive. One thing not mentioned is the work ethic and dedication of these swimmers. Many report working harder in the *Dryland for Swimmers* program than other dryland programs. Despite this, the volume and training is much different.

Remember, work hard, be smart, and make gains.
Structuring Dryland

Many dryland programs have swimmers working individually or as an entire group. These are coach dictated dryland workouts result in many swimmers falling into the danger of dryland programs.

Instead, having swimmers work in pairs and educate the swimmers on correct form accelerates correct biomechanics, helping achieve the 10 benefits of a proper dryland program. At many club teams, our philosophy of allowing swimmers to predominantly use peer motivation has made unmeasurable benefits.

This philosophy has worked with groups of ~20 swimmers as young as 11-years-old.

Remember, progress and regress when needed. If a swimmer is not ready to progress to an advanced exercise variation, don’t let them! Likewise, if a 10-year-old can perform pull-ups, progress them on this exercise. Go over the progressions and regressions with the group and challenge them!

Steps for Structuring Dryland:

1. **Correct Form of Exercise Progressions/Regressions:** The coach must fully comprehend all the exercise progressions and regressions for each exercise. This part is quintessential as the coach will teach the swimmers the correct technique and progressions. Therefore, watching and understanding the videos is mandatory!

2. **Print Templates for Each Swimmer:** Each swimmer will receive a template where they write their name and goals on the sheet. These templates should be stored at the pool or wherever the swimmers do dryland. This template sheet provides individualization and customization for each swimmer. This template sheet can provide motivation for the swimmer, while helping the coach track progress.

3. **Instruct the Dynamic Warm-up:** The first day of a new dryland template involves the coach teaching the team. The coach will go through the dryland warm-up as a group. After the first day, the swimmers should lead themselves through the warm-up with a team captain or different leader each day.

4. **Partner Swimmers:** Either pair swimmers or allow them to select partners. Instruct them the following:
   “You will be working with a partner today. The role of having a partner is crucial! Make sure you have an appropriate partner to work with as the partner’s job is more important than the person exercising. During this routine, one person will exercise while the partner observes, provides feedback,
motivates, etc. After the partner exercising finishes one set, then you will
switch. It is the partner’s responsibility to provide feedback for correcting the
movement. It is also the partner’s role to motivate a partner exercising and
instruct them to increase the intensity, if warranted.”

5. **Types of Feedback:** Once the swimmers understand the roles of partners, they
are ready for instruction on types of feedback. Providing feedback can come in
three main methods:
   a. Verbal: talking to the partner, telling them the correct technique
   b. Tactile: Moving the partner into the correct movement or giving them a
cue while their touching an external object.
   c. Visual: Showing them an example of the correct movement.

6. **How to know if the Swimmer is Using Correct Technique:** Here are the
following methods a coach or a partner can use to tell if the person exercising
is using correct technique:
   a. Visual: Watching a swimmer perform the movement provides the coach,
partner, and swimmer (if it is recorded or used with a mirror) feedback if
the exercise is correct.
   b. Tactile: If the correct muscle is activating it will become firm and
contract. Therefore, the swimmer, coach, or partner can touch the
muscles working and see if they are activating.
   c. Verbal: If a swimmer is performing the correct movement, ask them
what muscles they feel working. If they respond with the correct
muscles, then the swimmer is likely doing it correctly.

7. **When to Progress:** Teaching swimmers when to progress exercises is key. If the
swimmer is internally motivated, they will intuitively know when an exercise is
easy, they need to progress. If they are not sure, asking them to rate the
exercise 0 - 10, with 10 being the hardest and 0 the easiest gives an object
rating of the difficulty. If the swimmer demonstrates correct technique during
the exercise and rates the exercise as 7 or lower, it is time to progress.
Exercise difficulty should be 8 or 9 for most swimmers in this program. There
are other methods to tell if an exercise is too easy:
   a. The swimmer is talking during the exercise.
   b. The swimmer is not concentrating or is looking around.
   c. The swimmer can do 3 or more repetitions of the exercise with correct
form.

There are also cues if the exercise is challenging:
   a. The swimmer is breathing hard.
   b. The swimmer is in deep focus.
   c. The muscles are shaking.
   d. The pupils constrict.
Exercise Progressions and Regressions

The below program is one example of an exercise routine. It is similar to the below flow chart. Nearly every exercise can be progressed and regressed, so coaches should have a flow chart of exercises for advanced and novice swimmers.
Part III: Warm-Up

Warm-up Essentials
Doing warm-up is not fun; I often call it the vegetables of exercise, as it is beneficial, but often ignored.

Warm-up can help improve posture, range of motion, and reduce injuries for swimmers. Each warm-up takes 10 - 15 minutes and consists of dynamic mobility, self myofascial release, and motor control training.

Self Myofascial Releases (SMR)
Self-myofascial release is simply that category of myofascial release techniques that are performed by the individual themselves rather than by a clinician. Consequently, self-myofascial techniques most often involve a tool with which the individual puts pressure upon the affected area. The most commonly-used self-myofascial release tool is the foam roller.

Paul Ingraham, a massage therapist in Canada, notes one interaction between his client using SMR and their orthopedic specialist:

“He didn’t know about using tennis balls for massage! He asked what helped my back pain, and I told him I always lie on a tennis ball. He looked at me like he was going to refer me to a psychiatrist! How can an orthopedic surgeon not know about the tennis ball thing? Doesn’t everyone know about the tennis ball thing?”

Unfortunately, no: not everyone knows about the tennis ball thing. But it is one of the most time-honored simple solutions for chronic muscle aches and pains (Ingraham 2010)”

What is Foam Rolling?
Foam rolling is a common form of self-myofascial release that is often used by fitness enthusiasts and athletes prior to a workout with a view to improving flexibility or after a workout with a view to reducing muscle soreness and promoting quicker recovery. However, the available research has until recently been very limited in respect of both of these effects [see below].
What is Tennis Ball Rolling?
Tennis balls are used to perform self-myofascial releases to more precise locations than the foam roll. These can be replaced with lacrosse balls or baseballs if tennis balls are unavailable or a harder surface is desired.

What is the Mobility Stick?
Mobility sticks are the rolling pins of mobility. Unfortunately, these devices are commonly used incorrectly, as many muscles are too aggressively rolled.

Research on SMR

Self Myofascial Releases and Range of Motion
Although foam rolling is a very new area of research for sports scientists, it is increasingly being studied. The following studies have investigated the effects on range of motion:

Self Myofascial Releases and Acute Effects on Range of Motion
MacDonald (2012) investigated whether two 1-minute bouts of foam rolling would affect knee joint range-of-motion (ROM), voluntary and involuntary quadriceps muscular force during isometric knee extension at a 90-degree knee angle, rate of force development and quadriceps electromyographic (EMG) activity acutely in 11 male subjects from a university.

They found no significant differences in muscle force, rate of force development or muscular activation between the control and foam roller conditions but they did observe that the foam rolling condition produced a significantly greater improvement in knee joint ROM in comparison with the control condition. The researchers therefore concluded that two 1-minute bouts of foam rolling significantly increased joint ROM but did not impede the production of muscular force or rate of force development.
Self Myofascial Releases and Long-term Effects on Range of Motion

Miller (2006) investigated whether foam rolling would cause increases in range-of-motion (ROM) in the hamstrings muscle group in 23 healthy college students with tight hamstrings. The subjects were selected if they had active knee extension of <80 degrees while supine and with the hip maintained at 90 degrees of flexion.

The subjects were divided into 2 groups: a foam rolling group and a control group for an 8-week intervention, during which the foam-rolling group performed 3 sessions of foam rolling per week for 3 sets of 1-minute of foam rolling on the hamstrings. The control group was instructed to continue with normal activity but to avoid additional stretching that was in addition to their normal regimen.

The researchers found that both foam rolling and control groups had significant increases in ROM for both the dominant and the non-dominant leg. However, there was a trend for the foam rolling group to display a larger increase in ROM than the control group.

The researchers therefore concluded that foam rollers are an ineffective technique for increasing hamstrings flexibility over an 8-week time period. However, the significant increase in ROM observed in the control group in this study is a cause for concern that implies that there may have been problems either in the accuracy of the measurements or in respect of the behavior of the control group.

Scherer (2013, non-peer reviewed) investigated the effects of 4 weeks of foam rolling
on hamstring flexibility, as assessed by the sit-and-reach test in 18 college-aged students with resistance-training experience. The researcher allocated the subjects randomly to either a foam rolling group or to a control group.

The foam rolling group carried out foam rolling for 3 - 5 minutes, 2 - 4 times per week for the 4-week intervention period, using 30-second periods of hamstring foam rolling interspersed with 30-second periods of rest. The researcher found that the foam rolling group significantly improved sit-and-reach test performance while the control group did not improve. The researcher therefore concluded that in resistance-trained, college-aged populations, foam rolling was able to improve hamstrings flexibility over a 4-week time period.

**Self Myofascial Releases and Effects on Arterial Stiffness**

Okamoto (2013) explored the acute effect of self-myofascial release with a foam roller on arterial stiffness and vascular endothelial function, as measured using pulse wave velocity in 10 healthy but sedentary subjects (7 males and 3 females). They compared self-myofascial release with a foam roller and a control condition in a randomized, cross-over design, at least 3 days apart.

They measured brachial-ankle pulse wave velocity and plasma nitric oxide (NO) concentrations both before and 30-minutes after both conditions. The researchers found that brachial-ankle pulse wave velocity significantly decreased after the self-myofascial release with a foam roller condition but did not change following the control condition. The researchers also found that plasma NO concentrations significantly increased after the self-myofascial release with a foam roller condition but did not change significantly after the control condition.

The researchers therefore concluded that self-myofascial release with a foam roller is able to reduce arterial stiffness, improve arterial function and improve vascular endothelial function in sedentary subjects. They suggest that foam rolling may consequently be a useful tool for improving cardiovascular health in the general population.

**Summary:**

In the short-term, SMR appears to improve ROM. Unfortunately, the exact mechanism is not well understood. The literature is conflicting in respect of whether foam rolling can improve joint range-of-motion (ROM) over a longer period of time.
Additionally, we must take caution in drawing too many inferences from either study. The study by Scherer (2013) was not peer-reviewed and in the study by Miller (2006), a significant improvement in joint ROM was found in the control group, which raises concerns over the quality of the study. SMR also seems to acutely improve arterial stiffness and function.

**Self Myofascial Releases and Performance**

Healy (2013) investigated whether self-myofascial release with a foam roller would alter athletic performance acutely in comparison with a control condition. The researchers therefore recruited 26 recreationally active, college-aged subjects (13 males and 13 females) for the trial, which was performed in a randomized, crossover design, with the trials separated by 5 days to avoid any interactions.

The control condition involved a similar position to the foam rolling condition but without the foam roller: holding a plank position for 30 seconds. Before and after each condition, the researchers took measurements of muscle soreness, fatigue and perceived exertion as well as 3 performance tests: isometric quarter squat force in a Smith machine squat bar using a force plate, counter-movement jump height and power using a force plate, and agility using the 5-10-5 yard shuttle run.

The researchers found no significant differences between the foam rolling and control conditions for all of the athletic tests, but they did observe that fatigue was significantly greater after the plank (control) condition than after the foam rolling condition. The researchers therefore concluded that use of a foam roller prior to exercise does not improve or reduce athletic performance acutely.

Sullivan (2013) investigated the effects of a mobility stick provided by Theraband on joint range-of-motion (ROM) and performance in 17 subjects (7 males and 10 females). The researchers randomly allocated the subjects to either a roller-massager group or to a control group.

They measured flexibility using the sit-and-reach test, muscle activation, maximum voluntary isometric contraction (MVIC), knee flexion torque, evoked twitch force, and electromechanical delay before and after 4 different interventions of hamstrings mobility stick (either 5-second or 10-second durations, and either 1 or 2 sets).

The researchers found that the mobility stick produced a significant increase in sit-and-reach performance and they noted a trend towards a dose-response effect with
10-seconds of roller-massager rolling being slightly more effective at increasing sit-and-reach performance than 5-seconds, irrespective of the number of sets. They also noted that potentiated twitch force was significantly reduced after roller massage in comparison with no roller massage. However, the researchers found no significant differences between conditions for MVIC knee flexion torque, muscle activity or electromechanical delay.

The researchers therefore concluded that use of a roller-massager on the hamstrings led to significant increase in sit-and-reach performance, but did not cause any significant decreases in MVIC knee flexion torque.

Fama (2011 non-peer reviewed) investigated the acute effects of foam rolling and of a dynamic warm-up on strength, power, and reactive power in 9 college-aged, recreationally active males with 1-year of plyometric training experience. The researchers therefore tested squat jump, counter-movement jump and depth jump performance both before after two different warm-up protocols. One warm-up protocol comprised a general warm-up (5 minutes of treadmill walking) plus a dynamic warm-up (walking lunges, reverse lunges, single-leg Romanian deadlifts, walking leg kicks, and straight-leg skipping).

The other warm-up protocol comprised a general warm-up plus foam rolling. The foam rolling was performed for 1-minute for each of the major muscle groups that were similarly affected by the dynamic warm-up (i.e. gluteals, hamstrings, quadriceps and calves). The researchers reported that there was a significant increase in jump height following the dynamic warm up in the counter-movement jump but there were no other significant changes between pre- and post-warm-up. There was a trend towards a small reduction in counter-movement jump performance in the foam rolling protocol but this did not reach statistical significance.

The researchers therefore concluded that a dynamic warm-up improves countermovement jump performance acutely while foam rolling does not.

Sharp (2012 non-peer-reviewed) compared the effects of a manual therapy technique (Emmett) and foam rolling on the iliotibial band for improving lower body flexibility and lower body power in 15 asymptomatic non-professional, rugby forwards, aged 19 - 30 years. The subjects were randomly allocated to one of 3 groups: a foam rolling group, an Emmett technique group and a control group. The foam rolling was carried out for 60 - 90 seconds. Both interventions targeted the iliotibial band. Before and
after the intervention, the researcher measured dynamic flexibility associated with the iliotibial band and counter-movement jump performance.

The researcher found that while the Emmett technique improved the dynamic flexibility associated with the iliotibial band, the foam rolling technique did not. Moreover, the researchers found that neither the Emmett technique nor the foam rolling technique had any effect on counter-movement jump performance.

**Summary:**

*These individual studies suggest that foam rolling does not impede the production of muscular force or rate of force development and having no detrimental effects on athletic performance pre-workout.*
Self Myofascial Releases and Soreness
The following studies have assessed the effects of foam rolling on aspects of recovery:

MacDonald (2014) investigated whether foam rolling would affect delayed-onset-muscle-soreness (DOMS) in 20 physically active, male subjects with resistance-training experience. The researchers randomly allocated the subjects to either a foam rolling group or to a control group. All subjects performed 5 different testing sessions, which included 1RM squat testing and a series of further tests performed both pre- and post-(at 0, 24, 48 and 72 hours) a workout protocol intended to create DOMS (10 sets of 10 reps of squats at 60% of 1RM with a 4-second eccentric phase and a 1-second concentric phase with 2 minutes of rest between sets).

The researchers measured thigh girth, maximal voluntary isometric contraction (MVIC) knee extension torque at a knee angle of 90 degrees, quadriceps and hamstrings range-of-motion (ROM) measurements and counter-movement vertical jump performance. The subjects in the foam rolling group performed several foam rolling exercises for 2 bouts of 60-seconds per exercise.

The researchers found that neither thigh girth nor MVIC knee extension torque were significantly different between groups at any time point. However, they found that muscle soreness was significantly reduced in the foam rolling group in comparison with the control group at 24, 48 and 72 hours post-workout, that quadriceps passive ROM was significantly larger in the foam-rolling group at 48 and 72 hours post-workout, that hamstrings passive ROM was significantly larger in the foam-rolling group at 72 hours post-workout, that hamstring dynamic ROM was significantly larger in the foam rolling group at 24 hours post-workout, that muscular activation during the MVICs was reduced by significantly less in the foam rolling group at all-time points, and finally that the foam rolling group displayed a significantly smaller reduction in countermovement vertical jump height after 48 hours than the control group.

The researchers concluded that foam rolling produced significant reductions in muscle soreness at all-time points and significant increases in ROM and vertical jump height at certain time points along with no changes in torque production.
Summary:

This individual study indicates that foam rolling reduces muscle soreness while increasing range-of-motion (ROM), reducing deterioration in vertical jump height and leaving torque production unaffected. Obviously, the existence of only one study makes it harder to be sure that the effects were not coincidental.

SMR Locations

The following are all the SMR spots I recommend. Overall, at least ten spots are recommended before each practice for elite swimmers. Here are some recommendations for each stroke:

Plantar Fascia - 1

<table>
<thead>
<tr>
<th>Impairments:</th>
<th>Muscle (s):</th>
<th>Injuries:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain on the bottom of the foot, foot cramping, decreased ankle plantarflexion.</td>
<td>Arch muscles.</td>
<td>Plantar fasciitis, ankle sprains.</td>
</tr>
</tbody>
</table>

SMR Plantar Fascia Summary

Purpose:

The bottom of the foot is believed to have a high blood and neural supply. SMR to this area is believed to increase circulation and nerve mobility. Also, in athletes who continually point their toes (ballet, diving, swimming), this may be beneficial.

Directions:

Stand and roll a tennis ball under the base of your foot.

Peroneals - 2

<table>
<thead>
<tr>
<th>Impairments:</th>
<th>Muscle (s):</th>
<th>Injuries:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shin pain, ankle pain, knee pain, and limited ankle mobility (specifically pointing the feet outward).</td>
<td>Peroneus longus, peroneus brevis, peroneus tertius.</td>
<td>Shin splints, ankle sprain.</td>
</tr>
</tbody>
</table>
**SMR Peroneals Summary**

*Purpose:*

*Breaststroke, ballet moves, and running requires a swimmer to move their feet into eversion (point laterally). Performing this motion is predominantly from the peroneals, which can cause tightness in this area.*

*Directions:*

*Sit-up with one leg straight and the other bent, then place the tennis ball under the outside calf of the straight leg. Point your toes to the outside of your body.*

**Tibiallis Anterior - 3**

<table>
<thead>
<tr>
<th>Impairments:</th>
<th>Muscle(s):</th>
<th>Injuries:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shin pain, pain during running, pain during ankle pointing, decreased ankle mobility.</td>
<td>Tibialis anterior.</td>
<td>Shin splints, drop foot, anterior compartment syndrome, medial tibial stress syndrome, plantar fascitis.</td>
</tr>
</tbody>
</table>

**SMR Tibialis Anterior Summary**

*Purpose:*

*SMR may improve ankle mobility and decrease injury/pain at the shins.*

*Directions:*

*In a half kneeling position, place a tennis ball on the outside of your shin bone. Gently lower your weight onto the ball. Perform slowly, as some spots are extremely tender and if you press too hard the ball may squirt out.*
### Plantar Flexors - 4

<table>
<thead>
<tr>
<th>Impairments:</th>
<th>Muscle (s):</th>
<th>Injuries:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain in the calf and foot, calf cramping and limited ankle mobility.</td>
<td>Gastrocnemius, soleus.</td>
<td>Plantar fasciitis, heel pain, shin splints, low back pain, hip pain, knee pain.</td>
</tr>
</tbody>
</table>

**SMR Plantar Flexors Summary**

**Purpose:**

*Many swimmers report calf cramping. This is likely exacerbated from overuse (repeated ankle pointing during kicking).*

**Directions:**

*Sit-up with one leg straight and the other bent, then place the tennis ball under the outside calf of the straight leg.*

### Iliotibial Band - 5

<table>
<thead>
<tr>
<th>Impairments:</th>
<th>Muscle (s):</th>
<th>Injuries:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knee pain, low back pain, impaired knee extension (or hyperextension).</td>
<td>Iliotibial band (ITB).</td>
<td>Knee pain, iliobibial pain syndrome, patellofemoral pain syndrome, low back pain, hip pain.</td>
</tr>
</tbody>
</table>

**SMR IT Band Summary**

**Purpose:**

*The iliobibial band is a common contributed to knee pain, specifically in breaststroke swimmers and runners.*

**Directions:**
Lie on your side with a tennis ball under your lower thigh, on the bottom leg, just above your knee. Bend the top leg’s knee and place it flat in front of the bottom leg. Push through your top leg and forearms to move the tennis ball.

**Quadriceps - 6**

<table>
<thead>
<tr>
<th>Impairments</th>
<th>Muscle(s):</th>
<th>Injuries:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thigh pain, knee pain,</td>
<td>Quadriceps (vastus lateralis,</td>
<td>Iliotibial band syndrome,</td>
</tr>
<tr>
<td>groin pain, impaired</td>
<td>vastus lateralis, vastus</td>
<td>patellofemoral pain syndrome</td>
</tr>
<tr>
<td>knee extension strength.</td>
<td>medialis, rectus femoris).</td>
<td></td>
</tr>
</tbody>
</table>

SMR of the Quadriceps Summary

**Purpose:**

The quadriceps can become tight from excessive sitting in our society. This can prevent hip extension, an important motion during all sports (like dolphin-kicking, running).

**Directions:**

Lie on your stomach with your hands underneath your shoulders and the foam roll under your thighs. Push through your hands to move your body on top of the foam roll. Both legs may be on the thighs at the same time or you can emphasize one leg by hooking one leg behind the other leg.

**Adductors - 20**

**Tennis Ball Adductors**

<table>
<thead>
<tr>
<th>Impairments</th>
<th>Muscle(s):</th>
<th>Injuries:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groin pain, knee pain,</td>
<td>Adductor longus,</td>
<td>Groin strain,</td>
</tr>
<tr>
<td>impaired hip strength,</td>
<td>adductor brevis,</td>
<td>patella femoral pain syndrome,</td>
</tr>
<tr>
<td>impaired hip range of motion.</td>
<td>adductor magnus.</td>
<td>hip bursitis.</td>
</tr>
</tbody>
</table>

SMR to the Adductors Summary

**Purpose:**
The adductors can become excessively tight in breaststroke kickers. This tightness can also contribute to adductor strains and injuries, as well as impair adductor strength.

**Directions:**

Lie on your stomach with your body propped on your forearms. Then, bring one thigh to your chest while keeping your other leg straight and place the foam roll under the thigh closest to your chest and roll the foam roll under the inside of your thigh.

