Chapter 2
Physiological, Psychological, and Medical Aspects of Water Polo

Physiology:

Physiologically and psychologically, water polo is a very demanding and mentally challenging sport. A panel of eight exercise physiologists (Ludovese, C6) ranked water polo highest in athleticism when comparing it to badminton, baseball, basketball, cross-country, football, golf, soccer, softball, swimming, tennis, track and field, volleyball, and wrestling. This ranking included measures for aerobic endurance, agility, anaerobic endurance, body composition, quickness, skill, speed and strength. Let's look at the physiological, psychological, biomechanical, and medical bases for this high ranking.

First, water polo combines the sport of swimming with ball handling. Swimming itself utilizes 15.7-20.0 kilocalories per minute, more than any other form of physical activity (Wilmore and Costil, p.148). In addition, swimming has been found to have a Metabolic Equivalent (MET) value of 20-30, roughly the same as running (Wilmore & Costil, p.622).

Like swimming, water polo makes large demands on aerobic and anaerobic systems. The variety of work involved in the game for field players can be broken down as roughly 50-60% aerobic, 30-35% anaerobic, and 10-15% , immediate energy (ATP-PC) system (Smith, p.331). The third component listed – immediate energy - is largely the result of the physical contact involved in the game.

> **To your health**: Calories burned by 180 lb. man in 30 min. of H2O polo: 410; Tennis: 287; Running: 512

Water polo is very intermittent, with intense bursts of activity occurring and activity varying according to the players' positions in the pool. It has been observed that elite male water polo players have approximately 6-20% greater oxygen consumption than competitive swimmers (Smith, p.328). Other studies have shown that VO_2 max is higher for international level swimmers than water polo players or pentathletes (Cazorla & Montpetit, p.253). Regardless, the sport requires tremendous endurance. (Vo2 is a measure of the bodies' ability to use oxygen in the production of energy that is aerobic energy, measured in Liters per minute)

Water polo players' heart rates have been measured in excess of 150 beats per minute for 91.8% of actual playing time (Smith, Pinnington, et. al., p.6). And, water polo players blood lactate levels have been measured at a range of 6.72mmol/L for younger female players (Nemet, et.al. p.360) to 7-9mmol/L. for older elite and female male players (Rodriguez….Hollander). Lactate levels are a measure of energy output during exercise and the typical resting, non-exercise rate is between 1 and 2 mmol/L. (The term mm is a measure of the concentration of a substance in the blood that accounts for actual molecules in solution). Track competitors, by comparison, have blood lactate levels ranging between 8-10mmol/L. during competition (Wilmore & Costill, p.199)

The usual distance swum by players during a water polo competition is between 1500-1800 meters (Smith, p.322, Hohmann & Frase, p.316). Considering the percentage of aerobic work being done during water polo, this system should be addressed very similarly to swimmers' training (4-6,000m./day). Both aerobic and anaerobic systems must be built in the training of water polo players, because of the total playing time a large percentage of the swimming was "steady state" and below the aerobic threshold (Hohmann & Frase, 316).

Secondly, given that muscular endurance is the ability of a single muscle or group to sustain high intensity, repetitive, or static exercise, it is likely that the most effective form of conditioning for water polo is "…repeated, fast-paced, brief variable bursts with short rest intervals between bursts…" to achieve the exercise most similar to the water polo game(Wilmore & Costil, p.273). A combination of training that includes both aerobic and anaerobic emphases is best to develop the musculature and cardiovascular systems necessary for the competition. Fatletk (fast/slow) training with about 20% of the time swimming at sprint speed and 80% at slow speed is another recommended form of training (Hohmann & Frase, p.319).

Additional positive physical benefits of the sport are enlargement of the heart muscle in order to pump more blood, and an increase in body mass as a result of the physical struggle and contact made between players (Pavli, et. al).