**Tensor Fasciae Latae - 7**

<table>
<thead>
<tr>
<th>Impairments:</th>
<th>Related Muscle(s):</th>
<th>Injuries:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain in the low back, hip, buttocks (especially immediately under the buttocks), side of the thigh, hamstrings, decreased hip range of motion (specifically internal rotation), decreased low back range of motion.</td>
<td>Tensor fasciae latae, gluteus medius, gluteus minimus.</td>
<td>Nonspecific low back pain, herniated disc, “lower cross syndrome”, knee pain, hip pain, groin pain, anterior knee pain, sacroiliac joint pain.</td>
</tr>
</tbody>
</table>

**SMR to the TFL Summary**

**Purpose:**

*SMR to the TFL may improve poor hip internal rotation or alleviate low back, knee, or hip pain/soreness.*

**Directions:**

*Lie on your side and put the tennis ball directly behind your hip. To find the proper position, find your hip bone place the ball two finger breadths behind, and then lie directly on your side with the tennis ball directly behind this bone.*
### Piriformis - 8

<table>
<thead>
<tr>
<th>Impairments:</th>
<th>Related Muscle (s):</th>
<th>Injuries:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain in the lower back, buttocks, hip, hamstrings, sensations down the entire back of the leg, limited hip and low back range of motion.</td>
<td>Piriformis, gluteus maximus.</td>
<td>Piriformis syndrome, sciatica, nonspecific low back pain, knee pain (clicking or popping), groin pain, herniated disc, “lower cross syndrome”.</td>
</tr>
</tbody>
</table>

**SMR to the Piriformis Summary**

**Purpose:**

*The piriformis is commonly tight in people with poor hip extension range of motion (touching one's toes), as it can restrict sciatic nerve mobility.*

**Directions:**

*Long sit with one leg straight and the other bent. Put the tennis ball on the outside of your glute of the straight leg and roll the tennis ball on the outside of your hip.*

### Psoas - 19

<table>
<thead>
<tr>
<th>Impairments:</th>
<th>Related Muscle (s):</th>
<th>Injuries:</th>
</tr>
</thead>
</table>

**SMR to the Psoas Summary**

**Purpose:**
The psoas may limit spinal and hip mobility, as well as contribute to low back pain.

Directions:

Lie on your back with your legs on a bench or leg rest (elevated approximately 45 degrees). With one end of a mobility stick perpendicular to your body, press into the muscle. You can flex your hip to see if the stick moves, but once in the correct position, hold.

### Quadratus Lumborum - 9

<table>
<thead>
<tr>
<th>Impairments:</th>
<th>Related Muscle(s):</th>
<th>Injuries:</th>
</tr>
</thead>
</table>

### SMR to the QL Summary

### Purpose:

The quadratus lumborum likely weakens frontal plane strength and can cause excessive spinal mobility during freestyle (wiggling).

### Directions:

Lie on your back, approximately 30 degree from vertical with the tennis ball one your side in between your rib cage and pelvis.

### Wrist Extensors - 10

<table>
<thead>
<tr>
<th>Impairments:</th>
<th>Muscle(s):</th>
<th>Injuries:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain in the elbow, arm, wrist, and hand. Impaired forearm strength and range of</td>
<td>Extensor muscles of the forearm, mobile wad (brachioradialis,</td>
<td>Carpal tunnel syndrome, tennis elbow (lateral epicondylitis),</td>
</tr>
</tbody>
</table>
motion.

| extensor carpi radialis longus and brevis, extensor digitorum, extensor carpi ulnaris | golfer’s elbow (medial epicondylitis), thoracic outlet syndrome, and several more. |

Summary of the wrist extensors

**Purpose:**

*Most elbow and forearm pain is aided by the wrist extensor muscles. Not only can they cause pain and soreness, but can impair strength in the forearms.*

**Directions:**

*Against a wall, lean your body against a tennis ball directly above your elbow. Gradually increase your body weight into the wall.*

**Foam Thoracic Spine - 12
Mobility Stick Thoracic Spine**

<table>
<thead>
<tr>
<th>Impairments:</th>
<th>Muscle (s):</th>
<th>Injuries:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoulder pain, low back pain, impaired breathing, limited shoulder mobility, poor thoracic spine mobility.</td>
<td>Erector spinae (iliocostalis, longissimus, spinalis), transversospinalis, multifidus, levator costum.</td>
<td>Shoulder impingement, shoulder tendinopathy, nonspecific low back pain, and any respiratory pain.</td>
</tr>
</tbody>
</table>

Summary of the thoracic spine

**Purpose:**

*Improve thoracic spine mobility for streamlining, shoulder range of motion, recovery, and breathing function.*

**Directions:**
Lie on your back with your knees bent and place a foam roll parallel to your spine. Make sure your head and tailbone are on the foam roll and your head is relaxed. Place your arms on the ground for support and roll back and forth at your desired speed and amplitude.

**Trapezius - 11**

<table>
<thead>
<tr>
<th>Impairments:</th>
<th>Muscle (s):</th>
<th>Injuries:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoulder pain, neck pain, headaches, raised shoulders. Impaired shoulder strength and range of motion.</td>
<td>Upper trapezius, middle trapezius, and lower trapezius.</td>
<td>Swimmer’s shoulder (shoulder tendinitis, shoulder impingement), labral tear, and any other shoulder issue.</td>
</tr>
</tbody>
</table>

**Summary of the trapezius**

**Purpose:**

The upper trapezius can elevate the shoulder, increasing the risk of shoulder impingement, pain, and weakness.

**Directions:**

Lie on your back with your knees bent and place the tennis ball on your upper shoulder. This ball should lie on the muscle and not on any bones. Rolling is possible from side to side to release the whole muscle. A common trigger point is located on the lateral aspect of the upper trapezius. Trigger points are believed to occur from excessive elevation of the shoulder girdle. Trigger points can occur on the lateral neck or superior to the shoulder blade.

**Levator Scapulae - 12**

<table>
<thead>
<tr>
<th>Impairments:</th>
<th>Muscle (s):</th>
<th>Injuries:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoulder pain (specifically between the shoulder blades), decreased shoulder strength.</td>
<td>Levator scapulae, erector spinae muscle group.</td>
<td>Swimmer’s shoulder (shoulder tendinitis, shoulder impingement), labral tear, and</td>
</tr>
</tbody>
</table>
SMR to the Levator Scapulae Summary

**Purpose:**

Trigger points often occur due to sustained elevation of the shoulders, causing excessive activation. The common trigger points are on the superior medial border of the scapula, along the muscle belly. This muscle can refer down the bottom of the shoulder blade or to the posterior deltoid.

**Directions:**

Lie on your back with your knees bent and place the tennis ball in between your shoulder blades, not on the spine, on the top side. Rolling is possible up and down to release the whole muscle.

Infraspinatus - 13

<table>
<thead>
<tr>
<th>Impairments:</th>
<th>Muscle (s):</th>
<th>Injuries:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoulder pain and upper arm pain. Decreased</td>
<td>Infraspinatus, teres</td>
<td>Swimmer’s shoulder (shoulder</td>
</tr>
<tr>
<td>internal rotation range of motion and strength.</td>
<td>minor.</td>
<td>tendinitis, shoulder</td>
</tr>
<tr>
<td></td>
<td></td>
<td>impingement), labral tear, and</td>
</tr>
<tr>
<td></td>
<td></td>
<td>any other shoulder issue.</td>
</tr>
</tbody>
</table>

SMR to the Infraspinatus Summary

**Purpose:**

The infraspinatus is repeatedly stretched during the catch phase of swimming or follow through of throwing. This overuse likely causes a rebound effect on the muscle creating tightness/trigger points. Common referral pattern down the front and back (around the deltoid tuberosity) of the arm, and trigger points are along the muscle belly.

**Directions:**
Lie on your back with your knees bent and with the opposite arm place the tennis ball under the acromion, a bone on your shoulder blade. This muscle is small, but make sure to find the most tender trigger point.

**Pectoralis - 14**

<table>
<thead>
<tr>
<th>Impairments:</th>
<th>Muscle (s):</th>
<th>Injuries:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain in the chest, upper arm, shoulder, weakness during catch, and limited shoulder extension.</td>
<td>Pectoralis major, pectoralis minor.</td>
<td>Swimmer’s shoulder (shoulder tendinitis, shoulder impingement), labral tear, and any other shoulder issue, respiratory dysfunction</td>
</tr>
</tbody>
</table>

**SMR to the Pectoralis Summary**

**Purpose:**

This muscle can become overworked from sustained anteriorly rolled shoulders and poor posture, a typical swimmer’s posture. A tight pectoralis limits scapular upward rotation, external rotation, and posterior tilt, thereby reducing subacromial space and potentially causing impingement.

**Directions:**

Lie on your stomach and place a tennis ball on the upper, outer portion of your chest. Place the tennis ball as close to your shoulder as possible, with the ball still on the muscle. You may need to position your arm diagonally to allow your arm to relax with your head rolled towards the arm being mobilized. Common trigger points are noted on the front of the shoulder and referred pain is typically seen on the anterior deltoid or down the inside of the arm.

**Subscapularis - 21**

<table>
<thead>
<tr>
<th>Impairments:</th>
<th>Muscle (s):</th>
<th>Injuries:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain in shoulder, weakened internal rotation. Limited</td>
<td>Subscapularis.</td>
<td>Swimmer’s shoulder (shoulder tendinitis,</td>
</tr>
</tbody>
</table>
SMR to the Subscapularis Summary

**Purpose:**

After repeated internal rotations (catch phase), the subscapularis is believed to be overworked and result in trigger points. The subscapularis typically has trigger points on the muscle belly, but it refers pain to multiple locations: posterior and middle deltoid as well as the wrist and shoulder blade.

**Directions:**

With a mobility stick in one hand, wrap your arm out like you are putting your arm around someone. Next, slide the mobility stick in your armpit, applying a firm pressure. Relax the mobilizing arm and maintain a steady pressure.

**Scalenes - 16**

<table>
<thead>
<tr>
<th>Impairments:</th>
<th>Muscle (s):</th>
<th>Injuries:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain in upper back (often between shoulder blades), neck, side of face, chest, arm, decreased neck rotation and extension for breathing. Decreased breathing capacity.</td>
<td>The scalenes (anterior, middle, posterior).</td>
<td>Thoracic outlet syndrome, lump in the throat, hoarseness, TMJ syndrome.</td>
</tr>
</tbody>
</table>

SMR to the Scalenes Summary

**Purpose:**

The scalenes may impair neck motion and breathing. It may also mimic other pain sensations in the body.
Directions:

In sitting, gently use your index, middle, and ring finger as you apply pressure to the side of the neck. Make sure you study the position of these muscles first!

**Masseter - 17**

<table>
<thead>
<tr>
<th>Impairments:</th>
<th>Muscle (s):</th>
<th>Injuries:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain in the side of the face, jaw, and sometimes teeth. Impaired breathing and headaches.</td>
<td>Masseter.</td>
<td>Bruxism, headache, jaw clenching, TMJ syndrome, toothache, tinnitus.</td>
</tr>
</tbody>
</table>

**SMR to the Masseter Summary**

**Purpose:**

The masseter is involved in breathing, especially mouth breathing utilized in sports like swimming. Also, the trigeminal nerve complex running through the masseter may increase fatigue if it feels extra pressure.

**Directions:**

While sitting, take your thumb and place it in front of your earlobe. Tighten your teeth to feel the muscle pop into your thumb. This is the muscle, now take your time and apply some firm pressure.

**Suboccipitals - 18**

<table>
<thead>
<tr>
<th>Impairments:</th>
<th>Muscle (s):</th>
<th>Injuries:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain almost anywhere in the head, face and neck, but especially the side of the head, behind the ear, the temples and forehead. Limited cervical spine strength and range of motion.</td>
<td>Suboccipital muscles (recti capitis posteriores major and minor, obliqui inferior and superior),</td>
<td>Headaches, neck pain.</td>
</tr>
</tbody>
</table>
SMR to the Suboccipitals Summary

Purpose:

*Tight suboccipitals can cause headaches and other facial pain.*

Directions:

*Lie on your back with your knees bent, then place a tennis ball right next to the bump on the back of your skull. Next, press your head into the ball gradually.*

**Dynamic Stretching**

Dynamic stretches appear most beneficial before exercise. These dynamic stretches have been helped many improve their mobility for exercise. However, these exercises must complement the desired task, as performing the task is the best means of improvement.

Dynamic stretching is moving the body freely through its available range of motion. Now, this definition may seem simple, but the applications for swimming may be dramatic! For this reason, many top teams are having their swimmers perform these unorthodox warm-ups before a meet and practice. As you'll see, the benefits of dynamic stretching are worth the extra ~10 minutes!

**Dynamic Stretching and Acute Power**

Power is the amount of energy consumed per unit time. Skilled swimmers generate high amounts of power during the start, turn, and catch phase of most strokes. Research suggests dynamic stretching before an activity increases acute power. The mechanism behind this improvement is not well unknown, but may simply be by warming-up the body. Luckily, dynamic stretching appears to improve power of
the knee extensors (Manoel 2008). In fact, it seems power is greater following dynamic stretching compared to other forms of stretching.

**Dynamic Stretching on Acute Performance**

Power is great, but no gold medals are awarded for power production. Instead, performance is the main guide in swimming. Unfortunately, many studies only analyze power. Remember, performance parameters are key. Unfortunately, many studies only analyze power or force, yet these do not always translate to performance. When reading research, keep this in mind!

In another study, the effects of different stretching were also assessed on vertical jump height. This study found collegiate athletes had the greatest vertical jump after dynamic stretching or dynamic flexibility (Holt 2008).

General warm-up and general warm-up + dynamic warm-up resulted in greater countermovement jump height (Pagaduan 2013).

Dynamic stretching had greater vertical jump performance enhancement in recreationally trained athletes (Perrier 2011).

Dynamic warm-up significantly increased relative strength index and flight time compared to static and only warm-up groups (Werstein 2012).

A few studies have found decreases in torque after dynamic stretching. However, these studies still showed improvements in performance (Pagaduan 2012; Holt 2008; Perrier 2011).
Dynamic stretching doesn’t improve or impair endurance performance during a 30-minute time trial (Zourdos 2012).

It also seems dynamic stretching is most beneficial 3 - 5 minutes before performance (Turki 2011).

**Summary:**
*Dynamic stretching has been shown to improve performance (measured by vertical jump). When combined with a general aerobic warm-up, dynamic stretching also appears to further enhance performance. Dynamic stretching also doesn't need to be before an activity, as it has been shown to improve performance 3 - 5 minutes before an activity.*

The following are some of the dynamic stretching I recommend. Overall, 5 minutes of dynamic stretching is most beneficial. All the videos have the password ‘CORSMR’.

**Beginner Dynamic Warm-up**

**Jumping Jacks**
Slightly jump off the ground with your legs separating. At the same time, bring your arms to your side, then to your head. Return to the starting position.

**Back Pedal**
Keeping your hips and knees bent with shoulders positioned over the balls of your feet. For the first 10 yards utilize short choppy steps. For the second 10 yards open up your stride and kick back.

**Carioca**
Stay on the balls of your feet with your hips in a low semi-squat position. Begin the drill by twisting your hips and crossing one leg in front of the other, bring your trail leg through, and cross your lead leg behind the trail leg. Your shoulders remain square through the entire drill.

**Bridge**
Lie on your back with the knees bent at 90 degrees and the palms flat on the ground. Pushing through the heels, raise the hips as high as possible using the gluteal muscles. Move solely around the hip joint and keep the lower back in a neutral position. Hold the bridge at the top position for a moment, then lower the hips to the starting position.
**Squat**
Stand with a narrow stance and feet slightly turned outward (~30 degrees). Place the arms crossed in front of the body. Initiate the movement by simultaneously breaking at the knees and hips and dropping straight down. Keep the weight on the whole foot, keep the chest up, and force the knees out of the bottom of the movement so that the knees track over the middle of the feet. Descend as deeply as possible while keeping a flat lower back. Return to the standing position.

**Standing Row**
Stand-up straight with your knees slightly bent. Next, bring your elbows next to your side with your elbows bent approximately 90 degrees. During this motion squeeze your shoulder blades together. Repeat.

**Toe Soldiers**
Kick your leg up and touch your toes to the fingers of your opposite hand. Repeat the cycle with your opposite leg.

**Stationary Buck Kicks**
Flexing your knee and bringing your heel back and around to your buttocks. Maintain a slight forward lean throughout the drill, and stay on the balls of your feet.

**Back Steps**
Stand upright, the take a long step back with one leg onto the ball of your feet. Return, repeat on the other side.

**High-Knee Jog**
Take an exaggerated high step, driving your knee as high as possible, and simultaneously push up on the toes of your opposite foot. Use the proper arm swing; 90° angle at the elbows, hands swing up to chin level and back beyond rear pocket.

**Side to Side Leg Swing Dynamic Stretch**
Swing your opposite arm and leg side to side, trying to only move at the hip and shoulder joints.

**Forward Backward Dynamic Stretch**
Swing your opposite arm and leg forward and backward, trying to only move at the hip and shoulder joints.

**Cervical Flexion Dynamic Stretch**
In standing, simply tuck your chin and lower your head. Concentrate on not letting the shoulders and thoracic spine flex.
**Cervical Rotation Dynamic Stretch**
In standing, simply rotate your head side to side. Concentrate on not letting the shoulders and thoracic spine rotate.

**Scarecrow Dynamic Stretch**
In standing, start with both of your arms flexed 90 degrees at the shoulders and elbows. Next, rotate both hands downwards to face the floor, then switch.

**Intermediate Dynamic Warm-up**

**Push-up Thigh Tough**
Place your hands next to your sides on the ground and approximately make a 30-degree angle with your arms and your body. Tighten your glutes and abdominals while obtaining the compact position. In this position, bring one arm to your thigh without letting your body lower. Repeat on the other side.

**Shoulder Rotation Dynamic Stretch**
Lean against a wall to block your shoulder blade and place your opposite hand on the head of your humerus. Next, push your hand back into the wall, not allowing the head of the humerus to move forward.

**Side-Step**
Stand upright with your knees slightly bent. Quickly step your right foot, then your left foot towards your right. Repeat towards the opposite side.

**Upper Cuts**
Stand with your knees slightly bent, then squat slightly down and return up. During the return up, punch one arm up, moving the arm directly in front of the face, stopping once the biceps is close to the face, then return.

**Rotational Punches**
Stand with your knees slightly bent, and then rotate your right foot and right arm to the left side. Return rapidly, then perform on the other side.

**Swimming Punches**
Bend approximately 90 degrees from the waist and perform an alternate arm circle punch.

**Gate Openers**
Begin standing with your arms bent. Lift one knee up, then move it out to the side. Return the leg to the start and repeat on the other side. Keep your chest open and your abs engaged!
**Lateral Lunge**
Keep your torso upright and take a long stride out to the side. Lunge out bending your forward knee to 90° while keeping your trail leg straight. Lower your hips and shift your body weight to the opposite leg. Recover by bringing your feet together and standing upright.

**Stationary lunge**
Step out with a long stride, striking the heel of your forward foot and extending onto the toes of your back foot. Complete the cycle by bringing your trail leg through and standing upright.

**Leg Drives**
Begin with one leg back and on the balls of your toes and the front knee slightly bent. Next, Drive the back leg up and forward into a position where the hip and knee are bent 90 degrees.

**Stationary Skip**
The power skip is executed by doing an explosive, exaggerated skip while emphasizing height rather than distance. Emphasize a big arm swing and explosive knee lift.

**High Knee with Hip External Rotation**
While standing, grab your ankle and knee rotating your hip, pull to your chest. Return leg, and then repeat on other leg.

**Ankle Eversion Dynamic Stretch**
In sitting, attempt to move only your foot side to side. Make sure your knee and hip do not rotate with the foot.

**Hip Rotation Dynamic Stretch**
Flex your hip and knee 90 degrees, then rotate your hip and arms around the transverse plane. Attempt to only move at your hip and do not allow your lumbar spine to twist, as twisting will increase low back stress.

**Advanced Dynamic Warm-up**

**Box**
Draw or find a small on the ground. Start in one corner of the box. Next, step forward with both feet, then diagonally with your feet going to the opposite corner. Repeat.

**Push-up IR**
Place your hands next to your sides on the ground and approximately make a 30-degree angle with your arms and your body. Tighten your glutes and abdominals while obtaining the compact position. In this position, bring one arm to your lower back without letting your body lower. Repeat on the other side.
**Bear Crawl**
Start on all fours, brace your abs in tight, and lift your hips slightly to raise knees off the floor. Step forward with right hand and left foot, and then immediately do the same with the left side.

**Dead Lifts**
Keeping that knee slightly bent, perform a stiff legged deadlift by bending at the hip, extending your free leg behind you for balance. Continue lowering until you are parallel to the ground, and then return to the upright position.

**Egyptian Dynamic Stretch**
In standing, start with both of your arms flexed 90 degrees at the shoulders and elbows. Next, rotate one hand down and the other back, then switch.

**Spiderman**
Start on all fours, brace your abs in tight, and lift your hips slightly to raise knees off the floor. Step to the side with right hand and right foot, and then immediately do the same with the left side.

**Elite and Individualized Dynamic Warm-up**

**Single Leg Squat**
Stand in front of a sturdy box, chair, bench, or step, with the hands in front of the body. Standing on one leg, sit back and down onto the surface, keeping the chest up and the spine rigid. The knee tracks over the midfoot as you push through your heel. Lift the arms for counterbalance. Pause on the box for a moment, then rise to standing, making sure to contract the glutes.

**Single Leg Deadlift**
Stand on one leg. Keeping that knee slightly bent, perform a stiff legged deadlift by bending at the hip, extending your free leg behind you for balance. Continue lowering until you are parallel to the ground, and then return to the upright position.

**Cross Leg Extension Dynamic Stretch**
Start with your legs crossed, this position blocks your lower back and pelvis from rotating. Next, raise both arms overhead and lean back as far as possible.

**Cross Leg Rotation Dynamic Stretch**
Start with your legs crossed, this position blocks your lower back and pelvis from rotating. Next, rotate both arms and your heads towards one side, attempting to improve rotation.
**Egyptian with Cervical Rotation Dynamic Stretch**
Simply start the Egyptian dynamic stretch, then rotate your heads towards the side where your fingers are pointing to the floor. Switch back and forth.

**Squat Extension Dynamic Stretch**
In a full squat, this position blocks your lower back and pelvis from rotating, raise both arms overhead and lean back as far as possible.

**Squat Rotation Dynamic Stretch**
In a full squat, this position blocks your lower back and pelvis from rotating, rotate both arms and your heads towards one side, attempting to improve rotation.

**Example SMR Programs**

**Freestyle**
1. Plantar fascia
2. Calves
3. Anterior Tibialis
4. Quadriceps
5. Quadratus Lumborum
6. Thoracic Spine
7. Upper Trapezius
8. Levator Scapulae
9. Pectoralis
10. Infraspinatus

**Backstroke**
1. Plantar fascia
2. Calves
3. Anterior Tibialis
4. Quadriceps
5. Quadratus Lumborum
6. Thoracic Spine
7. Psoas
8. Upper Trapezius
9. Levator Scapulae
10. Pectoralis
11. Infraspinatus

**Butterfly**
1. Plantar fascia
2. Calves
3. Anterior Tibialis
4. Quadriceps
5. Quadratus Lumborum
6. Psoas
7. Upper Trapezius
8. Levator Scapulae
9. Pectoralis
10. Infraspinatus

Breaststroke
1. Plantar fascia
2. Anterior Tibialis
3. Peroneals
4. Quadriceps
5. Adductors
6. Quadratus Lumborum
7. Psoas
8. Piriformis
9. Pectoralis
10. Infraspinatus

Example Dynamic Warm-up Program
Like the SMR program, you can pick any appropriate 10 exercises for the dynamic warm-up. Here are some examples.

Beginner
1. Forward Backward Dynamic Stretch 15/side
2. Side to Side Leg Swing 15/side
3. Bridge 1x30
4. Squat 1 x 20
5. Jumping Jack 1x20
6. Carioca x 45 s
7. High Knee Jog x 45 s
8. Cervical Rotation Dynamic Stretch x 45 s
9. Scarecrow Dynamic Stretch x 30 s
10. Toe Soldiers x 12/side

Intermediate
1. Shoulder Rotation Stretch x 10/side
2. Push-up Thigh Touch x 15/side
3. Carioca x 30 s
4. Side-step x 30 s
5. Upper Cuts x 20/side
6. Swimming Punches x 20/side
7. Leg Drives x 10/side
8. Stationary Lunge x 8/side
9. High Knee with Hip External Rotation 6/side
10. Hip Rotation Dynamic Stretch 30 s/side

**Advanced**

1. Box x 45 s
2. Push-up IR x 12/side
3. Bear Crawl x 45 s
4. Deadlifts x 15/side
5. Egyptian Dynamic Stretch x 15/side
6. Stationary Skip x 8/side
7. Lateral Lunge x 12/side
8. Gate Openers 15/side
9. Spiderman x 45 s
10. Ankle Eversion Dynamic Stretch x 8/side

**Elite and Individualized**

1. Single Leg Squat x 6/side
2. Single Leg Deadlift x 8/side
3. Cross Leg Extension Dynamic Stretch x 10
4. Cross Leg Rotation Dynamic Stretch x 8/side
5. Bear Crawl x 45 s
6. Spiderman x 45 s
7. Push-up Thigh Touch x 15/side
8. Carioca x 30 s
9. Side-step x 30 s
10. High Knee with Hip External Rotation 6/side
Part IV: Testing

Testing
As mentioned, testing is essential for many reasons:
  1. Monitoring Compliance
  2. Building Confidence
  3. Monitoring Improvements

Test

Push-up
Directions: Place your hands next to your sides on the ground and approximately make a 30-degree angle with your arms and your body. Tighten your glutes and abdominals while obtaining the compact position. In this position, bring your chest to the floor by squeezing your shoulder blades together and keeping your body in one unit. Then push-up, moving your body away from the floor while maintaining the compact position.

*Note:* When able to perform >8 push-ups, perform single arm push-ups (see directions below).

Inverted Row
Directions: Grasp the sides of a sturdy table or a barbell, keeping the knees bent at about 90 degrees and the heels firmly planted on the ground. Keep your body in a straight line from the knees to the shoulders, then pull your body up until your chest reaches the table or bar. Lower yourself in a controlled fashion until you reach the starting position.

*Note:* When able to perform >8 inverted rows, perform the pull-up test (see directions below).

Plank
Directions: Form a pillar or bridge by supporting your body on your stomach with only the feet and forearms touching the ground. Next, keep your body straight with the elbows directly beneath the shoulders, the hands flat on the floor, and the head looking down and contract your quadriceps and glutes.

Side Plank
Directions: Form a side pillar or bridge by supporting your body in a side-lying position with just one foot and one forearm touching the ground. Stack the legs and place the hand of the upper arm on the hip. Keep your body in a straight line and contract your glutes.
Trunk Extension
Directions: With your partner holding the backs of your ankles, drape your body over the end of a couch or sturdy table so that your legs are straight and secured. Make sure the neck is in a neutral position and your arms are in the mummy position. Bend at the hips and not the spine, getting a good stretch in the hamstrings. Raise the torso while squeeze the glutes to lockout.

Squat
Directions: Stand with a narrow stance and feet slightly turned outward (~30 degrees). Place the arms crossed in front of the body. Initiate the movement by simultaneously breaking at the knees and hips and dropping straight down. Keep the weight on the whole foot, keep the chest up, and force the knees out of the bottom of the movement so that the knees track over the middle of the feet. Descend as deeply as possible while keeping a flat lower back. Return to the standing position.

Note: When able to perform >8 squats, perform the pull-up test (see directions below).

Broad Jump
Extend a tape measure on the floor and secure it with tape. Stand normally with your toes at the line, then crouch down into a partial squat, swing your arms back, and jump forward landing with both feet. Begin with five easy jumps at 50 percent of maximal effort. Next, perform 1 - 3 jumps at 90 percent of your effort, then perform one at maximal effort.

Alternate Test Exercises

Single Arm Push-up
With one hand on the floor and your body at a 45 degree angle, place your hands next to your sides and approximately make a 30-degree angle with your arms and your body. Tighten your glutes and abdominals while obtaining the compact position. In this position, bring your chest to the floor by squeezing your shoulder blades together and keeping your body in one unit. Then push-up, moving your body away from the floor while maintaining the compact position.

Pull-up
Place your hands over the top edge of a sturdy door with your palms facing the door (wedge a book or towel underneath the door). Raise your body as high as you can while keeping a straight line from the shoulders to the knees. Slowly lower to the starting position.
**Single Leg Squat**
Stand on one leg. Sink down by breaking at the hips and knees simultaneously. Raise the arms and flex the hip of the nonworking leg, keep the chest up, and push through the heel. Descend until the desired path (not allowing the spine to flex), then return to standing.

*Testing Score Sheet*

<table>
<thead>
<tr>
<th></th>
<th>Marco 1</th>
<th>Marco 2</th>
<th>Macro 3</th>
<th>Macro 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Push-up/Single Arm Push-up</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inverted Row/Pull-up</td>
<td></td>
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<td></td>
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<tr>
<td>Plank</td>
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<tr>
<td>Side Plank L</td>
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<tr>
<td>Side Plank R</td>
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<tr>
<td>Trunk Extension</td>
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<tr>
<td>Squat/Single Leg Squat</td>
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<tr>
<td>Broad Jump</td>
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</tbody>
</table>
Part V: Team Dryland Training

Dryland Training

Beginner
Beginner (~6 – 10 years): This phase emphasizes dryland initiation, biomechanics, motor control, and diversification. If you are working with a large group, consider having each coach at an exercise station. Also, some in this age-group are not mature enough to work with partners. Using partners is at the discretion of the coach.

Routine Outline
Dynamic Warm-up: 10 Minutes Daily
Dryland Training: 2x/week
Energy Days: 2x/week optional, designed for teams using more aerobic training approach
Other Sport: 2x/week optional

Beginner Exercises

Wall Push-up
With your hands against a wall and your body at a 45 degree angle, place your hands next to your sides and approximately make a 30-degree angle with your arms and your body. Tighten your glutes and abdominals while obtaining the compact position. In this position, bring your chest to the floor by squeezing your shoulder blades together and keeping your body in one unit. Then push-up, moving your body away from the floor while maintaining the compact position.

Elevated Push-up
Place your hands next to your sides on a surface approximately 12 inches off the ground (a box or bench) and approximately make a 30-degree angle with your arms and your body. Tighten your glutes and abdominals while obtaining the compact position. In this position, bring your chest to the floor by squeezing your shoulder blades together and keeping your body in one unit. Then push-up, moving your body away from the floor while maintaining the compact position.

Floor Push-up
Place your hands next to your sides on the ground and approximately make a 30-degree angle with your arms and your body. Tighten your glutes and abdominals while obtaining the compact position. In this position, bring your chest to the floor by squeezing your shoulder blades together and keeping your body in one unit. Then
push-up, moving your body away from the floor while maintaining the compact position.

**Decline Push-up**

Place your hands next to your sides on the ground and approximately make a 30-degree angle with your arms and your body. Place your feet on an elevated surface approximately 12 inches off the floor (a chair). Tighten your glutes and abdominals while obtaining the compact position. In this position, bring your chest to the floor by squeezing your shoulder blades together and keeping your body in one unit. Then push-up, moving your body away from the floor while maintaining the compact position.

**Wall Plank**

Form a pillar or bridge by supporting your body on your stomach with only the feet and forearms touching a wall. Next, keep your body straight with the elbows directly beneath the shoulders, the hands flat on the floor, and the head looking down and contract your quadriceps and glutes.

**Elevated Plank**

Form a pillar or bridge by supporting your body on your stomach with only the feet and forearms touching an elevated surface like a table. Next, keep your body straight with the elbows directly beneath the shoulders, the hands flat on the floor, and the head looking down and contract your quadriceps and glutes.

**Kneeling Plank**

Form a pillar or bridge by supporting your body on your stomach with only the feet and forearms touching the ground. Next, keep your body straight with the elbows directly beneath the shoulders, the hands flat on the floor, and the head looking down and your knees bent on the ground.

**Plank**

Form a pillar or bridge by supporting your body on your stomach with only the feet and forearms touching the ground. Next, keep your body straight with the elbows directly beneath the shoulders, the hands flat on the floor, and the head looking down and contract your quadriceps and glutes.

**Wall Side Plank**

Form a side pillar or bridge by supporting your body in a side-lying position with just one foot on the ground and one forearm touching a wall. Stack the legs and place the hand of the upper arm on the hip. Keep your body in a straight line and contract your glutes.
**Elevated Side Plank**
Form a side pillar or bridge by supporting your body in a side-lying position with just one foot on the ground and one forward on an elevated surface. Stack the legs and place the hand of the upper arm on the hip. Keep your body in a straight line and contract your glutes.

**Kneeling Side Plank**
Form a side pillar or bridge by supporting your body in a side-lying position with just one knee and one forearm touching the ground. Stack the legs with and place the hand of the upper arm on the hip. Keep your body in a straight line and contract your glutes.

**Side Plank**
Form a side pillar or bridge by supporting your body in a side-lying position with just one foot and one forearm touching the ground. Stack the legs and place the hand of the upper arm on the hip. Keep your body in a straight line and contract your glutes.

**Prone Glute Squeeze**
Lie on your stomach and maximally squeeze your glutes.

**Prone Leg Raise**
Lie on your stomach and maximally squeeze your glutes to lift your legs off the ground. Return to the ground.

**Glute Bridge**
Lie on your back with the knees bent at 90 degrees and the palms flat on the ground. Pushing through the heels, raise the hips as high as possible using the gluteal muscles. Move solely around the hip joint and keep the lower back in a neutral position. Hold the bridge at the top position for a moment, then lower the hips to the starting position.

**Glute March**
Lie on your back with the knees bent at 90 degrees and the palms flat on the ground and foot elevated off the ground. Pushing through the heel of the leg on the ground, raise the hips as high as possible using the gluteal muscles. Move solely around the hip joint and keep the lower back in a neutral position. Hold the bridge at the top position for a moment, then lower the hips to the starting position.

**Wall Sit**
Lean your back against a wall with your feet in front of you, with your hands on your hips. Lower your body until the hips reach a 90-degree angle and the thighs are
parallel to the ground. The knees are at a 90-degree angle with the shins perpendicular to the ground and the feet flat on the ground. Hold.

**Marching Wall Sit**
Lean your back against a wall with your feet in front of you, with your hands on your hips. Lower your body until the hips reach a 90-degree angle and the thighs are parallel to the ground. The knees are at a 90-degree angle with the shins perpendicular to the ground and the feet flat on the ground. Slowly, raise one knee towards your chest, without letting your lower back round.

**Sumo Squat**
Stand with wide stance and feet slightly turned outward (~30 degrees). Place the arms crossed in front of the body. Initiate the movement by simultaneously breaking at the knees and hips and dropping straight down. Keep the weight on the whole foot, keep the chest up, and force the knees out of the bottom of the movement so that the knees track over the middle of the feet. Descend as deeply as possible while keeping a flat lower back. Return to the standing position.

**Squat**
Stand with a narrow stance and feet slightly turned outward (~30 degrees). Place the arms crossed in front of the body. Initiate the movement by simultaneously breaking at the knees and hips and dropping straight down. Keep the weight on the whole foot, keep the chest up, and force the knees out of the bottom of the movement so that the knees track over the middle of the feet. Descend as deeply as possible while keeping a flat lower back. Return to the standing position.

**3-Point Scapular Squeeze**
Sit back on your shins and place your head on the ground. Next, grasp your hands near your belt line and squeeze your shoulder blades together.

**Wall Angel**
In a mini squat against a wall, bring your arms in a “touchdown” signaling position against the wall. Next, keep the forearms and hands against the wall and raise them toward the ceiling, then lower. Do not let your forearms come off the wall or your back arch.

**3-Point Windmill**
Sit back on your shins and place your head on the ground. Keeping the arms as straight as possible, bring one arm forward and keep the other arm behind. The forward arm should have the thumb up; the backward arm should have the thumb down. Lift both arms, thinking about bringing your shoulder blades together.
3-Point Y
Sit back on your shins and place your head on the ground. Keeping your arms as straight as possible (at 11:00 and 1:00), bring both arms in front of your body with the thumbs facing upwards. Raise the arms as high as you can, remembering to raise them only as far as you can to maintain your starting back position. Lower the arms slowly and repeat.

Tabata Wall Run
Place both hands on the wall and lean your body weight against it. Next, raise your hips towards your chest and “run” towards the wall as fast as you can.

Other Sport/Game
The other sport may be any other activity, organized or unorganized. This is simply a day for fun and stressing other muscles.
### Beginner Program

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Intermediate (11 - 13 years): For most, this stage is an adaptation phase for swimmers. Overall, the swimmer’s bodies are changing, making adaptation difficult. This phase gradually increases dryland volume

Routine Outline

*Dynamic Warm-up: 10 Minutes Daily*
*Dryland Training: 3x/week*
*Energy Days: 2x/week optional, designed for teams using more aerobic training approach*
*Other Sport: 1x/week optional*

Intermediate Exercises

**Push-up**
Place your hands next to your sides on the ground and approximately make a 30-degree angle with your arms and your body. Tighten your glutes and abdominals while obtaining the compact position. In this position, bring your chest to the floor by squeezing your shoulder blades together and keeping your body in one unit. Then push-up, moving your body away from the floor while maintaining the compact position.

**Decline Push-up**
Place your hands next to your sides on the ground and approximately make a 30-degree angle with your arms and your body. Place your feet on an elevated surface approximately 12 inches off the floor (a chair). Tighten your glutes and abdominals while obtaining the compact position. In this position, bring your chest to the floor by squeezing your shoulder blades together and keeping your body in one unit. Then push-up, moving your body away from the floor while maintaining the compact position.

**Plank with Hip Extension**
Form a pillar or bridge by supporting your body on your stomach with only the feet and forearms touching the ground. Next, keep your body straight with the elbows directly beneath the shoulders, the hands flat on the floor, and the head looking down and contract your quadriceps and glutes. Next, raise one leg towards the ceiling without letting your back arch or your body rotate. Return this leg and repeat on the other side.
**Dead Bug**
Start on your back with the hips, knees and shoulders flexed ~90 degrees. Lower one leg and the opposite arm together toward the floor while engaging your abdominals.

**Plank with Shoulder Extension**
Form a pillar or bridge by supporting your body on your stomach with only the feet and forearms touching the ground. Next, keep your body straight with the elbows directly beneath the shoulders, the hands flat on the floor, and the head looking down and contract your quadriceps and glutes. Next, raise one arm towards the ceiling without letting your back arch or your body rotate. Return this arm and repeat on the other side.

**Side Plank**
Form a side pillar or bridge by supporting your body in a side-lying position with just one foot and one forearm touching the ground. Stack the legs and place the hand of the upper arm on the hip. Keep your body in a straight line and contract your glutes.

**Side Plank with Hip Abduction**
Form a side pillar or bridge by supporting your body in a side-lying position with just one foot and one forearm touching the ground. Elevate the top leg off the ground and place the hand of the upper arm on the hip. Keep your body in a straight line and contract your glutes. Next, move the top leg off and hold.

**Feet Elevated Side Plank**
Form a side pillar or bridge by supporting your body in a side-lying position with one forearm touching the ground and the legs stacked on a small bench. Place the hand of the upper arm on the hip. Keep your body in a straight line and contract your glutes.

**Clam**
Start in the side-lying position with the hips bent at about 135 degrees and the knees bent at about 90 degrees. The neck rests on the arm of the ground. The arm is on the hip. With the heels touching each other, rotate the top hip up. Be sure to move at the hips. Don’t lean to one side or move at the spine. The heels stay together for the entire set. Return to the starting position. Complete the desired number of repetitions and repeat on the other side.

**Bird Dog**
Get in the table top position, being on all fours. Have your hands under your shoulders and knees under your hips. Next, extend your opposite arm and leg back, then return.
**Hip Thrust**

Facing upward, place your upper back on the top of a couch, sturdy chair, or weight bench with your feet flat on the ground. Place the hands on the ears and extend the hips by squeezing the glutes. Push through the heels and keep the lower back in a neutral position. Raise as high as possible through the hips and then lower your hips to the starting position.

**Hip Thrust March**

Facing upward, place your upper back on the top of a couch, sturdy chair, or weight bench with one foot flat on the ground and the other foot in the air. Place the hands on the ears and extend the hips by squeezing the glutes. Push through the heel and keep the lower back in a neutral position. Raise as high as possible through the hips and then lower your hips to the starting position.

**Static Lunge**

Get into a split-stance position that is wide enough that your front shin is vertical at the bottom of the lunge. Your hands are on the hips and feet pointed straight ahead. Keeping the torso upright, descent until the back knee approaches or touches the ground. Return to the starting position.

**Step-Ups**

Begin with your entire foot placed on top of a step, box, or sturdy chair while the other foot remains on the ground. Shift your weight forward and lift your body weight by stepping up, making sure that the top leg does most of the work and the bottom leg doesn't provide too much momentum. Stand tall and squeeze the working glute. Do not touch the working leg on the bench and swing the non-grounded knee upward by flexing the hip. Lower yourself slowly.

**Alternate Lunge**

Step forward into a split-stance position that is wide enough that your front shin is vertical at the bottom of the lunge. Your hands are on the hips and feet pointed straight ahead. Keeping the torso upright, descent until the back knee approaches or touches the ground. Return to the starting position and switch legs.

**3-Point Y**

Sit back on your shins and place your head on the ground. Keeping your arms as straight as possible (at 11:00 and 1:00), bring both arms in front of your body with the thumbs facing upwards. Raise the arms as high as you can, remembering to raise them only as far as you can to maintain your starting back position. Lower the arms slowly and repeat.
**Inverted Row**
Grasp the sides of a sturdy table or a barbell, keeping the knees bent at about 90 degrees and the heels firmly planted on the ground. Keep your body in a straight line from the knees to the shoulders, then pull your body up until your chest reaches the table or bar. Lower yourself in a controlled fashion until you reach the starting position.

**Feet Elevated Inverted Row**
Grasp the sides of a sturdy table or a barbell, with your feet elevated on a small box or bench. Keep your body in a straight line from the knees to the shoulders, then pull your body up until your chest reaches the table or bar. Lower yourself in a controlled fashion until you reach the starting position.
## Intermediate Program

### Macro 1

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**Advanced**

Advanced (14-16 years): At this stage, swimmers progress the strengthening program, like in the intermediate program. Safe, simply plyometrics also begin. If a swimmer is superior, then an individualized program may help at this stage. Lastly, visualization and breathing exercises are initiated.

**Routine Outline**

*Dynamic Warm-up: 10 Minutes Daily*

*Mobility Warm-up: 10 Minutes Daily*

*Dryland Training: 3x/week*

*Energy Days: 2x/week optional, designed for teams using more aerobic training approach*

*Mobility Days: 2x/week optional*

**Advanced Exercises**

**Weighted Floor Push-Up**

Place your hands next to your sides on the ground and approximately make a 30-degree angle with your arms and your body while wearing a weighted vest or bookbag. In this position, bring your chest to the floor by squeezing your shoulder blades together and keeping your body in one unit. Then push-up, moving your body away from the floor while maintaining the compact position.

**Wall Single Arm Push-Up**

With one hand against a wall and your body at a 45 degree angle, place your hands next to your side and approximately make a 30-degree angle with your arms and your body. Tighten your glutes and abdominals while obtaining the compact position. In this position, bring your chest to the floor by squeezing your shoulder blades together and keeping your body in one unit. Then push-up, moving your body away from the floor while maintaining the compact position.

**Plyometric Wall Push-Up**

Place your hands next to your sides on the wall with your arms and body making an approximately 30-degree angle. Tighten your glutes and abdominals while obtaining the compact position. In this position, bring your chest to the floor, keeping your body in one unit, then explode off the ground.

**Plyometric Elevated Wall Push-Up**

Place your hands next to your sides on a surface approximately 12 inches off the ground (a box or bench) and approximately make a 30-degree angle with your arms and your body. Tighten your glutes and abdominals while obtaining the compact position. In this position, bring your chest to the floor by squeezing your shoulder...
blades together and keeping your body in one unit. Then push-up, moving your body away from the floor while maintaining the compact position, then explode off the ground

**Plank with Shoulder Flexion and Hip Extension**

Form a pillar or bridge by supporting your body on your stomach with only the feet and forearms touching the ground. Next, keep your body straight with the elbows directly beneath the shoulders, the hands flat on the floor, and the head looking down and contract your quadriceps and glutes. Next, raise one arm and the opposite leg towards the ceiling without letting your back arch or your body rotate. Return this arm and leg, then repeat on the other side.

**Walking Plank**

Form a pillar or bridge by supporting your body on your stomach with only the feet and forearms touching the ground. Next, keep your body straight with the elbows directly beneath the shoulders, the hands flat on the floor, and the head looking down and contract your quadriceps and glutes with your feet pointed. Next, step forward with your arms, attempting not to move your hips side to side.

**Sliding Plank Walkout**

Form a pillar or bridge by supporting your body on your stomach with only the feet and forearms touching the ground. Next, keep your body straight with the elbows directly beneath the shoulders, the hands flat on the floor, and the head looking down and contract your quadriceps and glutes. Next, slide your hands forward without moving your body, then return to the plank position.

**Bunkie**

Form a side pillar or bridge by supporting your body in a side-lying position with one arm touching the ground while stacking the legs on a small bench. Place the hand of the upper arm on the hip. Keep your body in a straight line and contract your glutes.

**Bunkie with Hip Abduction**

Form a side pillar or bridge by supporting your body in a side-lying position with one arm touching the ground and the bottom leg on a small bench. Next, raise the top leg toward the ceiling and hold. Place the hand of the upper arm on the hip. Keep your body in a straight line and contract your glutes.

**Feet Elevated Hip Thrust**

Facing upward, place your upper back on the top of a couch, sturdy chair, or weight bench with your feet on a sturdy box or bench. Place the hands on the ears and extend the hips by squeezing the glutes. Push through the heels and keep the lower back in a neutral position. Raise as high as possible through the hips and then lower your hips to the starting position.
**Feet Elevated Hip Thrust March**

Facing upward, place your upper back on the top of a couch, sturdy chair, or weight bench with one foot on a sturdy box or bench. Place the hands on the ears and extend the hips by squeezing the glutes. Push through the heel and keep the lower back in a neutral position. Raise as high as possible through the hips and then lower your hips to the starting position.

**Partner-Assisted Back Extension**

With your partner holding the backs of your ankles, drape your body over the end of a couch or sturdy table so that your legs are straight and secured. Make sure the neck is in a neutral position and your arms are in the mummy position. Bend at the hips and not the spine, getting a good stretch in the hamstrings. Raise the torso while squeeze the glutes to lockout.

**Single leg box squat**

Stand in front of a sturdy box, chair, bench, or step, with the hands in front of the body. Standing on one leg, sit back and down onto the surface, keeping the chest up and the spine rigid. The knee tracks over the midfoot as you push through your heel. Lift the arms for counterbalance. Pause on the box for a moment, then rise to standing, making sure to contract the glutes.