Psychology:

The major factor regarding the psychology of water polo has to do with the tactical decision-making the players utilize while expending the bodily energy just mentioned. When compared with expert volleyball and basketball players, water polo players were found to be highest in decision-making (game situation), visual reaction time, and spatial orientations – while basketball players were better on prediction and selective attention and volleyball players were best on perceptual speed, focused attention, prediction, and estimation of speed and direction of a moving object (Kiomourtzoglou, et.al, 1998).

A second variable which has been proven beneficial for water polo athletes is the development of a pre-performance routine. Marlow, et. al. (1999) found significant increases in water polo penalty shot performances due to personalized pre-performance routines including concentration cues, relaxation, imagery, and cue words.

Water polo requires thinking which is analytical and immediate. Players, because of the lack of visual memory that is available through the media, are much the beneficiaries of actual experience in complex situations that accumulate over a number of years.

Biomechanics:

As in all sports, strength training is of great value in enhancing successful water polo performances. There are several muscle groups utilized in the basic actions of throwing a ball as well as in swimming head up and eggbeatering.

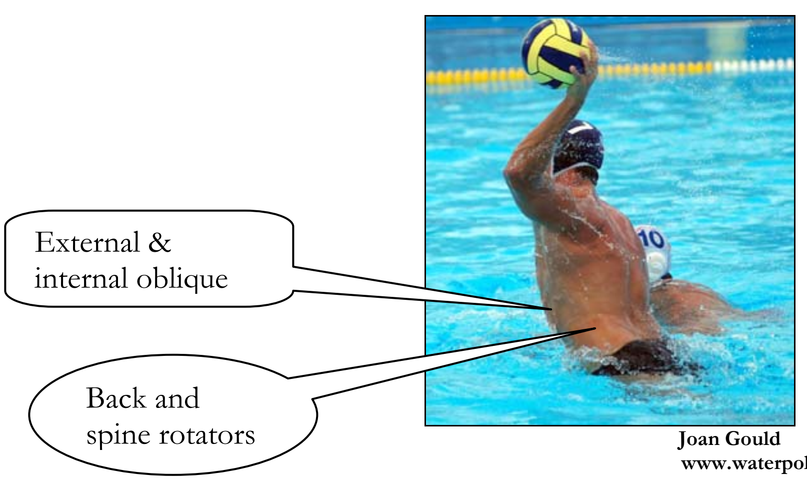
Regarding throwing technique, Newton's 2nd law of motion ($F=m \cdot a$), as applied to acceleration states that the velocity of an object…..depends upon both the amount of force and the length of time that it is applied. Therefore, the more muscles that are used over a longer distance, the more force attainable. And, the more contributing body parts (muscles) that are brought into the action, if they are timed so that the part below has reached its maximum speed, the more ultimate speed is obtainable. (Broer, p.234,246)

The optimal succession of levers for the overarm baseball throw is:

Outward/inward rotation of spine & back ⇨ extension to flexion, external to internal rotation and horizontal ab- to adduction of shoulder ⇨ extension to flexion of elbow ⇨ extension to flexion and pronation of wrist and fingers.

Upcoming are photographical representations of the over **thirty-five** major muscle groups utilized in water polo, in the approximate sequence of their chain.

Upper body musculature – major muscle groups as part of throwing motion:



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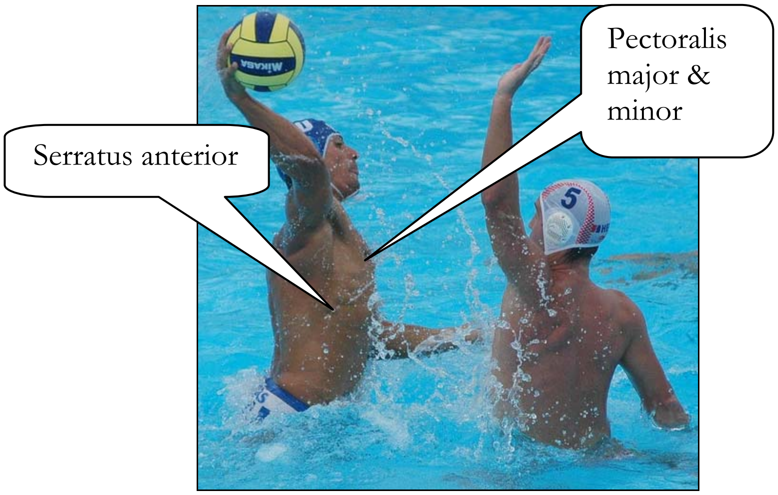