**Skater Squat**

Stand on one foot and place the hands in front of the body. Sit back and down, breaking at the hips and knees while leaning forward at the trunk. Descend until the knee of the nonworking leg approaches or touches the ground. Stand up to return to starting position. Perform all the repetitions with the weaker leg first and then switch and repeat with the stronger leg.

**Lunge Jump**

Step forward into a split-stance position that is wide enough that your front shin is vertical at the bottom of the lunge. Your hands are on the hips and feet pointed straight ahead. Keeping the torso upright, descent until the back knee approaches or touches the ground. Then, rapidly jump off the ground, landing in the original split-stand position breaking at your hips and knees to absorb the landing.

**Alternate Lunge Jump**

Step forward into a split-stance position that is wide enough that your front shin is vertical at the bottom of the lunge. Your hands are on the hips and feet pointed straight ahead. Keeping the torso upright, descent until the back knee approaches or touches the ground. Return to the starting position and switch legs. Then, rapidly jump off the ground, landing in the original split-stand position breaking at your hips and knees to absorb the landing.
Standing Single Arm Inverted Row
Grasp a rail with one arm. Keep your body in a straight line from the knees to the shoulders, then pull your body up until your chest reaches the table or bar. Lower yourself in a controlled fashion until you reach the starting position.

Single Arm Inverted Row
Grasp underneath a bar with one arm. Keep your body in a straight line from the knees to the shoulders, then pull your body up until your chest reaches the table or bar. Lower yourself in a controlled fashion until you reach the starting position.

Assisted Pull-up
Place your hands over the top edge of a sturdy door with your palms facing the door (wedge a book or towel underneath the door). Raise your body as high as you can while keeping a straight line from the shoulders to the knees. Have a partner hold your hips and assist you towards the top. Slowly lower to the starting position.

Pull-up
Place your hands over the top edge of a sturdy door with your palms facing the door (wedge a book or towel underneath the door). Raise your body as high as you can while keeping a straight line from the shoulders to the knees. Slowly lower to the starting position.
# Advanced Program

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**Elite**

Senior (17-21 years): Most athletes are physical mature at this age, however improving muscular imbalances and maintaining motor skills are still important. During this phase, strengthening continues, with greater volume and more emphasis on recovery.

**Routine Outline**

*Dynamic Warm-up: 10 Minutes Daily*
*Mobility Warm-up: 10 Minutes Daily*
*Dryland Training: 3x/week*
*Energy Days: 2x/week optional, designed for teams using more aerobic training approach*
*Mobility Days: 2x/week*

**Elite Exercises**

**Floor Single Arm Push-up**

With one hand on the floor and your body at a 45 degree angle, place your hands next to your sides and approximately make a 30-degree angle with your arms and your body. Tighten your glutes and abdominals while obtaining the compact position. In this position, bring your chest to the floor by squeezing your shoulder blades together and keeping your body in one unit. Then push-up, moving your body away from the floor while maintaining the compact position.

**Decline Single Arm Push-up**

Place your hands next to your side on the ground and approximately make a 30-degree angle with your arms and your body, then elevate your feet approximately 12 inches (on a bench). Place your feet on an elevated surface approximately 12 inches off the floor (a chair). Tighten your glutes and abdominals while obtaining the compact position. In this position, bring your chest to the floor by squeezing your shoulder blades together and keeping your body in one unit. Then push-up, moving your body away from the floor while maintaining the compact position.

**Plyometric Push-up**

Place your hands next to your sides on the ground, with your arms and body making an approximately 30-degree angle. Tighten your glutes and abdominals while obtaining the compact position. In this position, bring your chest to the floor, keeping your body in one unit, then explode off the ground.

**Plyometric Decline Push-up**

Place your hands next to your sides on the ground and approximately make a 30-degree angle with your arms and your body. Place your feet on an elevated surface...
approximately 12 inches off the floor (a chair). Tighten your glutes and abdominals while obtaining the compact position. In this position, bring your chest to the floor by squeezing your shoulder blades together and keeping your body in one unit. Then push-up, moving your body away from the floor while maintaining the compact position, then explode off the ground.

**Plank with knee tucks**

Form a pillar or bridge by supporting your body on your stomach with only the feet and forearms touching the ground. Next, keep your body straight with the elbows directly beneath the shoulders, the hands flat on the floor, and the head looking down and contract your quadriceps and glutes with your toes pointed. Next, slide your knees toward your chest, then return. Make sure not to round your back as you bring your legs up.

**Dragon Flag**

Lie on your back and grab hold of an object like a heavy couch or steady chair. Next, rotate your entire body about your upper shoulders, keeping the body in a straight line and maintaining a good core contraction.

**Bunkie with hip abduction**

Place a circular band around your ankles. Form a side pillar or bridge by supporting your body in a side-lying position with one arm touching the ground and the bottom leg on a small bench. Place the hand of the upper arm on the hip. Keep your body in a straight line and contract your glutes. Next, raise the top leg toward the ceiling and return.

**Bunkie with hip adduction**

Form a side pillar or bridge by supporting your body in a side-lying position with one arm touching the ground and the top leg on a small bench. Next, squeeze the bench between the bottom and top leg. Place the hand of the upper arm on the hip. Keep your body in a straight line and contract your glutes.

**Single Leg Partner-Assisted Back Extension**

With your partner holding the backs of one ankle (while the other knee is bent), drape your body over the end of a couch or sturdy table so that your legs are straight and secured. Make sure the neck is in a neutral position and your arms are in the mummy position. Bend at the hips and not the spine, getting a good stretch in the hamstrings. Raise the torso while squeeze the glutes to lockout.

**Reverse Hyper**

Lie with your torso across a sturdy table, draping your legs over the edge and grasping the edges of the table, knees straight. Keeping the torso locked into place, raise the legs, making sure to squeeze the glutes up top and prevent overextension of the low
back. Lower the legs to the starting position, keeping the spine stable and making sure to prevent rounding the low back.

**Single Leg Reverse Hyper**

Lie with your torso across a sturdy table, draping your legs over the edge and grasping the edges of the table, knees straight. Bend one leg toward the table, then while keeping the torso locked into place, raise one leg, making sure to squeeze the glutes up top and prevent overextension of the low back. Lower the leg to the starting position, keeping the spine stable and making sure to prevent rounding the low back.

**Bulgarian Split Squat**

Stand in front of a step, stair, couch, bench, or table. Reach back with one foot, resting on the top of the foot on top of the surface (laces down). With an upright trunk sink the knee of the rear leg down and slightly back while trying to keep most of the body weight on the front leg. Descend until the back knee almost touches or touches the ground, then return to the starting position.

**Pistol Assisted Squat**

Wrap a towel around a pole or pillar. Stand on one leg. Sink down by breaking at the hips and knees simultaneously. Raise the arms and flex the hip of the nonworking leg, keep the chest up, and push through the heel while using the arms for support. Descend until the desired path (not allowing the spine to flex), then return to standing.

**Pistol Squat**

Stand on one leg. Sink down by breaking at the hips and knees simultaneously. Raise the arms and flex the hip of the nonworking leg, keep the chest up, and push through the heel. Descend until the desired path (not allowing the spine to flex), then return to standing.

**Russian Leg Curl**

Find a rail, beam, stable couch, or partner to stabilize your feet. Kneel on top of a pillow or folded towel to reduce pressure on the knees. With an upright trunk slowly lower the body under control while keeping the glutes tight, making sure not to bend forward too much at the hips or allow the pelvis to anteriorly rotate too much. At the bottom of the movement, catch yourself in a push-up position and spring back to the starting position, using your hamstrings for movement production.

**2:1 Lunge Jump**

Step forward into a split-stance position that is wide enough that your front shin is vertical at the bottom of the lunge. Your hands are on the hips and feet pointed straight ahead. Keeping the torso upright, descend until the back knee approaches or
touches the ground. Then, rapidly jump off the ground, landing in the original split-stand position breaking at your hips and knees to absorb the landing on one leg.

**Single leg Long Jump**

Stand on one leg. Initiate the movement by simultaneously breaking at the knees and hips and dropping straight down. Keep the weight on the whole foot, keep the chest up, and force the knees out of the bottom of the movement so that the knees track over the middle of the feet. Descend as deeply as possible while keeping a flat lower back, then explode upwards off the ground. Land softly by breaking at the knees and hips. Return to the standing position.
# Elite Program

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Part VI: Individualized Dryland Program

Ultra Elite
Elite (US Olympic Trial Qualifiers): This group receives the ultimate dryland for enhancement. Overall, biomechanics are the main determinant of success in all swimmers. This group deserves frequent attention, monitoring for any initial signs of injury and excessive attention to detail, focusing on the same biomechanical fault they are focusing on in the pool. All video passwords in this section are ‘swim@rio2016’.

Routine Outline
Dynamic Warm-up: 10 Minutes Daily
Mobility Warm-up: 10 Minutes Daily
Dryland Training: 5x/week, correlating with biomechanical flaw in the water
Mobility Days: 2x/week

Individualized Routine
Video: Introduction Lecture Part I, Introduction Lecture Part II

Posture
Videos: Posture Lecture, Posture Assessment

During the movement screen, you may observe postural deviations in your swimmers. You’ll also note much discussion about posture in this book, but it’s important to keep posture in context. Postural deviations are noted in people of all ages, especially during societal transitions from long seated periods, to standing, to horizontal in the water, and many variations in between. Athletes, especially swimmers, commonly present with rounded shoulders and slumped sitting. There are a few hypotheses for this, but the most logical is swimmers use their shoulders more than most sports, which greatly fatigues their arms, causing laziness while seated.

Whether static or dynamic, postural syndrome is a horrible cascade of tight and short muscles as well as long and weak muscles. A few weak muscles include the scapular stabilizers or upward rotators (serratus anterior, lower trapezius), deep neck flexors (longus colli), and the abdominals (rectus abdominus). These areas need to be strengthened, but the tight and short muscles also need to be lengthened. The tight muscles include the levator scapulae, pectoarlis minor, subscapularis, suboccipital muscles, quadratus lumborum and iliopsoas.
Stretching is often the default strategy for improving mobility in swimmers, but its safety and efficacy has been thoroughly challenged in the literature.\(^1\) \(^2\) Small muscle contractions often occur with stretching, and if these short, tight muscles are highly aggravated then they can spasm and become tighter with stretching, accelerating the problem. Reduced muscle length is often a neurological phenomenon, not a purely structural one. As such, adding muscle length requires care to not become overly aggressive with stretching but instead to provide the nervous system with the appropriate stimuli to encourage changes.

Self myofascial release (SMR) is a soft tissue technique using slow and moderate pressure into the muscle, often performed with tennis/lacrosse balls, pinky balls, foam rolls, etc. Evidence is still emerging in this area, but one recent study\(^3\) showed that foam rolling the quadriceps for two minutes elicited a ten degree improvement in range-of-motion. This same research has shown that SMR may not impair acute strength, as seen in static stretching.\(^4\) Anecdotally, many have also found that rolling the soles of the feet with a tennis ball may improve toe touch and sit-and-reach flexibility. Though the exact mechanisms are unclear behind these changes, this is simply one other example of how similar approaches may improve mobility without traditional stretching.

Though static posture offers clues, most important is how the swimmer maintains dynamic posture during movement. If a swimmer can’t begin with appropriate static posture, all subsequent movements become more difficult. That said, many great athletes have suboptimal static posture but find optimal posture dynamically. Further the link between posture and pain is inexact. Posture is a risk factor but not determinative of pain. Both static and dynamic posture deserve attention but you should place more value on what strategies the brain and body use to achieve dynamic posture.

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\(^4\)
The dualism of tight and short and long and weak muscles still leaves many questions. The great Dr. Vladimir Janda raised several issues relating to this dualism:\(^5\)

- Random or part of generalized pattern?
- Because from a biomechanical view some muscles are stronger than others?
- Developed as a mechanical response to change in center of gravity secondary to faulty posture or as a result of reflex relationships between various muscles in a movement pattern?
- Innervation difference between tight and weak muscles?
- Do patterns develop as result of changes in postural reflexes associated with lumbar spine dysfunction or do they develop independently? (Myofascial releases can break this potential “reflex.”)
- Related to stereotypic movement patterns or lack of appropriate movements in developed countries (sitting for eighteen hours a day).

Overall, muscle imbalances including weaknesses and tightness will present in everyone, whether they do or don’t have symptoms. Remember just because an imbalance is present, doesn’t mean you are doomed for injury, as many swimmers have certain imbalances but no pain. Therefore, trying to equalize or create a “perfectly symmetrical” body is impossible, but finding weak planes of motion or weakness with gross movement should be fixed to prevent potential injuries. It is even clear swimmers have asymmetries on land, which is one focus of our screening system.\(^6\)

Exercises for postural improvement are scattered in this text. Here are a few effective exercises:
- ✔ Foam Roll Thoracic Spine
- ✔ Swiss Ball Y

**Breathing**

Videos: [Breathing Lecture](#), [Breathing Screen](#)

Video: [Maximum Inhale/Exhale](#)

Breathing is a uniquely simple, yet complex function performed by numerous muscles. In swimming, this simple task is more complex due to acute hypoxic events such as


breath holding at turns and when restricting breathing mid-pool. This uniqueness makes swimming a novelty compared to other terrestrial sports.

There are four types of respiration:

1. Quiet or passive inspiration
2. Quiet or passive expiration
3. Forced or active inspiration
4. Forced or active expiration

First, a basic understanding is necessary for breathing. Many confuse the chest as the primary area of respiration, a misconception likely due to the location of the lungs. The predominant muscle of respiration (on-land and during swimming) is the diaphragm.  

During passive inspiration, the diaphragm contracts and the pleural and alveolar pressure lowers, resulting in a flow of air through the mouth and into the lungs. Passive expiration is simply the elastic recoil of the lungs and chest, resulting in no muscle activation.

However, during exertion many muscles become involved. Specifically, the external intercostals raise the lower ribs up and out. The scalene muscles and sternocleidomastoid muscles help raise the push out the upper ribs and chest.

During forced expiration, the abdominal muscles facilitate an increase in the intra-abdominal pressure during contraction. These muscles also push up the diaphragm, helping elevate the pleural and alveolar pressure, pushing out air. Lastly, the internal intercostals help pull the ribs down and in, decreasing in chest volume.

These are the main functions and muscles involved during respiration. However, during forced expiration even more secondary respiratory muscles, including many which attach to the shoulder blade and collarbone, become active and potentially increase shoulder demand.

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Breathing and swimming

Much recent research has looked at inspiratory muscle training and inspiratory muscle fatigue and swimming performance. Overall, it is consistent that inspiratory muscle fatigue contributes to fatigue in swimming. However, the amount of intensity and point during a race where inspiratory fatigue sets in is still uncertain and likely individual and event dependent. Moreover, including inspiratory muscle training has been suggested to improve swimming performance. Consider the wide range of breathing patterns even at the highest levels, from Sun Yang occasionally breathing consecutive strokes to others in the same event breathing every two or three strokes. Also, the frequency of breathing likely contributes to fatigue, as inspiratory muscle fatigue seems inversely correlated with breathing frequency.

Many studies have used different mechanisms to increase inspiratory muscle strength with variable results, yet it is clear that swimming induces respiratory fatigue. However, questions still remain: if swimming improves total lung capacity and forced expiratory volume, will additional inspiratory training improve performance? Also, are the methods being used in these limited trials adequate to yield changes in elite athletes?

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Regardless, it seems evident relaxed breathing should be autonomous and not recruit every muscle in the body for ideal energy conservation. If improper breathing occurs, one likely fatigues their secondary respiratory muscles, signaling the “cheater” muscles. Breathing is a primal reflex nearly impossible to suppress, so if the primary muscles aren’t doing their job, the brain’s hardwired impulse to obtain oxygen and expel carbon dioxide will call upon cheater muscles for survival. Many athletes need to start simple, learning how to utilize the primary respiratory muscles with relaxed breathing, not allowing the cheaters to activate and cause altered motor control, early fatigue and increase the risk of injury!

**Land Tests**

**Breathing screen**

When performing breathing screens on your swimmers, do not let them know what you’re looking for. This task is difficult with deep breathing, but simply telling them to take a deep breath and encouraging them to take in more air brings out their competitive side and reveals their true breathing pattern.

**Forced inspiration**

During a forced inspiration there are three steps to look for:

1. Diaphragm descends.
2. Ribs expand, elevate and rotate forward.
3. Shoulder blades move laterally.

**Relaxed inspiration**

During a relaxed inspiration simply look for complete relaxation; this is key for energy conservation. As discussed, the diaphragm is the main respiratory muscle. As the diaphragm contracts during relaxed inspiration, the lungs recoil back to their original position without any muscle contraction. This is why breathing is considered an autonomous activity; it requires no thought, and the body simply breathes.

The lungs are just like a like a balloon. If you blow up a balloon the outsides are stretched and forced to expand, but if you let out air, the balloon will recoil to its original position without any assistance.

In relaxed breathing, look for a wave of motion, starting from the stomach rolling superiorly (upward) to the chest when viewed from the anterior (front) side of the body. Some experts suggest a stationary chest is necessary during relaxed breathing, but in reality a slight forward (not upwards) movement is likely to occur.
Common Findings (Waves)
If one of the major breathing muscles (i.e. diaphragm) is not working properly, the other muscles likely increase their demand, as breathing will occur even during dysfunction. During forced respiration (athletic activities), if the primary respiratory muscles are not involved, a swimmer is vulnerable to more injuries and unnecessary stress on structures. If the body must choose between oxygen and athletics, the body will choose oxygen. Poor diaphragm use may lead to subsequent overuse of your swimming “prime movers” to breathe such as the latissimus dorsi, pectoralis, and trapezius. When these muscles fatigue prematurely due to increased use, swimming speed decreases as well. Living in a semi-hypoxic state is part of swimming, but we must understand the body’s natural compensation habits to address breathing in the context of stroke troubleshooting.

Stroke Flaws (Tsunamis)

Late breathing
Late breathing can result from many causes in freestyle and butterfly, but one cause is the lack of relaxation in the water during acute hypoxia or carbon dioxide buildup.

Labored breathing
Take long belated breaths suggests for muscle timing breathing the muscles of respiration.

Bobble head
Moving the head excessively during breathing is potentially caused by excessive involvement of secondary muscle respiration.

Secondary respiratory muscle breathing
This is easier to spot on land than in the water, but still deserves mention here. Ideally swimmers would use primary respiratory muscles at all times. Some secondary muscle contribution is inevitable during high exertion, but overuse may result in
damage to vulnerable structures in the neck and shoulders. Another side effect of secondary muscle contribution is removal of these muscles from their primary roles in propulsion and stabilization.

**Corrections**

Dryland corrections must assess the tests described earlier. One area of concern is total lung capacity during stress. For improvement in this facet, performing maximal breath holds out of water is key. Next, learning coordination between the abdominal, shoulder, and respiratory muscles is essential for ideal breathing. Follow the breathing routine below to incorporate these elements.

Many of the breathing exercises correlate with the breathing tests. This is purposeful, as learning to breathe is essential for success. Proper differentiation helps the athlete prevent fatigue of the inspiratory muscles. Future chapters will discuss differentiation tactics for multiple joint systems.

However, improvement of maximal breathing is also important like in the “breathing routine.” This routine encompasses:

**Deep breathing**

Taking a big breath in through the mouth, holding for one second, and then exhaling for 10 seconds through your almost-closed mouth with tongue pressed against your lower teeth. It should be a hissing exhalation and make a “tsssssss” sound. All breathing and exercises—both inhalation and exhalation—are performed through the mouth, as this is how we breathe in the pool.

**Kazoo abs or Balloon abs**

Video: [Kazoo Abs](#)
Blowing into a kazoo or blowing up a balloon are both effective breathing drills. Follow the directions in the attached video for proper setup and progression.

**Purging**

A strong exhalation as if you were trying to blow a toy sailboat across a pool, followed by a big but faster inhalation. (Imagine the Big Bad Wolf blowing the pigs’ houses down.) Be careful not to heave or rock back and forth, as this increases the respiratory demand. Keep as still as possible.

**Semi-purging**

Breathing somewhere between deep breathing and purging. More forceful than deep breathing but less forceful than full purging.
Cat vomit

Video: Cat Vomit
Another version of purging, cat vomit integrates flexion and extension movements with breathing coordination.

Breathing routine

Video: Breathing Routine
All durations are in MIN: SEC format, and everything should be performed lying down. Total for this routine is approximately twenty minutes but can be adjusted based on the individual swimmer’s capabilities. The numbers below are recommended for a high school or senior level swimmer. To modify for lower levels, a general guide is to take thirty seconds off each allotted time for middle school or junior level; take forty-five seconds off each time for beginners. However, always consider individual capabilities, as these are numbers are merely suggestions. During the whole routine, have your swimmers wiggle their fingers every 0:30 for safety purposes.

1)  1:15 purging (if you feel like you’re going to pass out, do it less intensely).
2)  Hold breath for a target 1:30, no more.
3)  After that hold: Take three semi-purge breaths.
4)  1:30 deep breathing.
5)  1:30 purging.
6)  Hold breath for a target 2:30, no more.
7)  After that hold: Take three semi-purge breaths.
8)  2:00 deep breathing.
9)  1:45 purging.
10)  Hold breath for as long as possible.
11)  After exhalation: Take 3-10 hard semi-purge breaths until you recover.

Summary
This seemingly simplistic feature requires assessment and correction in all sports, but more so in swimmers due to the acute hypoxic events during the sport. With the emergence and expansion of underwater kicking, incorporating ideal breathing and relaxation techniques can isolate and amplify these features for swimming success. Moreover, the ability to utilize the appropriate muscles decreases excess stress on stability muscles, allowing them to aid in propulsion and injury prevention.
Cervical Spine

The cervical spine, or the neck, is a delicate area that protects critical elements of the nervous system. Some refer to the neck as the body’s “circuit breaker.” Neck dysfunction and pain have cascading effects throughout the body and minor insults to this region can have profound implications in swimming.\(^\text{18}\)

The neck is sensitive to other movements in other regions, particularly the thoracic spine (upper back), which sits immediately below the cervical spine. Furthermore, as the neck muscles, such as the upper trapezius and sternocleidomastoids, are innervated by the cranial nerves, neck movements can offer a window into the state of the autonomic nervous system.

Breathing and neck function are also closely linked, particularly with swimming naturally high in oral breathing utilization. Because oral breathing is most common, it is important to understand the type of stress imposed on the swimmers upper extremities, as the head and neck may affect the more commonly injured shoulders. Okoru\(^\text{19}\) found that oral breathers had worse cervical spine posture and decreased respiratory muscle strength than nasal breathers. There are times when those accessory muscles are needed, such as during extended periods of intense activity. However, diaphragmatic breathing as a default setting spares the accessory breathing muscles. As such, breathing can promote optimal neck function in and out of the water. Tight cervical muscles may impair nearby regions in the shoulder and thoracic spine, particularly if the neck muscles are fatigued from overuse.

A forward head position, which is common in the classic “swimmer posture,” adds stress elsewhere in the body. Sometimes the body adjusts and is asymptomatic, but often compensations result in alterations to muscle length, strength and timing. When this occurs, the body may overstress connective tissue such as tendons and ligaments causing the body to rely on passive structures like vertebrae and bones for stability.

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Forward head position is also linked to upper extremity trigger points and headaches. Pain affects neck flexor endurance, but improving endurance can help relieve pain. Manual therapy on the neck was also shown to improve grip strength in judo athletes. However, once pain is present, movement is inconsistent, as the literature shows no correlation between cervical range of motion and pain.

**Land Tests**

Video: [Cervical Land Assessment](#)

One basic question behind assessment and correction for swimmers: "Does the swimmer have a physical limitation that prevents him/her from doing what they need to do in the water?" With all joint systems, we check for mobility, stability, and coordination, which is expressed as muscle length, strength and timing.

**Active range of motion (ROM) - Muscle length**

**Length**

For all length screens use the following start position:
1) Standing with feet together
2) Mouth closed
3) Arms at sides

**Flexion**

Tuck the chin to the sternum. Common restrictions include inability to touch the chin toward the sternum or using the shoulders to drive the movement. Mouth should remain closed during the movement.

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Extension
Gently look overhead. Goal is not to achieve end range but rather to see if basic mobility exists to balance flexion. Follow the directions in the video for proper execution. Common restrictions include inability to extend neck or excess contributions from the shoulders. Mouth should remain closed.

Rotation (Left and Right)
Looking right and left. Common findings include compensatory movement from the shoulders or the mouth.

Strength and timing

Cervical flexion test
Video: Cervical Flexion Endurance
Lying supine, tuck your chin to create a double chin. Hold for ten seconds. While doing so, slightly lift the back of the head off the ground, but without bending the neck.

Why is this test important? Although there is minimal direct load on the neck in swimming (unlike in football or wrestling), the neck is inherently unstable, much like a golf ball resting on a golf tee. Now imagine the tee moving around in the water and you can see the importance of the neck in swimming! Additionally, even sprints require cervical spine endurance to maintain a relatively neutral head and neck.

Particularly of concern are innate reflex patterns, some of which are consistent with optimal swim biomechanics but which directly contradict the stroke. Because the head and neck are primary sensory centers for the body, understanding the body’s inherent programming is important for future stroke corrections. Many flaws are the body’s subconscious strategies to deal with these reflexes.

First, it’s important to understand that swimming is a primitive reflex. Testing this reflex is not recommended, as submerged infants commonly swallow water, but if infants are placed on their stomach submerged in water, they will reflexively paddle and kick up until approximately six months. This suggests that contrary to popular belief, swimming is not a wholly unnatural activity to human beings.
Even though swimming is a reflexive movement, other primitive reflexes counteract the ideal biomechanics for optimal horizontal positioning. A couple of other examples include:

**Asymmetrical tonic neck reflex**
This reflex disappears approximately after the fourth month of life. This reflex consists of a baby turning their head to the side (for example, the right) and their ipsilateral arm (right) extends, while the contralateral arm (left) flexes. As one breathes during freestyle, their arm on the non-breathing side typically extends and their breathing side is typically bent (although, not always in straight-arm catch freestyle). This opposition of primitive reflexes likely contributes to difficulty of freestyle patterning as a youth.

**Palmar grasp reflex**
Another reflex disappearing at six months of age occurs as any pressure is placed in an infant’s palm, as they grasp the object. This seems uninvolved in swimming, but it occurs at turns, specifically altering proper touch turns on flat walls. Imagine hitting a flat wall turn at Nationals. One must block the palmar grasp reflex, as grasping the wall is instinctive. This can also occur during swimming, as water is a denser medium than air, potentially forcing reflex inhibition during every stroke.

Adjusting swimming biomechanics for primitive reflexes is purely theoretical, but worth considering when teaching the stroke. Understanding how the body is preprogrammed can help coaches understand why certain flaws are persistent in their swimmers.

**Common Findings (Waves)**
The movement screen specifically addresses the above listed deficits, but also consider these factors:

**Overall posture**
Faulty neck position can result from postural syndromes involving the whole body (upper crossed and lower crossed along with hybrids of the two). Dr. Vladimir Janda is credited with first observing the phenomenon of reciprocal inhibition and the related postural syndromes of the upper and lower body. In reciprocal inhibition, the glutes, abs, serratus anerior, lower traps, and deep neck flexors are prone to inhibition or weakness. These are known as the phasic muscles. The tonic muscles such as hip flexors, low back extensors, pectorals, upper traps, and levator scapulae are prone to tightness or hyperactivity.
**Breathing**

Training in a semi-chronic hypoxic environment and often breathing poor quality air indoors, swimmers are susceptible to developing tight breathing muscles.

**Coordination into global movement**

Does the neck function in isolation but lose function when combined with other body movements?

**Medical history**

Remnants of old injuries can lead to pain avoidance movement compensations.

**Stroke Flaws (Tsunamis)**

**Chronically extended neck/excessively high head position**

There are several causes of why this flaw may appear, including full-body postural syndromes that affect the activation of the neck muscles. It is also a natural occurrence to have the head elevated, due to the flotation of the lungs. For this, it is necessary to “swim downhill,” feeling more pressure through the chest.

Body line is the most important reason for keeping a neutral head position. Having the head down brings the hips towards the surface of the water and helps maintain a straight low back. This position keeps the athlete’s momentum going forward creating an important sensation. Any deviation from a horizontal body position will increase frontal drag, which is like swimming with a set of brakes.

When an athlete holds their head in slight extension, the lumbar spine will slightly arch and the spine will shorten (relatively). Keeping a relatively neutral helps establish a straight bodyline from the back of the head to the tailbone and promotes core activity as the swimmer skips on top of the water. For swimmers who have spent years with an extended neck (head up), they may need to feel like they are packing their chin into a “compact” position to ensure optimal alignment.
**Head bobbing**

Potentially from instability, the neck is like a golf ball on a tee, and without proper muscle strength the head will weave throughout the water. This will impede velocity and increase risk for injury.

Strong shoulders are essential in swimming. Putting the head in slight extension weakens the scapular stabilizers, which are essential in sprint freestyle where the shoulders are the driving force, which some might call shoulder-driven freestyle. A recent study suggests those with shoulder pain have increased activity of scalene muscles. 26 When one arches the neck, multiple muscles in the neck activate, putting the muscles in a suboptimal firing position and putting the shoulder at risk for injury, due to a decrease in strength. Maximal shoulder blade muscle strength is essential not only to prevent injury but to maximize force production in an event where the shoulders are the main force producers.

**Lifting the head to breathe**

Neck mobility limitations frequently contribute to this flaw. In freestyle, we know a swimmer with improper breathing biomechanics lifts their head, but what is the root cause? Is it because the swimmer is compensating for their rotation deficit with cervical extension?

**Burying the head into the chest**

This may be in freestyle and backstroke, or during the entry on butterfly. Both flaws typically result due to limitations in the thoracic spine, which will be covered further below. First of all, the tucked chin position increases activity of a few

muscles in the front of the neck that prevent cervical rotation. If these muscles are inhibited, then the head will improperly rotate or may utilize compensatory movement to extend during short axis breathing.

**Corrections**

**Length**

Video: Tennis Ball Routine

You can use any type of soft ball (but not an actual “softball,” as that’s too hard), and a tennis ball is usually the most convenient. This correction is similar to the active range of motion screening. Place the ball on the back of the head and use the ball to guide the neck through flexion, extension, and rotation.

**Strength**

The deep neck flexor screen can be used as an exercise and a screen.

**Timing**

Video: Gangsta Driver

Gangsta Driver: Turn the head to one side and rotate the shoulder in the opposite direction. Example, as the head turns left, right shoulder externally rotates, as the head turns right, the right shoulder internally rotates. This move trains disassociation between the neck and upper extremities, which is critical for all strokes. Failure to effectively disassociate head, neck, and shoulder movements is one possible cause of tightness in the upper extremities. Posture plays a role, interfacing the body with its environment such that perception and action can ensue. 

**Summary**

Limitations in the cervical spine will limit a swimmer’s ultimate potential in the water. Virtually our entire skeleton sits beneath our cervical spine. The slightest change in the neck can have cascading effects throughout the body. In coaching, we need to know what the neck is capable of doing before we ask it to support repetitive advanced movements in the water under physical and mental duress.

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Limitations at the neck can feed into shoulder and thoracic spine issues, as these joints are close neighbors to the neck and play vital roles in each stroke. Even though the neck rarely suffers a direct injury in swimming, it remains vitally important when examining other body regions. Keep this concept in mind through the ensuing sections.
Shoulder
Video: Shoulder Lecture

The shoulder complex undergoes the highest amount of stress in swimming compared to other joint complexes, with obvious reasons as competitive swimmers take approximately 5,000 to 10,000 strokes a day! Moreover, the position of internal rotation and shoulder flexion, during the catch of free, back, and fly, decreases the amount of room for the rotator cuff muscles to glide. This results in excess rubbing and recurrent microtraumas throughout the course of a career.

However, the importance of the shoulders is not isolated to injuries, as the arms are believed to contribute the most for force production, at least in free, back, and fly. Therefore, finding the balance between maximizing performance and minimizing injury is essential for a successful swimming career. Let’s explore the differences between healthy shoulders and unhealthy shoulders.

Healthy shoulders
In swimmers without shoulder pain, the muscles around the shoulder typically have proper length, strength, and timing. Specifically, the muscles contributing to shoulder blade elevation and internal rotation require lengthening, while the shoulder blade muscles, specifically those stabilizing the shoulder, require specific strength. This strength provides a stable base for propulsion while protecting the posterior rotator cuff muscles.

Other muscles requiring proper strength are the rotator cuff muscles, which stabilize the upper arm (humerus), and the upward shoulder blade rotators, such as the serratus anterior, which is highly active during free, fly, and breast. Lastly, integrating strength and length helps muscles coordinate and time properly. Once again, multiple areas require proper timing, specifically the rotator cuff and the

shoulder blade muscles. Coordination of these muscles helps keep the joint balanced and healthy.
Painful shoulders

Painful shoulders during swimming typically exhibit the opposite features of a healthy shoulder. In painful shoulders, the serratus anterior, infraspinatus, subscapularis and teres minor demonstrate decreased and/or altered activity.\textsuperscript{32, 33, 34} This altered motor control appears to play an important role in painful swimming shoulders.

Land Tests

Videos: Shoulder Tests, Upper Quarter

The land tests are utilized for injury prevention and force production. For the arms, maximal power production seems imperative for swimming success as drag accompanies force production, therefore minimizing the time in this drag position is key. Moreover, testing the muscle length of the muscles typically contributing to glenohumeral internal rotation deficit (GIRD) is essential for all overhead athletes. A recent systematic review, noted pain during external rotation and a painful arc (painful motion during shoulder abduction) as two indicators of rotator cuff disease, luckily both of these tests can be performed easily by coaches.\textsuperscript{35}

For strength, the ever-popular rotator cuff muscles are important for analysis; however, the contributor of the scapular stabilizing muscles is equally if not more important for injury prevention and swimming success.\textsuperscript{36} Timing of the shoulder complex with surrounding joints demonstrates motor control and the ability to apply relaxation and tension, essentials for swimming success.

Muscle strength also demonstrates many alterations in those at risk for shoulder injury. Common findings include:


- Weak stabilization of the rotator cuff muscles: noted in standing internal rotation test.
- Weak stabilization of the shoulder blade muscles: noted during active range of motion of shoulders.

The timing of the shoulders is complex, since the shoulders interact closely with the neck and thoracic spine in swimming. In fact, swimming contradicts many innate motor reflexes present as infants, forcing the body to fight against natural reflexes for ideal biomechanics. These are called righting reflexes help orient the head and vestibular system upwards.

Despite these reflexes, specific timing is necessary between the following joints:
- Cervical spine and shoulder blade
- Cervical spine and glenohumeral joint
- Shoulder blade and glenohumeral joint
- Shoulder blade and thoracic spine
- Glenohumeral joint and thoracic spine

Deviations in any of these during motions of multiple joints (complex movements) represent possible risk factors under loads. In this screen, such deviations may be noted in tests for the arms and other body parts (overhead squat and prone alternate arm and leg).

**Shoulder flexion**

Simply have the athlete lift their arms up leading with their thumb.

**Shoulder abduction**

Have the athlete lift their arms to the side, raising their biceps to their ears.

**Shoulder internal and external rotation**

Have the athlete start with their elbow and shoulder bent 90 degrees, then rotate their hands underneath their elbow. Having too much (>100 degrees) or too little (<93 degrees) of shoulder range of motion is a risk factor of shoulder injury in swimmers.
Common Findings (Waves)
Finding and correcting muscle length, strength, and timing for the shoulder in and out of the water are essential for a healthy, prosperous swimming career. The land tests of the shoulders provide a lot of beneficial information. However, it is believed the most important findings are those indicating an injury. In the shoulder, impingement is the most common injury, but grouping of different forms of impingement in still not readily practiced or understood by most in the swimming community. In elite swimmers, external impingement is the most common form of injury, due to the repeated internal rotation resulting in damage to the posterior rotator cuff muscles. Therefore, common findings, during the screen, include poor muscle length of many muscle groups:

- Pectoralis Major/Minor: noted by rounded shoulders
- Upper Trapezius: noted by elevated shoulders
- Subscapularis: noted by rounded shoulders
- Infraspinatus: noted by decreased internal rotation
- Levator Scapulae: noted by elevated shoulders

Upper crossed posture
Upper crossed syndrome is a term often used to describe a group of muscular limitations, but is not considered a true diagnosis. Many swimmers demonstrate upper crossed syndrome, most commonly seen in poor posture. These limitations are perpetuated by tight muscles in the chest, upper back, and weak muscles in the anterior neck, and lower back. Once again, muscle length and strength are the culprits for symptoms.

Soft tissue restrictions (both painful and non-painful)
A few well selected tennis ball spots can find sore spots a swimmer never knew about. Plus, these restrictions can limit essential ranges of motion for force production.

Scapular Dyskinesia
Scapular dyskinesia is not a diagnosis, but the term for a poorly controlled shoulder blade. The shoulder blade is controlled by muscle groups working together for one composite motion. These groups of muscles work together to move the shoulder blade in all directions. In scapular dyskinesia, certain muscles exhibit poor control in the upward and downward scapular motion. These movements are also improperly timed, potentially leading to injury.
Scapular dyskinesis increases from 37% to 68% at the midway point of practice and to 73% at three-quarters of practice. More staggering, after the full training session 82% of the swimmers demonstrated scapular dyskinesia (Madsen 2011). This indicates poor endurance strength of the scapular stabilizing muscles is influenced by training.

This increase in fatigue combined with an abnormal internal/external strength ratio, likely increasing risk of injury.  

**Stroke Flaws (Tsunamis)**

In the pool, there are two main groups of tsunamis, increasing stress at the shoulder complex:

- Injurious and impeding swimming velocity.
- Injurious and potentially increasing swimming velocity.

It is likely coaches will disagree on some items in these two categories, but they are mostly accepted views on pool decks.

**Injurious and impeding swimming velocity**

**Cross-over**

During the catch of every stroke, when the hand crosses under the body the amount of space for the rotator cuff muscles decrease. Moreover, this motion displaces the force of the water, likely causing the hips to wiggle, like “hula-hooping.”

**Buried head to chest**

A buried head may result from cervical spine (neck) restrictions as noted in the previous section but also shoulder restrictions. This once

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again decreases the amount of clearance of the rotator cuff muscles.

**Head bobbing**
As discussed in the cervical spine section, the head may bob up and down while breathing as a way for the swimmer to compensate for missing shoulder mobility.

**Late breathing**
Late breathing was addressed in the breathing section, but may also relate to poor muscle timing in basic shoulder function. Flaws in breathing coordination such as late timing are often paired with shoulder maladies.

**Labored breathing**
This flaw was also addressed earlier but deserves a second mention, as shoulder issues may contribute to labored breathing patterns.

**Elevated Hand Recovery**
Excessively elevated arm recovery increases shoulder stress as the greater the distance the arm is from the body, the larger the lever arm and more stress at the joint. This position also delays recovery and may create bouncing or submerging of the head and chest during the arm recovery.

**Catch-up Stroke**
Despite popular use, the catch-up stroke is an injurious position as it reduces space for the supraspinatus to move. Being in this position likely increases the risk of swimmer’s shoulder. Also, this position provides no propulsion, being a wasted phase in freestyle.
Injurious and potentially increasing swimming velocity

**Thumb-first entry**
A thumb-first entry likely decreases wave drag during the entry. However, this also decreases the space at the rotator cuff muscles and can cause increased shoulder stress. Note, it is important to distinguish between a thumb-first entry driven by glenohumeral rotation (from the shoulders) versus from the forearms, the latter of which is healthier.\(^{41}\)

**Straight-arm catch**
A straight-arm catch potentially increases the propeller surface area for greater force production. However, the greater distance for the arm from the body increases demand on the shoulder.

**Scapular protraction catch**
Protracting the shoulder blades helps increase distance per stroke, but in those with poor scapular control, it increases the risk of shoulder injury. Moreover, it can decrease force production if maintained during the catch and push phase.

**Corrections**
Methods for correction include those directed towards the waves and tsunamis.

**Length**
Video: [Tennis Ball Shoulder Routine](http://www.swimmingworldmagazine.com/lane9/news/Commentary/28549.asp)

SMR can improve range of motion, likely without damaging the peripheral nerve signals. Make sure to work on the periscapular muscles and rotator cuff muscles. Stretching may increase instability and decrease nerve signaling in seasoned swimmers. This suggests shoulder stretching is not indicated for success and likely impedes performance while increasing the risk of injury.

**Rules for muscle length**

1. Lie on the tennis balls with your knees bent, unless instructed otherwise.
2. The more sensitive or tender the area, the slower you should go (vigorous rolling is rarely necessary). If extremely tender, just lie on the ball.
3. Stop if the exercises cause pain.
4. Perform for 30 seconds - 3 minutes.

**SMR upper trapezius**

Video: [SMR upper trapezius](#)

Lie on your back with your knees bent and place the tennis ball on your upper shoulder. This ball should lie on the muscle and not on any bones. Rolling is possible from side to side to release the whole muscle. A common trigger point is located on the lateral aspect of the upper trapezius.

**SMR infraspinatus**

Video: [SMR infraspinatus](#)

Lie on your back with your knees bent and with the opposite arm place the tennis ball under the acromion, a bone on your shoulder blade. This muscle is small, but make sure to find the most tender trigger point.

**SMR pectoralis in prone**

Video: [SMR pectoralis in prone](#)

Lie on your stomach and place a tennis ball on the upper, outer portion of your chest. Place the tennis ball as close to your shoulder as possible, with the ball still on the muscle. You may need to position your arm diagonally to allow your arm to relax with your head rolled towards the arm being mobilized.

**SMR subscapularis**

Video: [SMR subscapularis](#)

Slightly round your shoulder blades to bring your shoulder blade to the side of your thoracic spine (body cavity; this will bring your armpit to the outside of your body).
Slowly, insert the end of a Pro-Tec Roller Massager (or other mobility stick) into your armpit. Slowly add force through the stick into your armpit, while attempting to relax the arm not holding the stick. Hold for approximately 60 - 180 seconds.

**Strength**
Rotator cuff and scapular stability is key. This includes exercises opposing normal freestyle movements (external rotations) and exercises causing distraction of the joint (forcing approximation via muscle activation).

**Swiss Ball Y**
Video: [Swiss Ball Y](#)
Starting Position: Face down with your knees bent hugging the ball. Flatten your back (posterior tilt your pelvis). Tuck your chin (Note, athlete in video does not keep chin tucked; look down).
For the following exercises, as you bring your arms up you will have a tendency to arch your back. In order to target the correct muscles and not cheat through the thoracic and lumbar spine, only perform the exercises with the back flattened. Keeping your arms as straight as possible (at 11:00 and 1:00), bring both arms in front of your body with the thumbs facing upwards. Raise the arms as high as you can, remembering to raise them only as far as you can to maintain your starting back position. Lower the arms slowly and repeat.

**Wall slide**
Video: [Wall Slide](#)
Sit with back to the wall, legs crossed. (Standing is a viable alternative if sitting is not possible). Place arms against the wall at 90-degree angles in the elbows (the “surrender” pose). Raise the arms overhead along the wall, but only as high as you can maintain contact with the wall. If you can’t move the arms without losing wall contact, just getting into the starting posture is enough.

**Timing**
Differentiation exercises are essential. Learn how to differentiate the main joints in the upper quarter for proper coordination between these joints.

**Corkscrew**
Video: [Corkscrew](#)
Lie on your back with one leg extended and one leg flexed, with the flexed foot on ground. Extend arm flat on same side as extended leg; arm on same side as bent leg raises kettlebell straight into the air. Rotate the arm clockwise and counterclockwise in a corkscrew motion.
**Bear crawl**

Video: [Bear Crawl](#)

Crawling is a highly underutilized exercise for shoulder timing. Start in the push-up position (hands under your shoulders and legs straight), then step with your opposite arm and leg, focusing on keeping your core stable. Next, return these appendages to the original position. Repeat with the opposite arm and leg.

**Summary**

The shoulders are the most delicate areas in swimmers. Moreover, the number of stroke deviations at this position likely impede velocity as well as increase injury risk. This stresses the importance of proper muscle length, strength, and timing, providing your body with the tools for proper stroke biomechanics. These tools are crucial for improvement, as traditional shoulder injury prevention programs are not effective. This ineffectiveness is potentially due to the use of static stretching and lack of exercise intensity/variety. Ensure these components exist in your prevention, rehabilitation, and shoulder enhancement programs!

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**Thoracic Spine**

Video: [Thoracic Spine Lecture](#)

The thoracic spine (T-spine) connects directly to five major joint systems: glenohumeral (shoulder), scapulae (shoulder blades), lumbar (low back) spine, cervical spine (neck), and the ribcage. No other joint system can make this claim. Muscles of respiration, trunk extension and flexion, rotation, stroke propulsion, and stabilization are all affected by thoracic spine function. It is the major source of trunk mobility in all planes with a greater inherent range of motion than the lumbar spine. Though the thoracic spine has its own section, note that screens and corrections may also fit for the shoulder. Remember that each body segment relates, particularly with the shoulders and thoracic spine.

**Land Tests**

**Flexion/Extension** (Note, these tests also apply to the lumbar spine and are included in a lumbar spine video)

Video: [Toe Touch/Back Bend](#)

- Standing toe touch (Flexion).
  - Feet together and touch toes. The upper back should have a slight curve. However, also note lower spine curvature and hip movement to determine length expressed in each spinal region.

- Standing back bend (Extension).
  - Feet together, reach overhead, and bend backward (helpful to have spotter). There should be a slight curve in the upper spine (extension) as the swimmer bends backward. Many swimmers will have difficulty achieving this due to chronic flexion dominance in resting posture.

**Rotation**

Video: [Upper Quarter](#)

Upper quarter rotation. Place rod across chest, sit with feet together, and turn to each side. Rod should create at least a 45-degree angle.

- Upper quarter rotation with scapular restriction. Same as above, with rod placed across the back to detect scapular compensations.

**Wall slide**

The wall slide is not only an exercise, it is also a screen. Sit with back to the wall, legs crossed. (Standing is a viable alternative if seated is not possible).
Place arms against the wall at 90-degree angles in the elbows (the “Surrender” pose). Raise the arms overhead along the wall, but only as high as you can maintain contact with the wall. If you can’t move the arms without losing wall contact, just getting into the starting posture is enough. If attaining the starting posture is not possible, then it signals a significant thoracic spine limitation.