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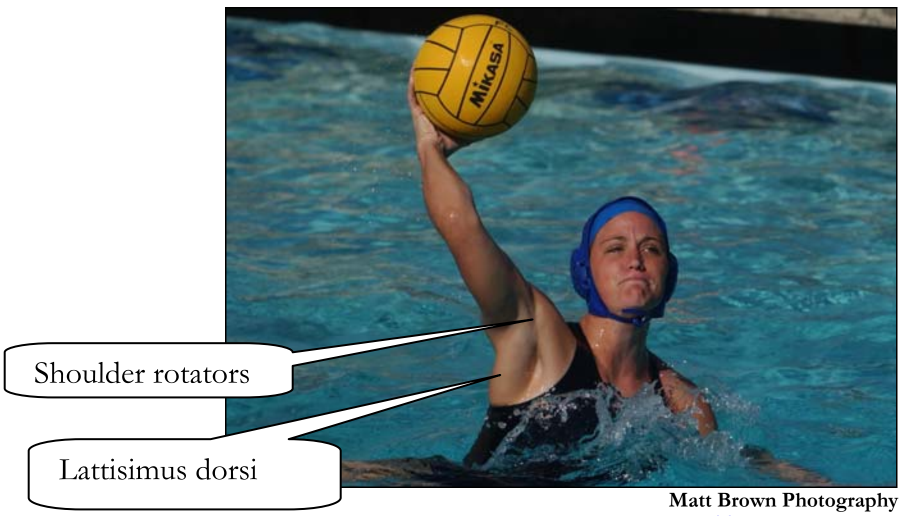

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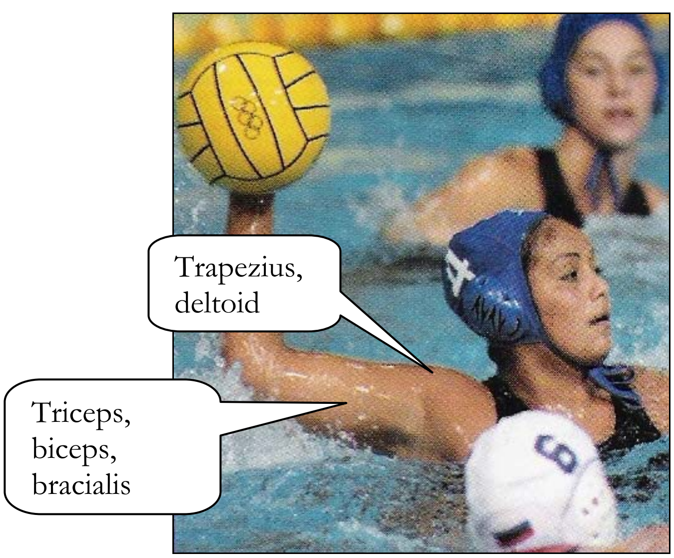
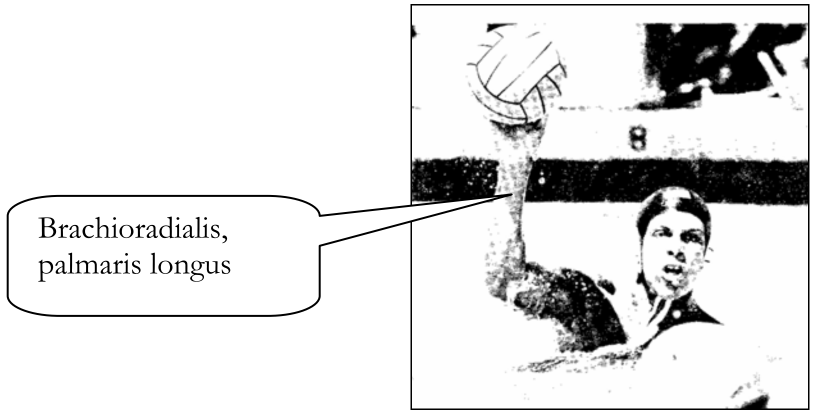