**Common Findings (Waves)**
Injuries are less common in the thoracic spine as compared to its neighbors the cervical spine, lumbar spine, and shoulders. However, limitations in the thoracic spine are often linked to injuries elsewhere. Below are several thoracic spine conditions that can develop through improper posture and movement both in the water and on land.

**Upper crossed posture**
A postural syndrome in which certain muscles become overactive and others inhibited. What may appear as weakness on first glance may be inhibition. Know that overactive muscles must “calm down” before the inhibited ones can express their full strength.

**Fixed kyphosis**
Go to a pool and see all the swimmers with a hunchback. It is an epidemic!

**Soft tissue restrictions (both painful and non-painful)**
A few well selected tennis ball spots can find sore spots a swimmer never knew about.

**Shoulder problems**
Shoulder injuries were discussed above, remember that thoracic spine dysfunction puts the shoulder at risk. Develop a functional T-spine to protect the shoulders!

**Cervical and lumbar problems**
If the T-spine is not working properly, the cervical spine and lumbar spine try to pick up the slack in capacities for which they were not designed. This increases instability and joint stress.

**Stroke Flaws (Tsunamis)**
A myriad of stroke flaws can result from thoracic spine limitations. Below is a list of common stroke flaws often related to thoracic spine function:
Streamlines

Does the streamline resemble a referee signaling a safety, or worse, a field goal? While this point is not to excuse swimmers who allow streamlines to deteriorate at the end of a long set, there are swimmers for whom a single good streamline is extraordinarily difficult based on their underlying physical characteristics. Cheating with compensations in the neck or low back is not desirable even if it makes the streamline visually acceptable.

Wide arm recovery and crossing-over

These are separate flaws but both are common compensations by the arms to in response to a thoracic restriction. If the surrounding muscles are too tight, then crossing over or poor distance per stroke can result. If not rotating well, might lack high recovery. Too flat swimming may result in crossing over.

Hula-hooping

Hula hooping occurs when the swimmer’s hips move like they’re swinging a hula hoop. It is frequently an indication of a poorly moving thoracic spine. Insufficient rotation and poor timing are both forms of thoracic spine movement deficits. If either deficit occurs, the body will seek alternate movement sources, often through excess lateral action. When the brain says “Go!” the body can only use the resources available to carry out the command. Even though rotation is more efficient than hula-hooping, the hips will frequently hula-hoop if a thoracic spine has a rotation deficit.

Sway back

Sway back often results as part of lower crossed syndrome in which a rounded upper spine is tied to an excessively arched lower spine. Once again, the body will follow the path of least resistance if the thoracic spine is too tight.

Frankenstein upper body in short axis

Poor upper body muscle length and timing can lead to powerful, but graceless
movements. This will increase frontal and wave drag, impairing swimming velocity.

**Dropped elbows underwater**

Keeping the elbow high is the role of the scapular retractors and the ability to internally rotate the shoulder. When surrounding muscles are tight, these muscles can be inhibited (weakened), a condition demonstrated in the photo above with the dropped elbow. In the pictures below, we see more optimal mechanics demonstrated both on land and underwater.

**Lifting head to breathe**

If the T-spine is immobile, the neck may compensate by lifting and excessively side bending in freestyle. A slight side bend is natural in freestyle breathing, but excess side bending is biomechanically inefficient. Stay within the proper range of side bending.

**Corrections**

**Length**

*Video: [Foam Roll Thoracic Spine]*

Foam roller thoracic spine and tennis ball thoracic spine. Place the implement in the upper back and roll gently along the thoracic spine. Keep the neck neutral during these exercises to avoid cheating.

**Rotation**

*Video: [Thoracic Rotation]*

Set up in quadruped position (all fours). Reach one arm between your arm and leg on the opposite side. Reach as far as possible while keeping your head stationary, and then reach your arm in the opposite diagonal, towards the sky.
Breathing

Training the breath is one of the most underutilized yet powerful tools to ingrain movement and is useful for training internal rotation. Many are familiar with the use of breath for stability, such as in the Valsalva maneuver to lift heavy weights, but we can also use the breath for mobility.

Exhalation drives spinal flexion and internal rotation. Conversely, inhalation is tied to extension and external rotation. If you let all the air out of your lungs, you’ll notice that your spine will round and your shoulders will internally rotate. If you do this forcefully such as in the cat vomit exercise, you note the same movements. Watch the video in its entirety and you’ll observe a dramatic increase in the tone of the latissimus dorsi, which is an internal rotator of the shoulder.

This tactic is valuable because it trains the shoulder to not only work with the spine, but also to work with the surrounding muscles that drive the countless breaths we take in our lives. With proper integration of the breath, we can improve scapulothoracic rhythm unconsciously. The more unconscious we can make this coordination (and breathing is about as unconscious as we can get) the better it will translate to our learning in the water. Since tension is often driven by neurological factors, breath training can also help restore a parasympathetic state in the body to facilitate recovery. Relaxing sympathetic tone also may improve the immune system.  

Summary

T-spine limitations both in and out of the water are often the root of symptoms elsewhere in the body. The shoulders, neck, and core all directly interact with the T-spine. Additionally, every breath we take directly affects the T-spine. As such, any limitations can be magnified when breathing is stressed. Because the possible stroke flaws and injuries related to the T-spine are well known, a prophylactic approach to assess the T-spine is critical. As with any assessment, consider overall factors for each individual swimmer.

Lumbar Spine

Nothing generates more controversy than the lumbar spine. Much like the neck, the low back offers equal opportunity affliction, with painful implications for both elite athletes and sedentary folks. Many swimmers bring to the pool lumbar pathologies that are not related to swimming.

For swimmers, lumbar spinal health and performance is primarily about motor control and relative strength. Absolute strength and structural integrity are other considerations, but both are secondary these primary qualities. Most swimmers have adequate *absolute* low back strength but lack *relative* low back strength. The lumbar spine literally has no place to hide when the thoracic spine, hips, and pelvis don't do their jobs.

The lumbar spine is designed for approximately 10-12 degrees of safe axial rotation. In contrast, some individual T-spine joints have that much alone. Not only is the lumbar spine at risk for damage if we exceed this range, adding range of motion to the low back without a corresponding level of control will come at the expense of hip and T-spine mobility.

Swimmers are often confused about ways to properly train the lumbar spine, because although we suggest limiting low back mobility on land, the lumbar spine appears to move substantially in the water. This is one area in which we use dryland to fortify the structure, not to mimic what already takes place thousands of times in the water and which is clearly a risk factor for injury.

In fact, though sit-ups are a common ingredient in many dryland programs, its possible their inclusion may cause more problems through spinal damage and through confused motor programming. For example, though many believe sit-ups train the abdominals to more effectively flip turn, the abdominals and hip flexors actually work to decelerate the body before turning...quite the opposite of what crunches train. Remember, sometimes the best troubleshooting isn’t knowing what remedies to add, but instead knowing what ingredients to omit.

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Land Tests

Length
Video: [Lumbar tests (Active range of motion)](#)
Adding mobility via muscle length is normally not a concern for the lumbar spine. Assess flexion and extension with a toe touch, back bend, and side bends. The breathing screen will assess diaphragmatic expansion but the spine should remain neutral. However, improving overactive muscles secondary to impaired motor control is key.

Strength
Video: [Lumbar tests (Strength and Timing)](#)
How effectively can the body create optimal muscle tension surrounding the spine for support? Swimming requires strength in all planes: sagittal, frontal, and transverse, along with the front and back sides of the body. Stroke specialists may have unique demands beyond normal values, but all swimmers must demonstrate basic lumbar strength.

Quadruped stability
Set up in quadruped position either with hands and knees touching FMS board or wooden 2 x 6. Extend ipsilateral arm and leg then try to touch elbow to knee, and extend again. If unsuccessful, touch contralateral limbs.

Timing
Can the brain effectively tense and relax muscles when called upon? Use the trunk stability push up to screen for core timing.

Common Findings (Waves)
Here are some common problems swimmers encounter with the lumbar spine.

Lower cross posture
Tight/overactive low back muscles and hip flexors in conjunction with weak/inhibited abdominals and glutes. Swimmers who live with this posture both in the water and on land aren’t able to access the full capabilities of their low back muscles.

Limited pelvic control
A limited range of motion not and/or chronic anterior tilt (common with Master’s swimmers) not only affects the undulation of the short axis strokes and underwater dolphin kicking, it will also impede hip rotation (possibly leading to hula hooping). Swimmers who aren’t afflicted with a postural limitation may still lack the pelvic
tilting skill. If the swimmer doesn’t have major underlying restrictions, most will pick up the skill quickly once taught.

Left to right imbalance
A swimmer who brings unevenness to the pool invites hula hooping, or at best, must inefficiently devote physical and mental resources to prevent hula hooping. In a sport where progress is measured by fractions of a second, we can’t afford to miss simple posture cues like this one. Sometimes we’ll work around the posture and sometimes we’ll actively correct it, but know that a one-size-fits-all approach to stroke instruction and dryland conditioning will not produce optimal results for these swimmers.

Nevertheless, when swimming may exacerbate low back issues, don’t forget to look elsewhere for the root cause, such as the thoracic spine and hips. Other common findings include...

Disc damage
Disc prolapses, herniations, etc. are common throughout society. The disc can press on lumbar nerves or on the posterior longitudinal ligament which is a highly innervated structure.

Nerve damage
Potentially from disc damage, or nerve entrapment from tight muscles. These symptoms commonly radiate or are described as tingling.

Stenosis
More typical in the Master’s athlete, but can be perpetuated by tight hip flexors and can cause nerve damage or entrapment.

Pain
Know that not all damage elicits pain and not all pain results from damage. Pain does not always equal injury.

Spondylolysis
Excessive extension or hinging from one segment of the lumbar vertebrae causes spondylolysis (making you a spondy), better known as stress fracture to the pars interarticularis. Spondylolysis is the most common form of back pain in adolescent athletes plaguing many athletes with pain and inhibiting their range of motion.
This mouthful of a diagnosis occurs from overuse. Divers do around one hundred approaches a practice, swimmers do thousands of dolphin kicks, and synchronized swimmers use poor form to sit up in the water, repeatedly arching their low back. These repeated extensions can cause a stress fracture. A stress fracture is typically painful, especially with movement (most notably extension).

**Other fractures**

If these occur, there are usually other problems at work such as poor nutrition, but know that inappropriate mechanical stress can break bones under intense repeated use. Many swimmers have low bone mineral density. Master’s female swimmers are especially at risk.

However, as noted above know that structural damage does not always correlate with pain. In this study, authors compared national team swimmers with recreational swimmers. Sixty-eight percent of national team members and twenty-nine percent of recreational swimmers exhibited disc degeneration. There was “no significant relationship observed among the variables of low back pain symptoms, swimming strokes, and disk degeneration.”

But how does a coach know if an athlete has excessive mobility? The Beighton score discussed in the movement screen section is one way assess hypermobility, but remember that true hypermobility is a specific clinical diagnosis. Don’t confuse poor stability or control for hypermobility.

Many push swimmers to utilize more range of motion at the low back, especially during dolphin kick, to increase force production, but the low back minimally contributes to flexion and extension. Also, forcing excess movement at this joint leads to instability, the most common form of low back pain in athletes. Improving stability at these joints is essential for injury prevention.

Preventive exercises that use a full range of motion are required, because obtaining stability within a small range of motion is easy. Body builders have great stability, but their range of motion is minimal. It is essential for the athlete with hypermobility to obtain strength through their whole range of motion. It’s not the stiff areas that create painful movement; it’s often the parts that move too much. Unfortunately, how much is “too much” is relative.

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It is essential to catch the athlete with instability before they have warning signs!

**Stroke Flaws (Tsunamis)**

**Sway back**
A common strength or timing flaw in short axis strokes during undulation but also an alignment flaw in long axis. However, sway back may also result from limited mobility in the thoracic spine and hips.

**Snaking/Hula hoop**
Lumbar spine lacking lateral stability causing hips to shift side-to-side with each stroke cycle during long axis.

**Dropped hips**
Similar to the sway back and can occur simultaneously to the sway back. Dropped hips are noted by lower than ideal lower body position, while a sway back and occur with legs still sitting high in the water.

**Flat short axis**  
*(overcompensating)*
Many swimmers lack sufficient undulation during short axis swimming. This flaw may exist for numerous reasons, but a common reason is insufficient low back motor control. Athletes with a history of back pain or those without motor control to “trust” their underlying core strength may limit undulation to protect themselves.

**Corrections**
Corrections track closely with the screening protocol and swimming flaws. Match corrections to the screen findings.
Length
Video: Tennis ball quadratus lumborum
Quadratus lumborum, tensor fasciae latae, iliotibial band, and piriformis all respond to self myofascial release techniques. However, stretching the low back muscles is rarely advised. Reversing lower crossed posture can improve muscle length in the erector spinae and paraspinals.

Strength

Plank
Video: Plank
Find normal planking position but place arms closer together and slightly further forward. Slightly posteriorly tilt your pelvis. Create tension in the glutes, quads, and abdominals. “Pull” the elbows down toward your feet and drive the heels backward. Strive for maximal tension for approximately ten seconds. If you can hold this position longer than twenty seconds, you likely are not tensing hard enough!

Timing

March
Marching was introduced as a screen earlier in this section and can be used both as an assessment and an exercise.

Summary
Above all, optimal lumbar function is a matter of control. As with any aspect of training, the goal is to improve our ability to deliver match the demands of swimming. However, virtually every swimmer can improve their lumbar spine with a stronger posterior chain and properly functioning thoracic spine. Understanding the patterns of lumbar spine behavior and its relation to nearby body segments is an important step toward technical refinement in the water and effective dryland programming.
**Hips**

Video: [Hip and Pelvis Lecture](#)

Although they are separate joint systems, the hips and shoulders are closely related. Anatomically, contralateral limbs are related via the serape effect: the left hip connects to the right arm, and the right hip connects to the left arm. The hips are the primary source of lower body mobility but also provide a stable platform to support the arms during the catch and pull. In fact, many arm flaws relate directly to the hips. In swimming, the interconnection of the opposite arm and hip is essential in long axis strokes, as this connection helps balance the body. Moreover, breast kick highly stresses the hip joint, a rising injury concern in this stroke. Lastly, hip mobility and strength in the sagittal plane is key for dolphin kicking.

**Land Tests**

Videos: [Leg Raise Tests](#) and [Craig’s Test](#)

Hip injuries are relatively uncommon in the pool, but hip deviations may contribute to lumbar spine issues and knee issues in breaststrokers. These tests will help troubleshoot hip movements to select appropriate interventions.

**Length**

**Range of motion**

Swimming does not require abnormal flexion and extension, but normal ranges are essential to protect neighboring joints. Many screens for the lumbar spine are equally applicable to the hips. Internal and external rotation are crucial for an effective breaststroke kick and to limit knee stress.

**Active straight leg raise**

Lie supine with legs straight and arms relaxed at sides. Raise one leg upward like performing a hamstring stretch. Note how far up the leg comes before bending. Also note the “down” leg for any compensatory rotation. If the swimmer feels a tug in their hamstring, also consider pelvic stability. Also, pay attention to the lumbar spine motion during the straight leg raise. If the lumbar spine begins to flatten early during the movement, it is likely the hips lack mobility.

**Side hip raise**

Have the swimmer lie on their side with a neutral spine. Raise the top leg upward (“Jane Fonda style”). Note any range of motion limitations, shakiness, or if the swimmer moves the leg forward rather than upward.
**Strength**
Hips do not require absolute strength in the water but relative strength is essential. Test whether the hips can maintain position in all planes, as they provide stability for the arms.

**Timing**
Can the muscles tense and relax as needed? Chronic tension will limit mobility and speed; chronic relaxation or late relaxation will impair force production. One way to test muscle timing with the hips is stand on one leg, with the non-grounded leg raised with the knee at a ninety-degree angle (thigh parallel to ground and shin perpendicular to the ground). Add challenge by closing the eyes. Every swimmer should reach ten seconds without losing balance.

**Common Findings (Waves)**

**Limited extension and flexion**
These limitations would present in a leg raise or a toe touch.

**Limited rotation**
Consult Craig’s test for internal and external rotation. This is most important for breaststroke.

**Side lying. Adduction and abduction**
Swimmers do not need abnormal abilities for these movements, but limitations in adduction and abduction may offer clues into the anterior and posterior chains.

**Instability**
Instability can occur in any plane. Consider the hip screens in context of other screens to confirm whether the problem is mobility or stability.

**Poor timing**
Poor timing may occur if the muscles have adequate strength but fire too late or too early, both of which will impair underlying qualities of mobility and stability.

**Stroke Flaws (Tsunamis)**

**Swayback, hula hoop, or dropped hips**
These were noted in the lumbar spine section but can also be viewed as hip tsunamis.
No rotation
If the hips aren’t rotating in long axis strokes (especially during hip driven strokes and distances), is it a stroke problem or are the hips inherently limited (which you would find out in screening)?

Kicking with too large of an amplitude.

This flaw may result from balance problems as the swimmer over-kicks to remain near the surface or relies on the legs to compensate for a poor catch.

Kicking too wide
Related to amplitude, but differs in that movement occurs in the frontal and transverse planes in addition to the sagittal planes. Consider whether the swimmer has poor control of their lateral and posterior hip muscles on land.

Excess knee bend
Having excess knee flexion is often seen as a flaw, but must be seen in full context. Excess knee flexion is often a sign of limited contributions from the hips, but many swimmers do flex and extend the knees substantially while kicking. What’s important is not just flexion itself but instead proper timing with the hips and ankles.

Hip abduction/adduction (breaststroke)
If the swimmer lacks internal and external rotation, the hips will adduct and abduct excessively, placing stress on the knees.
Corrections

Length
Video: Tennis ball soft tissue
Hip flexion and extension. Also note length of the lateral hip (TFL, ITB). Hip corrections typically overlap with the lumbar spine and knees.

However, note that in swimmers with a history of back problems, the hips may be tight as a protective mechanism. Utilize caution when training hip muscle length in these swimmers.

Strength and timing

March
Video: March and Posterior Tilt

Rules
1. Maintain the back position as instructed.
2. Do not let that position change at all during the exercise.
3. Stop if the exercise causes you pain.
4. Stop if cannot keep the correct back position.

Directions
Lie on your back, posteriorly tilt your pelvis to "tuck under." Ensure your abdominals are tight and expanding three-dimensionally for maximal contraction. To feel if your abs are tight, place your hand under the small of your low back. This hand is your feedback mechanism; don't let the pressure in your hand alter during the exercise. Also, keep your shoulders relaxed and on the ground!

Avoid exercises that target the low back, as these may train the swimmer to utilize the low back muscles rather than the hips. Strength exercises for the lateral hips may also improve length, as what appear to be length deficits may actually be signs of muscle inhibition or poor motor programming.

Hip abduction with band
Video: Hip Abduction with Band
Addresses length, strength, and timing. Although we list these in the hip section, they remain a viable exercise to also support the lumbar spine and knees.
Summary
Muscle length, strength, and timing are all crucial for the hips. It is nearly impossible to separate the hips from the shoulders both anatomically and functionally. Shoulder problems may have their roots in the hips due to length, strength, and timing impairments. Sound hip mechanics not only maximize performance, they also protect against problems in the lumbar spine and knees. Most importantly for your breaststrokers and IM-ers, save their knees by taking care of their hips.
Pelvis

Most discussion of the pelvis focuses on pelvic tilt in static posture. Frequently you’ll hear the pelvis in the context of lower crossed syndrome. This condition is tied to abdominal weakness, limited hip extension, lower back stiffness, poor glute strength, along with several medical conditions such as hernias, hip impingement, and low back pain. Though static posture is important to consider, it doesn’t tell the whole story.

So what does this mean for swimming? The low back is swimming’s great paradox. We know the low back craves stability and the ability to resist excess movement, but certain swimming movements require lumbar mobility in the sagittal plane: dolphin kicking, butterfly, start and turns (and though breaststroke doesn’t require extreme lumbar mobility, the low back does move). This is where the pelvis comes in.

One answer is learning pelvic precision, which falls under the “timing” emphasis of the length-strength-timing triumvirate. Pelvic precision refers to the ability to disassociate the pelvic tilt movement from non-essential movements when taking the pelvis through its full range. From a motor learning perspective this is no different than learning to throw a ball efficiently with your hands and arms, rather than lunging forward with your entire body to throw. The key term is inhibition, or training non-essential motor units to stay quiet at the right times. Control of the pelvic tilt is one example of inhibition at work.

Land Tests

Video: Pelvis Tests

Length

Length is a function of the lumbar spine and hips. Check whether the brain can express muscle length via movement. You can test pelvic tilts while in quadruped (all fours) position or while supine.

Strength

At end ranges of movement, can the pelvis remain stable (particularly in posterior tilt)?

Timing

Length and timing are similar for the pelvis. Timing is a matter of movement quality. Is the pelvic tilting motion smooth or inconsistent (“shake and bake”)?
Common Findings (Waves)

Locked pelvis
This may be a mechanical issue or may be a neural issue. You can parse out the causes with careful screening.

Sacroiliac joint dysfunction
Absent pain, this can often be addressed by addressing hip flexion and hip extension, but sometimes a manual assist is necessary to allow proper movement.

“Shake and bake”
Ask someone to tilt their pelvis anteriorly and posteriorly and you may find something called shake and bake, in which the muscles can’t take the pelvis through the movement smoothly.

Stroke Flaws (Tsunamis)
Many tsunamis of the pelvis overlap with the hips and lumbar spine. Common pelvic stroke flaws include:

Sway back
Chronically arched back while swimming (Janda’s lower crossed). Certainly a back arch will occur during the short axis strokes but the swimmer must be able to change position and should not remain there during long axis swimming.

Limited undulation
Not sway back at rest, but unable to undulate in short axis strokes or during dolphin kick.

Limited pelvic undulation but excess lumbar undulation
This is hard to detect with the naked eye, but it is more common with swimmers whose hips drop and those who kick excessively to maintain balance.

Corrections

Length
Video: Tennis ball Soft Tissue
Through self myofascial release, address the hips and low back through the methods referenced in those sections.
**Strength**

Pelvic floor is often overlooked, especially in female athletes. Learning proper breathing mechanics will train the pelvic floor to support the pelvis and surrounding areas.

**Timing**

Strength and timing are one in the same for the pelvis. Correct breathing patterns will improve timing, as the pelvis moves in response to breathing. In addition, the initial posterior pelvic tilt in the plank. Note you can include the posterior pelvic tilt for many exercises.

**Summary**

Since we can’t eliminate pelvic movement, nor should we attempt to do so, we should strive for maximum precision to eliminate damage and the risk of pain. The goal of pelvic tilting is not to add range of movement or even to stretch out the back. All we're checking for is to see if your brain knows how to do the movement with precision, which is ultimately required in the water.

McGregor studied collegiate rowers at several intensities and stroke rates and found significant “changes in pelvic rotation at the catch and finish stages of the stroke with significantly less anterior rotation occurring at the catch position at higher rowing intensities.” If pelvis kinematics change based on velocity, and stroke style is a function of velocity (sprinter versus 200fly/400IM), then pelvic precision will change with each type of stroke. It may follow that we can tailor core training and pelvic precision specific to event and individual needs.

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**Knees**

The knee is estimated to be the second most commonly injured body part in swimmers. Therefore, proper prevention and rehabilitation from injury is paramount for swimming success. All the swimming strokes, except breast, have a minimal amount of knee stress compared to ground-based sports. However, the unorthodox nature of the breast kick increases stress at the knee joint, increasing the risk of injury. Quite simply, the knee primarily moves in one plane and is not designed for torque in other planes.

For performance, the musculature around the knees allows much of the motion allotted during the kick. Therefore, having proper length, strength, and timing at these muscles is essential for swimming success.

In breast, the legs are also the main site of propulsion. Therefore, adequate strength is even more important, since propulsion from the legs drives the horizontal velocity.

**Land Tests**

Video: [Overhead Deep Squat/Single Leg Squat](#)

The two hypothesized types of knee injury in swimming are patellar tendinopathy and patellofemoral pain syndrome (PFPS). Therefore, proper screening of these injuries is essential to prevent injuries and time away from the pool.

**Length**

PFPS is characterized by muscles of poor length. This poor length is tested during the squat and trunk motions, as poor range of motion likely present during these tests during PFPS. Moreover, the single limb squat can assess control of the hip and knee, likely detecting early signs of PFPS.

**Strength**

Strength is essential at the hips and knee for knee injury prevention. Patellar tendinopathy typically contains weak eccentric strength of the quadriceps. Moreover, PFPS has a typical presentation of weak hip stabilizers, which results in excess knee movement. This is assessed both the squat and the single limb squat.

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Timing
The hips and core musculature often control knee motion (specifically in breast). Therefore, timing of these two areas is key for a healthy breast kick.

Common Findings (Waves)

Wobbly Knees
Many young athletes have difficulties stabilizing their hips, which trickles down to knees. When the knees do not move in a controlled fashion, the amount of stress at the joint increases.

Misaligned Knees
As the knees are stuck in between the hips and feet, they often receive indirect stress. If the hips and feet are not aligned, then the knee is often put in a compromising position.

Forward Knees
When athletes do not have enough hip strength (specifically in the posterior sagittal plane), then often drive their knees forward during a squat (quadriceps dominant movement). This can increase the stress at the patellar tendon and increase the risk of a tendinopathy.

Stroke Flaws (Tsunamis)
Breaststroke requires a high degree of knee flexion (nearly 130 degrees) with large hip internal rotation (approximately forty degrees), combined with hip adduction. Knee flexion and hip internal rotation allows the foot to travel far away from the midline of the body, while hip adduction snaps the feet together during the inkick (the “whipping” portion). These contorted positions compress the outside of the knee and stretches the inside of the knee. Stretching the medial knee component is most problematic and is the most common site of knee pain in swimmers, as one study found most swimmers with knee pain had pain on the medial aspect of the knee.\(^5^1\)

Excess knee bend
Having excess knee flexion is often seen as a flaw, but must be seen in full context. Excess knee flexion is often a sign of limited contributions from the hips, but many

swimmers do flex and extend the knees substantially while kicking. If someone has excessive knee bend during flutter or double knee kicking, they are increasing the stress at their patellar tendon.

**Simultaneous Rotating Turns**

Rotating while pushing off the wall stresses the medial knee, specifically at the medial meniscus. Although, meniscus injuries are rare in swimming, it is likely this turning style is also less efficient than simply pushing off the wall, then rotating.

**Correction**

**Length**

Video: [Tennis ball Soft Tissue](#)

Self-soft tissue mobilization to the tensor fasciae latae (TFL), the iliotibial band (ITB), and piriformis, help improve strength and allow ideal hip motion, so less knee motion is required. Moreover improve length of the deep hip flexors for proper free, back, and fly kick. These corrections were introduced in the hip section but also are valuable for healthy and functional knees.

**Strength**

The glutes help control hip motion, therefore proper glute strength is essential in breast. In free, proper quad strength (specifically eccentrically) helps combat the high demands in the downkick. The goblet squat is another exercise for hip strengthening. This exercise specifically forces the swimmer to keep their knees wide on the squat movement.

**Goblet squat**

Video: [Goblet squat](#)

Start with your feet slightly wider than shoulder width and your feet slightly turned outward. Next, hold the kettlebell on the sides of the weight and pull the weight apart with the arms. Lower your body initiating with the hips moving backwards, while keeping the shins vertical and keeping your hips, knees, and ankles in a straight line. Slowly, lower yourself until your elbows touch in insides of your knees. When ascending, push through your heels, keeping your feet, knees, and hips shoulder width apart. Feel like you are “spreading the floor” through your feet. Make sure your legs remain in a straight line, as any deviations from this line results in excess stress in an unwanted area.
Timing
Knee muscle timing depends proper movements in the hips and ankles. As such, knee muscle timing is addressed indirectly with proper attention to surrounding areas.

Summary
Proper kicking in all the strokes stresses the knees. In breast, this stress increases the risk of patellofemoral pain syndrome, where the other strokes increase the chance of patellar tendinopathies. Improve the length of the anterior and lateral hips, while strengthening the posterior hips. Then, teach the body how to use the core, ankles, lumbar spine, and hips together for ideal prevention and performance.
Ankles
Video: Ankle Lecture

Because swimming is such an upper body dominant sport, the ankles are often neglected and misunderstood. Improving ankle mobility in freestyle, backstroke, and butterfly is often vexing for both swimmers and coaches. Some swimmers appear naturally blessed with mobile ankles. Others work madly to force plantar flexion (toes pointed down) but make little progress. Although plantar flexion and dorsiflexion (toes pointed up) are both needed for dynamic ankle mobility in the water, plantar flexion is the more common limitation in the water for most swimmers.

Improving plantar flexion safely involves more than forcing the toes to point through passive shin stretching. Though “sitting on shins” is a common way to address ankle mobility, we’ll discuss ways below that can improve the ankles without the associated risk of forcing the joint beyond its end-range-of-motion. However, before exploring improvement strategies, we must understand what prevents swimmers from having ankle mobility to begin with, which leads us to the latter three items on the list above.

Unresponsive ankles often reflect predictable patterns of limitation elsewhere in the body. When a swimmer kicks with stiff ankles, excessive knee flexion, and insufficient or poorly timed hip drive in free, back, and fly, the kick is often a symptom of a global limitations. Corrective strategies should not only address the ankles themselves, but also a provide dose of posterior chain activation from head to toe.

Land Tests
Video: Land Tests

Length
Test range of motion in plantarflexion, dorsiflexion, inversion, and eversion.

Strength and timing
Strength demands on the ankles are minimal in the water, other than the ability to maintain dorsiflexion during the breaststroke kick. Ankle relaxation is vital, yet specific information on ankle relaxation is still emerging. However, the first step for ankle relaxation is to ensure proper muscle length. Reflex patterns as noted previously in this book may also contribute to ankle tension and relaxation.
Common Findings (Waves)
Many swimmers have limited ankle mobility, while some have such extreme mobility they are unsafe on land. Key point is to determine if the swimmer can achieve ranges of motion on land that are being asked of them in the water. For free, back, and fly, plantarflexion is the more common and more serious limitation.

Stroke Flaws (Tsunamis)
Consequences of stiff ankles:

Excess drag due greater frontal exposure
Ankles chronically pointed upward (like a letter “L”) act like an anchor behind the swimmer.

Wasted energy
Larger muscles requiring more oxygen must work harder if the ankles aren’t moving properly

Lack of eversion
Weakened breaststroke kick. Many also forget that plantarflexion is important for breaststroke, as the ankles must attain a straight alignment for an effective streamline.
Soft tissue work

Improving ankle range of motion is essential for decreasing drag in swimming. If a swimmer has limited plantarflexion (ankle pointing), their feet act like an anchor and create excess drag during flutter and dolphin kick. The anterior tibialis is the primary muscle limiting ankle plantar flexion. If this muscle is tight, it can prevent ankle pointing.

Soft tissue anterior tibialis

Video: Shin Soft Tissue
Start in the Tebowing position (half kneeling), with a tennis or baseball underneath the leg on the ground. While holding onto a table or bench, slowly roll the external device on the outside aspect of the shin (anterior tibialis).

Dynamic mobility: Eversion and inversion

The picture to the right displays pronation, which is feet turned outward. This ankle movement is critical for breaststroke along with eversion. Many coaches can even recognize their potential breaststokers just by observing kids walk on land. Those with limited plantar flexion often struggle with eversion as well. Eversion improvements are valuable particularly for freestyle oriented IM-ers with ankle deficits, particularly if you aren’t able to fully address breaststroke specific hip rotation. If you train eversion, don’t neglect the opposite direction (inversion).

Summary

Swimming, like all sports, requires a specific amount of tension and relaxation for balancing proper biomechanics and energy conservation. This balance is key throughout the whole body, as each joint contributes to this delicate continuum. Luckily, these two areas commonly work together, but the ankles are one area where an over emphasis on reducing drag may cripple specific swimmers maximally forcing their ankles down during an entire race.

Though ideal ankle motor control is still uncertain, we do know that without improvements in muscle length, timing will not matter. Most importantly, veteran swimmers should be pleased to know that modern strength and conditioning and rehabilitation have found alternative strategies to improve muscle length. With literature showing potential negative effects from acute stretching prior to activity,
days of painful sessions sitting on shins or using devices like the rack are in the past. Tennis ball soft tissue massage and dynamic ankle mobility drills are two effective and complementary strategies to remove limitations to optimal ankle function.
**Mental Training**

“It’s not what the teacher says... it’s what the student hears.” To take it further, it’s not only what the student hears, it is what the athlete actually does. Application is what generates improvements and ultimately wins meets. Troubleshooting means nothing if we can’t get the right message to the athlete. No matter how astute your eye, communicating with the athlete matters most if you want the athlete to actually change.

**External and Internal Focus Cues**

“High elbow”
“Fast hips”
“Lead with your pinky”

We all have various cues to communicate with athletes. (“The coach observes what the athlete cannot see, and the athlete feels what the coach cannot feel” - Sweetenham.) Everyone’s cues vary with style, audience, and available tools such as video. Clarity is our goal with athlete communications. “Feel” does not always equate to “real,” which is why video is so powerful. Regardless of whether you use video or not, what matters most is how the athlete internalizes cues. As video becomes more commonplace, our job as coaches is not only to pick out stroke flaws but also to translate cues into useable language.

Think of our jobs as writing code for the computer in our athletes' brains. Without translating thought into useable language (i.e. code), the program won’t run very smoothly. Proper language makes good information useable, and our job does not stop with identifying the flaws and giving out drills. Automaticity in movement is the objective and is best accomplished via effective communication both between coach and athlete, but also via the athlete’s self-dialog and their ability to filter information from peers and parents.

Athletes have two choices for skill-based attention: internal focus and external focus. Internal focus is to focus on a specific body part. “High elbow,” “fast hips,” and “lead with your pinky” are all examples of an internal focus. External focus is based on the effect of movement in relation to the environment. “Pull the water back” is an example of an external focus.

The concept of internal vs. external focus is not to be confused with association vs. dissociation. Association refers to staying in the moment during a task, such as being aware of your surroundings or monitoring your physical state to optimize timing of your surge at the end of a race. Dissociation involves thinking about something other
than your present task. A classic example is thinking about your dinner plans during a set of repeat 1000s. These are related concepts, but not the same as internal versus external focus. Of course there is “losing focus,” which we never want to encourage.

Modern research has overwhelmingly supported external focus cues as most effective for skill acquisition. In fact, the term “modern” is somewhat redundant since most of the literature supporting the superiority of external focus is new. Some of this research may challenge what we think, since nearly everyone uses internal focus cues in some way. You may find it disarming to remove all your cues that make reference to a body part (Try it...not easy!). Fortunately, there are ways to reconcile research with practicality and explain ways we can apply these concepts in the unique aquatic environment.

Early research in this field began with a series of balance tests in various studies. For example, one study asked participants to keep a balance board level. Some were told to think about keeping feet level; others told to keep the markers on the board level. A control group was told to think about nothing. In this study and other similar ones, the external focus groups have universally outperformed the other groups, including the controls that were given no instructions and theoretically should have had the clearest minds. Similar data related to target accuracy has been shown in both novice and elite golfers. Without fail, an external focus directed toward the golf club or at the target results in better accuracy than thinking about a body cue at all skill levels.

Research has quantified movement efficiency in context of external focus strategies. In one study, subjects performed a bicep curl during which EMG data (muscle activity) was gathered. The internal focus group was told to contract the bicep; the external focus group was told to curl the weight. Control group was given no instructions. EMG activity was highest in the internal focus group. For movement efficiency when measuring a set load, a high EMG is not what we want because it shows that more effort is being used for the same task. Efficiency is ability to use the least resources possible for a task with maximum benefit.

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Another study involved dart throwing accuracy.\textsuperscript{55} Internal focus group was told to think about wrist flexion; external focus group was cued to think of the target. The external focus group not only had better accuracy and lower electromyographic (EMG) activity near the wrist; it also showed decreased activity on muscles away from the wrist. When internal focus is used, ALL muscles, not just those subject to internal focus, show increased activity. A focus on one body part makes the whole motor system work harder, sometimes in undesirable ways.

There’s also evidence that endurance performance can improve via external focus: Schücker (2009)\textsuperscript{56} looked at 10k distance runners with an average time of 36:27 (not elite, but much faster than novice). One internal focus group was told to focus on form; another was told to focus on breathing. External focus group was told to focus on the passage of surroundings. A control group was told to focus on nothing. The external focus group showed the best economy, or least oxygen consumption per unit of output. External focus was also shown a superior strategy for muscular endurance in a bench press test.\textsuperscript{57}

Freudenheim\textsuperscript{58} tested a group of intermediate swimmers in 16m sprints in a 16m pool. The internal focus group was told to pull their hands back fast or kick their feet down; the external focus group was told to pull the water back or kick the water down. Researchers noted a statistically significant improvement in the speed of the external focus condition compared to the internal focus condition. From a coaching standpoint, we might recognize the external cues as inherently superior anyway, since “pulling the hand back” could promote a sloppy catch and slipping water. Nonetheless, the result is consistent with a large body of research and deserves consideration in that context.

Stoate\textsuperscript{59} performed a similar study with expert swimmers in a 25m pool. Swimmers were instructed to swim under one of three focus conditions: internal focus (“pull hands back”), external focus (“push water back”), and control (no instructions). Both the external focus condition and control had significantly faster times than the

\textsuperscript{57} Marchant, D.C., Greig, M., Bullough, J., Hitchen, D.(2011) Instructions to adopt an external focus enhance muscular endurance. Res Q Exerc Sport. 82(3):466-73
\textsuperscript{59} Stoate, I. Wulf, G. Does the Attentional Focus of Swimmers Affect Their Performance? International Journal of Sport Science & Coaching, 6, 99-108
internal focus condition. Researchers probed further into the control condition and found that swimmers who voluntarily chose to focus on “speed” outperformed those who self-selected an internal focus condition on a body part. In fact, they found similar results between the self-chosen “speed” focus in the control condition and the external focus condition. One explanation was that at higher levels of skill mastery (expert swimming), external focus cues are less needed, as the proficiency of the athlete allows them to focus on movement outcomes such as feeling fast!

Using external focus imagery is most in-line with the literature, but as a practical matter we may need internal cues at the onset of interaction so the athlete knows what part of the body we are actually referring to. There just isn’t much creative imagery to describe an early vertical forearm catch to someone who doesn’t know what it is to begin with. Sometimes, a quick reference to the body part may be necessary to initially trigger the athlete’s awareness and then gradually transition to external cues.

Stroke analysis in video should go beyond breaking down the stroke, but also guiding the athlete to appropriate self-talk language for their stroke keys. Whenever possible, utilize external cues. If you work with young kids, you are probably good at finding creative cues already! If we can’t find an appropriate external focus cue for a movement, it may be a sign we’re not in the right place with that athlete. In other words, if you need to cue into a body part (internal focus) to explain a movement, perhaps what’s really needed is a regression to a different drill or exercise. According to the literature, cues should be distillable into external imagery. Again, we can make concessions for the unique aspects of swimming, but ultimately this is the intersection of drill with skill.

**Mirrored Swimming**

Within in past ten years the abundance and availability of elite swimming videos has exploded. This expansion has occurred online and on television with Universal Sports and more recently the Big 10 network broadcasting dual meets. This emergence isn’t isolated to the sport of swimming. Other sports have also had this Renaissance of film and video, but like other technologies they occurred decades ahead of swimming. Basketball has been regularly televised since the nineteen-sixties; the same with football and baseball.

Mirror neurons are a relatively newly discovered neural structure. Researchers only began to isolate and understand them within the past thirty years, but mirror neurons have been around much longer. Mirror neurons are neurons that fire when an animal sees another animal perform a task. These neurons are the reason people are more
likely to sneeze when they view someone else sneeze or why you check your cell phone when you see someone else checks their cell phone. These remarkable neurons have been extremely helpful throughout the history of mankind. Before language was developed, communication was largely dependent on visual cues. As a result, imitation was facilitated by motor neurons. This rapid transfer of ideas from one species to the next is Lamarkism, not Darwinism.

In swimming, being able to view an elite swimmer will make you a better swimmer. Where many go wrong is trying to deconstruct an elite stroke and copy what the elite does without matching body type and other physical traits. Use imagery of elite swimmers to etch a positive image into your brain (and if you are already an elite, study your peers who excel in areas where you can personally improve), while keeping in mind your anthropometrics, as all elite swimmers move differently to accommodate their bodies.

**Learning to Un-Learn**

“Before you make a pattern, you gotta break a pattern.” – Gray Cook

Whenever we make stroke changes, new movements must compete with old habits in our brain’s motor programming. If that was not the case, stroke changes could happen instantaneously and would remain permanent. Neuroscience is still unclear whether we can literally erase an old motor program or whether the older program is merely suppressed. Either way, it is important to have a strategy to deal with old programming when installing new ones.

Just as we must identify the backspace button when we type, we must identify our brain’s backspace button to break old habits. Typing new text doesn’t automatically erase old text. Trying to install a new program without accounting for an old one is like two people speaking simultaneously. Both can talk louder to be heard, or one can remain silent. The latter option brings clarity; the former brings chaos. Optimal learning requires clarity.

First, let’s understand why stroke changes aren’t easy, and why any change in habits can be hard. Recall that for every 300 reps to groove a pattern, it takes 3,000 to create a new one. Repetition of any skill creates physical changes, from increased myelination for delivering signals from the brain to motor units, to changes in tissues that reflect repetitive use. These are the mechanical changes, but we must also consider the environment of our own bodies that allows for such change.
One explanation is that we retain older motor patterns in anticipation of using them again. “[We] effectively learn by predicting the current state of the environment from our immediate past observation.” 60 Retention of motor programming exists as an evolutionary protective mechanism. If we survived this long with a motor pattern being used, that pattern likely had some value. Our brain is hardwired to retain successful patterns. If past observation has shown a particular strategy to be successful (and if we are still alive, then nearly all motor patterns are to some degree successful), that strategy will transfer to our subconscious mind so our conscious mind can worry about other matters. This is simply economization of mental resources.

Consider the Degrees of Freedom concept.61 Movement complexity consolidates via minimizing degrees of freedom. When you are first exposed to a task, the body faces many choices (degrees of freedom) for how to accomplish that task. Through practice, our programming becomes more refined as we learn to eliminate choices from the many degrees of freedom. For example, ask a novice to swim, and they will look like an uncoordinated mess of flailing arms and legs in different directions. Eventually, they may learn to swim, but early movements are often stiff and rigid.

Watch this novice try to rotate to breathe and they’ll often rotate their entire body to one side with constant tension in many muscles to accomplish this simple task. Proficiency develops as they un-learn recruitment of unnecessary muscles. There’s a reason we refer to experts as appearing “effortless” in their movement. Experts not only have taught themselves what muscles to use; they have also taught themselves what muscles to NOT use, which is a pretty amazing feat considering the vast number of options available for movement.

Rate of “forgetting” can depend on environment and reinforcement. 62 Manipulating environment is a tough one, because there is very little variation in swimming is a repetitive use activity, unlike soccer or basketball. The aquatic environment is constantly changing due to turbulence, but we’re always staring at the same black line for a fixed distance. However, we aren’t limited to the water in how we can affect the environment around the body.

Manual therapies can stimulate unlearning, whether skilled hands or by do-it-yourself tools. For example, if a muscle is excessively tight, it is receiving signals from the

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brain to contract when it shouldn’t be. Manual interventions help the muscle unlearn resting tension that can be replaced with a new strategy of relaxation to then facilitate optimal firing. In this light, foam rolling and tennis balls are actually adjuncts to learning.

When you think reinforcement, perhaps you have the image of a dog getting a treat when obeying a command, or since we’re talking swimming, maybe Shamu getting some fish after a trick. Rewards are one method to speed the adoption of a new strategy and suppression of an old one, though throwing treats to swimmers for picking up a stroke cue probably isn’t a workable strategy!

Fortunately, we can provide reinforcement to suppress the old patterns via concurrent learning. Visual feedback tied with new programming most effective when paired together close in time. Watching YouTube videos at home is helpful, but research suggests that watching models close in time to actually performing the task can have a more powerful effect. The best diving programs understand the importance of feedback immediacy in positioning a video system adjacent to the well so divers can get feedback exiting the water after each dive. With technology becoming more readily available by the day, opportunities are increasing to improve reinforcement.

As described with mirror neurons, observation can assist the learning process. For a young swimmer, maybe that means watching the senior group before their own practice starts. This likely occurs already just by hanging around the pool, but the concurrent learning effect can explain why a strong environment with positive examples is effective.

It may be hard for elite or senior groups have role models present if they are already among the best in the world at their craft. However, even those at the top of the food chain can have role models to assist in their weaknesses. In building a training group, ask what can each person bring to aid skill development in teammates? This contribution affects not only attitude and culture, but also the environment for learning.

**Summary**

Consider not just the act of learning, but the total interaction of muscle length, strength, timing, and biomechanics, all of which can affect the process of learning and unlearning. We might hypothesize that length, strength, and timing are actually reflective of previous learning strategies. Knowing the effect of these factors on the

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learning and unlearning process will help us manipulate the necessary variables to unlearn old strategies and pave the way for newer ones.
Part VII: Individualized Dryland Program Tests

Movement screening has become widely popular with the release of Gray Cook’s Functional Movement Screen (FMS). Screening is essential for athletes and individualized dryland programs. However, whereas the a basic movement screen like the FMS functions much like a blood pressure gauge to gain a general picture of cardiac health, additional testing is essential to gain a complete picture, especially for specialized athletes with specific demands.

Most important is to consider each screen in the context of other screens and each swimmer’s individual stroke traits. A particular result on a screen may be of no consequence for one swimmer, yet when combined for another swimmer that same result may unlock a physical limitation when paired with another screen. This makes knowing proper screening and swimming biomechanics key for unlocking flaws and connecting the dots between out of water and in water impairments.

Below is a specific movement screen to address swimmers’ needs. The grading system is similar to what is used for the FMS.

- 3 = correct movement pattern, no pain
- 2 = faulty movement pattern, no pain
- 1 = pain with movement pattern
- 0 = inability to perform movement

Static posture
Directions: Have the swimmer stand naturally. Observe the swimmer both from the front and in a profile view (side).

Keys: Common findings include
- left-to-right side asymmetries
- rounded shoulders
- palms facing backward (which is a sign of chronic shoulder internal rotation)
- flat or high arched feet
- thoracic kyphosis
- flat low back
- forward head

Note that because some may feel uncomfortable being evaluated while standing still, you can also observe these keys informally.
Stroke Implications: Static posture alone is neither positive nor negative for the stroke, but it does affect all movements. The keys noted above are frequently associated with common stroke issues (waves and tsunamis).

Breathing screen

Directions: When performing breathing screens on your swimmers, do not let them know what you’re looking for. This task is difficult with deep breathing, but simply telling them to take a deep breath and encouraging them to take in more air brings out their competitive side and reveals their true breathing pattern.

Keys: In relaxed breathing, look for a wave of motion, starting from the stomach rolling superiorly (upward) to the chest when viewed from the anterior (front) side of the body. Some experts suggest zero chest movement during relaxed breathing, but in reality a slight forward (not upwards) movement is fine. During forced respiration, make sure the diaphragm is contracting and sucking in.

Stroke implications: Breathing is fundamental to each stroke. If a swimmer has breathing faults on land, these faults may become exacerbated under increased stress in the water.

Cervical flexion

Directions: Have the swimmer stand with feet together and mouth closed. Instruct the swimmer to touch the chin to top of the chest while maintaining a closed mouth.

Keys: Looks for the following signs of physical limitation:
   • Does the mouth open as a substitute for flexion?
   • Is there excessive stretching in the upper back?
   • Does total posture change to accomplish this neck-only movement? Some may bend the spine or flex the knees to accomplish this movement.

Stroke implications: A swimmer who lacks cervical flexion may have difficulty maintaining horizontal body alignment during short axis strokes. The ability to flex the neck independently of other spinal segments is also an indication of the swimmer’s general skill at differentiating movements in separate body parts.

Cervical extension

Directions: Have the swimmer stand with feet together and mouth closed. Instruct the swimmer to extend the neck and look backward while maintaining a closed mouth.

Keys: Looks for the following signs of physical limitation:
• Does the mouth open as a substitute for extension?
• Is there excessive stretching in the lower back?
• Does total posture change to accomplish this neck-only movement? Some may bend the lower spine to accomplish this movement.

Stroke implications: Limited extension could impair short axis undulation and may indicate a preferred breathing pattern from the chest. As with the cervical flexion test, the ability to flex the neck independently of other spinal segments is also an indication of the swimmer’s general skill at differentiating movements in separate body parts.

Cervical rotation right and left
Directions: Have the swimmer stand with feet together and mouth closed. Instruct the swimmer to touch the chin to the left and right collarbones while maintaining a closed mouth.

Keys: Observe whether the swimmer move through the full range without the mouth opening or the shoulders contributing to the movement.

Stroke implications: Full range of motion on the swimmer’s preferred breathing side is essential for unimpaired freestyle rotation. If the swimmer lacks rotation they may substitute with faulty stroke patterns elsewhere in the body

Cervical endurance
Directions: Instruct to swimmer to lie supine. Lift chin to sternum with back of head slightly above table or ground. Hold for ten seconds.

Keys: Ensure movement comes from neck and does not become a torso crunch. Also note for strain, such as facial expressions, shoulder tension, or labored breathing.

Stroke implications: Insufficient flexor endurance may contribute to an excessively high head position in all four strokes.

Forward spinal flexion (toe touch)
Directions: Have the swimmer stand with feet together. Hands should be overlapping like a streamline. Touch fingers to floor (or as close as possible if full range not available)

Keys: Note how far the swimmer can descend without strain. Also note whether the swimmer can engage a posterior weight shift to initiate the downward flexion. A
swimmer who relies solely on the spine may lack the physical understanding to fully utilize their hips.

**Stroke implications**: Hip hinging occurs during short axis strokes. Without a hip hinge, the swimmer may rely upon excessive low back movement to drive their body undulation. Hip flexion and extension also occurs with each kick in the long axis strokes.

**Spinal Extension**

**Directions**: Have the swimmer stand with feet together. Hands should be overlapping like a streamline. Instruct the swimmer to lean backward with arms overhead, almost like a backstroke start.

**Keys**: In a profile view, shoulders should advance past the back of the heels; front of hips should clear front of toes. Note whether a continuous spinal curve occurs or whether any spinal segments remain flat. Many swimmers lack extension in the upper spine.

**Stroke implications**: Spinal extension occurs during body undulation. Insufficient thoracic spine extension is often linked to shoulder maladies.

**Side bend right and left**

**Directions**: Instruct the swimmer to bend to the right and then left as if trying to scratch the side of the right knee and left knee with the hand.

**Keys**: Observe whether the swimmer can limit their movement to flexion or whether they add rotation to accomplish this test.

**Stroke implications**: Side bending limitations may affect rotation and lateral stability during long axis strokes. Lateral flexion is required during both freestyle and backstroke.

**Shoulder flexion**

**Directions**: Instruct the swimmer to stand straight with feet together and back flat against a wall. Keeping arms straight, they should reach the arms overhead and attempt to touch wall with their thumbs.

**Keys**: Observe the distance at which the swimmer can flex the shoulders without flexing the elbows. Acceptable range of motion is when the swimmer can flex the biceps beyond the nose in profile view. If the swimmer cannot attain the start
position, it may indicate that any shoulder issues for that swimmer may relate to the core and lower body.

**Stroke implications:** Flexion is critical for all strokes. Insufficient shoulder mobility or stability may cause the swimmer to substitute motion elsewhere, possibly manifesting through a stroke flaw.

**Shoulder abduction**

**Directions:** With the swimmer seated or standing, instruct to raise each arm individually to the side, parallel to ground. Then instruct to raise arm to point straight upward.

**Keys:** Note any shaking in the shoulder blades on the upward and downward arc. Also note any extra movement via body lean, neck side bending, or torso rotation to accomplish the movement.

**Stroke implications:** Shoulder abduction occurs during all four strokes and is critical in the recovery phases. Limited shoulder abduction may lead to common recovery flaws, particularly in freestyle and butterfly.

**Shoulder external rotation**

**Directions:** Begin with the swimmer’s elbow flexed to 90 degrees and against the swimmer’s side. Then instruct the swimmer to externally rotate.

**Keys:** Observe whether the shoulder shakes or is otherwise limited in its motion. Note whether the swimmer struggles to keep the shoulder close to the torso during the movement. Separation between the arm and torso may indicate limited joint mobility or scapular stability.

**Stroke implications:** Each stroke takes the shoulder through external rotation. High elbow, early vertical forearm, and proper hand position all depend on external rotation.

**Shoulder internal rotation**

**Directions:** Raise the thumb up the back, trying to touch the opposite scapula. Record the position in relation to the spine.

**Keys:** Can the hand reach the opposite scapula? Does the swimmer use any non-essential contributory movement?
**Stroke implications**: Internal rotation is needed in all four strokes to maintain proper hand entry and orientation throughout catch and pull phases.

**Hawkins-Kennedy**

**Directions**: Position the patient standing with the shoulder abducted 90 degrees, and internally rotate the forearm. The presence of pain with movement is indicative of possible pathology.

**Keys**: Checking early signs of impingement. Also checks tightness in infraspinatus. If painful, further treatment necessary.

**Stroke implications**: Mostly relevant to check for pain, but can indicate extreme mobility to facilitate early catch and early vertical forearm.

**Upper quarter rotation**

**Directions**: Place rod across chest, sit with feet together, and turn to each side.

**Keys**: Rod should create at least a 45-degree angle compared to starting position. Avoid compensatory shoulder movement, side bending, or any other movements besides rotation.

**Stroke implications**: Thoracic spine rotation is crucial in long axis strokes and is often restricted causing insufficient rotation and compensatory movement in the neck and lower back. Additionally, limited muscle length, strength, and timing in the thoracic spine region can place the shoulder in compromised positions.

**Upper quarter rotation with scapular restriction**

**Directions**: Same as above, with rod placed across the back

**Keys**: Note whether rotation decreases as compared to upper quarter rotation without scapular restriction. Restricting the scapulae will expose whether the athlete is indeed obtaining their rotation through the thoracic spine or whether they are “cheating” with their shoulder blades.

**Stroke implications**: If a swimmer’s preferred movement pattern is to assist thoracic spine rotation with the scapulae, they may lack shoulder stability during the catch and pull phases of the stroke.
Wall slide
**Directions:** Instruct the swimmer to sit with back to the wall and legs crossed. (Standing is a viable alternative if seated is not possible). Place arms against the wall at 90-degree angles in the elbows (the “Surrender” pose). Raise the arms overhead along the wall, but only as high as the swimmer can maintain contact with the wall.

**Keys:** For some, merely getting into the start position will be a challenge. Wall slide tests shoulder and thoracic spine mobility along with scapular stability. Note any deviations from starting posture, including changes in wrist angles or if the arms or torso long wall contact.

**Stroke implications:** Posture, thoracic mobility, scapular stability, and glenohumeral range of motion are all vital for all four strokes. A swimmer who struggles with this test may be vulnerable to several stroke flaws and injury patterns.

Deep squat overhead
**Directions:** Instruct the swimmer to stand with feet parallel pointed straight ahead and shoulder width. Take bar or stick and position directly overhead with elbows at right angles. Squat as deeply as possible. If bar falls forward, ankles turn out, or knees cave in, repeat the squat pattern with hands resting next to head without any bar. Again, note any deviations from starting alignment.

**Keys:** In addition to the testing criteria noted above, observe any lateral weight shifting.

**Stroke implications:** The overhead deep squat tests a swimmer’s ability to maintain thoracic extension during dynamic movement. It also tests a swimmer’s ability to differentiating the hips from midback during body undulation.

Single leg squat
**Directions:** Have the swimmer perform a partial squat with one leg partially extended forward, while one leg squats. The goal is not total depth but instead to assess balance, basic strength, and lower extremity motor control.

**Keys:** Note any shaking, loss of balance, or misalignment in the squatting leg.

**Stroke Implications:** This test does not to the strokes, but hip and knee stability are crucial for durability in breaststroke.
Active straight leg raise

**Directions:** Instruct the swimmer to lie supine with legs straight and parallel. Place the hands at the side with palms up. Have the swimmer lift one leg upward while keeping leg straight and toe pointed forward.

**Keys:** Note the distance the swimmer can raise the top leg without any changes to either the top or bottom legs. Both legs must stay straight without rotation. Note any differences between the toe touch and the active straight leg raise. Swimmers who can raise a leg near vertical but cannot perform the toe touch may lack core stability for hip dominant patterns.

**Stroke implications:** The ability to differentiate each hip is critical for long axis kicking. The active straight leg raise is not only a mobility test, it is a test for neuromuscular control.

Ankle point

**Directions:** While seated, have the swimmer plantar flex (point) the toes.

**Keys:** Optimally, the swimmer could form a straight line between the shin and top of the foot. Note those swimmers who can’t achieve that range, as they may require extra troubleshooting in their kicks.

**Stroke implications:** If the swimmer lacks plantar flexion, optimal horizontal posture in the water will be difficult to attain. Alternation between plantar flexion (point) and dorsiflexion (toes pulled toward shin) is critical for long axis and butterfly kicking.

Foot eversion

**Directions:** Have the swimmer sit in on a chair with their two fists in between knees. Evert the ankles, or point soles of feet to outer walls, while keeping knees stable.

**Keys:** Knees must remain stable by maintaining fists in between. Excess movement in the knees or lack of movement in the ankles would signal a limitation.

**Stroke implications:** Feet must turn out (evert) during the breaststroke kick. Limited eversion will limit kick effectiveness and make the knees vulnerable to excessive strain injuries.

Trunk stability push-up

**Directions:** Instruct the swimmer to lie prone. Males place hands in standard pushup position on a line even with forehead approximately shoulder width apart. Compared
to a “normal” pushup the hands will be placed more forward to expose core instability. Females do the same with hands even with chin. If instability is noted, males slide hands down to chin level, females move hands down toward chest level.

**Keys:** Note whether the trunk elevates in one coordinated movement.

**Stroke implications:** The pushup addresses muscle length, strength, and timing in a basic motor pattern. All qualities are required for all four strokes. The pushup may also expose scapular instability. Streamlining demands straight body alignment for optimal hydrodynamics.

**Rotary stability**

**Directions:** Set in quadruped position either with hands and knees touching FMS board or wooden 2 x 6. Extend ipsilateral arm and leg (right to right, left to left) then try to touch elbow to knee, and extend again. If unsuccessful, touch contralateral limbs (right to left, left to right). Grounded back toes remain dorsiflexed during the movement.

**Keys:** Few swimmers will achieve the ipsilateral touches. Note any deviation from starting posture during the contralateral trials. Common flaws include excess weight shift and loss of spinal posture.

**Stroke implications:** All strokes involve rotary stability in ipsilateral and contralateral patterns. These are basic crawling patterns forming the basis for arm and leg coordination particularly in long axis strokes. This test may also reveal hip and shoulder instability.
Part VIII: Post-Workout Static Stretching

Static Stretching Cool Down
The purpose of stretching is to make the muscle and surrounding fascia suppler and increase in length. The most important part of any exercise program is compliance. This is particularly true for stretching exercises. When you stretch you get an immediate increase in tissue length. This is due to the viscoelastic properties of the tissue and improved stretch tolerance. However, the term elastic implies, this change will not last long. When you repeatedly stretch muscle and its fascia; you get more of a ‘plastic’ change in the tissue - a lasting change. To achieve this you must stretch daily. Missing several days will put you back to square one.

To improve, we have found that stretching each muscle for 30 seconds daily will get you results. Of course you can stretch longer, but at least do 30 seconds. You should feel a stretch sensation, not pain. As with any exercise, if it causes your ‘pain’ - stop.

Stretching also helps with recovery, specifically of the autonomic nervous system. For athletes having excessive training, light stretching after practice may aide recovery. Passwords for all these videos are ‘CORSMR’.

Adductor Stretch
Lie on your back with your knees bent. Tighten your stomach to make your back flat. Keep your back flat and let your legs fall apart until you feel a stretch on the inside of your thighs.

Single Knee to Chest Stretch
Lie on your back and bring one knee toward your chest. Let this leg fall out a bit as this is the natural angle of the hip.

Hamstring Stretch
Lie on your back. Bring one knee toward your chest and grasp behind your thigh with both hands. Keep the other knee bent. While holding the knee to your chest, straighten your knee until you feel a stretch on the back of your thigh.
**Piriformis Stretch**
Lie on your back and place the arch of one foot on the opposite thigh just above your knee. Grasp your knee with your opposite hand and pull across and up until you feel a stretch in the buttock.

![Piriformis Stretch Image](image1)

**Standing Iliopsoas Stretch**
Put one foot up on a table or other high object (depending on your height - no higher than the knee). Point the foot that is on the floor into a pigeon toed position. In this position, do a pelvic tilt or “tuck under.” You may feel a stretch in the front of your thigh. If you don’t, lean forward, leading with your hip and keep your chest in the same position. You will feel a stretch on the front of your thigh, and in the groin area. Hold onto an object with your hand to stay balanced.

![Standing Iliopsoas Stretch Image](image2)

**½ Kneeling Stretch**
Kneel on one knee with your other leg forward with your foot flat on the ground. Use a table or chair to your side for balance and a pillow under your knee if padding is necessary. Line up your body over the knee that you are kneeling on. In this position do a pelvic tilt or 'tuck under' and you will feel a stretch in the front of your thigh. Common mistakes are arching your low back or leaning forward which negates the stretch.

![½ Kneeling Stretch Image](image3)

**Gastrocnemius Stretch**
Stand with one leg behind the other facing a wall. Use a towel to support the arch of the foot that is behind you. Bend your front knee while keeping your back knee straight. Lean forward, using the wall for balance, until you feel a stretch in the calf or the back leg.

![Gastrocnemius Stretch Image](image4)
**Soleus Stretch**
Same ideas as above only you are standing directly over the foot you are stretching. Just bend your knee and allow your ankle to flex until you feel a stretch in the calf, closer to your heel. Use a towel to support your arch.
Conclusions
Overall, designing a dryland program for yourself or your team is highly specific to the situation. Sometimes, having dryland after practice is not an option, so modification occurs. Also, this is only one example of a dryland program for an entire team. As mention in the individualized section, there are many tools, assessments, and interventions for improving a swimmer and different route to success. However, identifying the area of weakness and providing a safe intervention or dryland program is necessary for whoever is leading dryland. This review and program hopefully results in better coaches and swimmers.

Our goal with this book is simple: make coaches better coaches and make swimmers better swimmers.

Swimming has progressed enormously in the last generation. Fluid dynamics, suit design, pool construction, video technology, among other factors, has all pushed swimmers to faster times in all events. Age groupers and average college swimmers routinely post times that would have won Olympic medals in years past. What can we possibly add to the collective knowledge in swimming science?

One untapped frontier is the understanding of each stroke as it relates to the human body’s physical attributes and limitations. Most teaching beings in the pool and molds the body to the stroke, regardless whether the swimmer can physically do what is being demanded. The approach we offer in this book does not replace what great coaches already do; instead our system will complement traditional approaches to stroke pedagogy.

The link between accessory training such as dryland, stroke drills, and rehabilitation remains hotly debated in the swimming world. But we do know that any swimmer’s ability to execute optimal stroke patterns depends on what their body can physically do. If you can’t perform certain movements, or if your body has habituated itself into suboptimal movement and postural habits, your approach to stroke mechanics must adapt. Swimming has far too high an injury rate and dropout rate to ignore these basic facts.

Think of this book as a GPS for your stroke coaching. Ancient mariners have navigated the seas relying solely on instinct and observation. But with the advent of GPS and greater understandings of the maritime science, mariners are better equipped to steer their vessels through routine waves and around dangerous tsunamis and other storms. By understanding the links between the stroke and the body, coaches and
swimmers can make their interventions into the stroke more effective and more permanent.
Appendix A: SMR Body
Appendix B: When to Lift by John Matulevich

Anyone who trains youth athletes knows that development is all over the place. One 12 year-old may more closely resemble a high-school football starter than he does his classmates, while another 14 year-old from the same group may look more like he’s arrived an hour late for his learn-to-swim program. Because of this dilemma, training young swimmers can vary drastically. For sake of simplicity, I’m going to assume ‘youth’ refers to all age group swimmers from 11-18, but I am also going to compartmentalize this post based on development, not biological age.

Prepubescent

These athletes have the most growth potential, and should be trained as broadly as possible. I suggest a land-based warm up before any kind of swimming work, which will: improve body awareness, reinforce movement patterns, activate appropriate tissues, and increase bone mineral density.

A land-based warm-up does not need to be long here, 5-10 minutes of big movements such as crawling variations, lunges, bodyweight squats, and dynamic stretches should be sufficient. Not only will this style of warm up help the athlete reap the aforementioned benefits, but it will also help keep the attention span of this hyperactive age group.

After swimming is a great time to reinforce the patterns established in the warm ups. Here, you can increase the volume of the exercises to bring about a training effect. You can also use similar exercises in the cool-down to encourage blood-lactate recycling to expedite the recovery process.

Prepubescent athletes are frequently young enough to be free of mobility restrictions associated with poor tissue quality (extended periods of sitting being the prime culprit). This makes this age the most crucial time to reinforce tissue quality, which will help the athlete later on, as more skill and strength will be able to develop. As an aside here, even national level swimmers at the youngest age group should have a definitive off-season from the sport. Early specialization will only hinder their performance later in their careers when performance matters more.
Pubescent

At no other point in someone’s life are there such dramatic changes in muscle mass, hormone levels, skill, and mechanics. Because of these changes in biomechanics, creating awareness of this new muscle mass and changing leverages is huge.

To ensure you are creating lasting neural changes in this population, dryland training in a fatigued state (immediately after swimming) may be the best option. This works by forcing the athlete to maintain proper form during fatigue (which forces the athlete to think about the movement and develop the mind-muscle connection).

This is also a great time to introduce more complicated lifts, as well as external load (i.e. weights or band resistance). Just remember the weight itself is not nearly as important as good form. Remember, in this age we are trying to introduce neural adaptations. Adaptations can occur with poor form and heavy load, but this would reinforce poor technique, which is not at all what we are seeking.

Postpubescent

By now elite athletes have developed some body awareness and are moving quickly towards sport-specificity. The goal of dryland training now is: injury prevention, improved proprioception, and general strength.

The best way to achieve these basic goals is in a non-fatigued state. Ideally, you want the athlete to have time to recover after the dryland workout because of the heightened demands on the Central Nervous System and Muscular System. This is best done with an individual practice consisting entirely of the strength work, and another devoted to swimming. This is where two-a-days can come in handy, if your governing body allows it (varies by state athletic associations).

If having a separate training session is not an option, alternating between swimming first, and dryland work first may be your best bet. Just make sure to reduce the volume and intensity on the days where the dryland work will come last. This will actually improve recovery time and allow better efforts for both pool and dryland work.

As these athletes develop, creating the general strength as I mentioned, is huge. An
easy way to add this general work is land-based warm ups and cool downs. I know from personal experience that younger swimmers tend to slack off on the cool down, so by switching to land, it will provide a relief from more pool volume, as well as a mental break.

Wrap-Up

The most important thing to realize for all populations is that any kind of dryland training will be extremely beneficial to the athlete. The above situations are ideal, but if you have restrictions with your athletes (i.e. NCAA time allotments), getting training in wherever you can is still critical. To break up monotony with youth swimmers, I suggest using some dryland work as a warm up, which will also enforce appropriate motor patterns, as a training session in itself to maximize strength, and as a cool down, to strengthen the athlete’s proprioception via enhanced CNS input.
Appendix C: Example Elite Group Dryland Program

After speaking with many coaches, they report the interest of including a general dryland program for a large group. Below is an example of a program, which can benefit an entire elite team. If looking for ideal individualization, include the Phase IV program above.
4 sets of 20 seconds/40 Rest, switch exercises after 4 sets. Rest 2 minutes between exercises.

1. Squat to Press – DB

2. RDL – Isometric Hold (Kettlebell in each hand)

3. Push Up w/ Alternating Knee Tuck

4. Box Jump (Step down off the box each rep, Do not jump down. NO MORE THAN 8 reps in the 30 time)

5. Medicine Ball Lunge – Isometric Hold

6. Pull Up

7. Pillar Ride Side
4 sets of :15 exercise :45 rest. 2 Minutes rest between exercises.

1. RDL

2. MB 14mm Push Up w/ Stability

3. Forward Lunge – 2 DB, Alternating Steps

4. Pull Up (vest if necessary)

5. KB Swings – 2.5mm

6. Suspension Row – 2.1mm (vest if necessary)

7. Switch Jump
4 sets of 5 repetitions, :60 rest between sets and 2 minute rest between exercises.

1. Box Jump (low-mod box, step down from box)

2. Squat to Press - DB

3. Pull Up (vest if necessary)

4. Dead Ball Slam

5. KB Swing – 2 Arm

6. MB 1 Arm Push Up w/ Stability