Scott Barbour, Allsport



U.S. Water Polo Hall of Fame

Matt Brown
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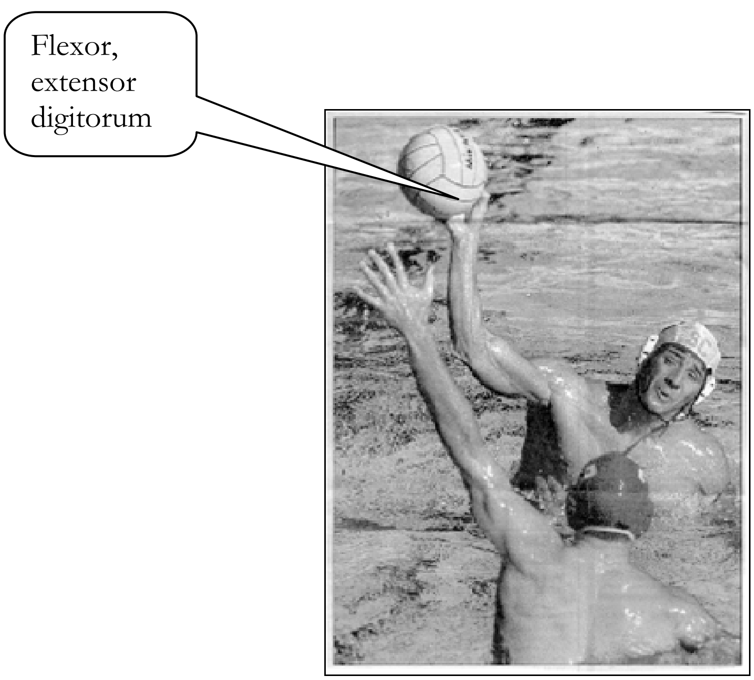

NCAA Sports

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The biomechanics and kinematics of successful and non-injurious arm movement in the throwing motion have been studied and analyzed with the following recommendations: (Davis & Blanksby, Elliot & Armour, Falcone, Feltner and Nelson, Whiting, et.al.)

- Regarding the angle bend at the **elbow**, during the throwing motion the initial starting point, after a circular path backward, is between 89-155º, with the optimal between 90-120º.
- The release point angle for the **elbow** is between 148º and 158º.
- At the conclusion of the throw, the release point for the **wrist** is between 148º and 180º.
- The follow through angle of the elbow should be 180º.
- The internal rotation and horizontal adduction of the shoulder, as part of the succession of levers, contribute significantly to ball speed at release.
- The eggbeater kick is an essential stabilizing component, as there is no fixed point from which the body can pivot. Typically the extension phase of the legs coincides with the forward movement of the throwing arm.

As itemized above in the sequence of levers which facilitate the transfer of torque from the large muscle groups to the small distal muscle groups, "The movement of the wrist joint should be coordinated with elbow extension if maximum ball velocity is to be achieved."(Elliott & Armour, p.113)

Progressive resistance, plyometric, and isokinetic exercises which can strengthen these muscles should be done before, during, and after the season of competition. These type of exercises, especially working on musculature which is significantly weaker and imbalanced with other muscle groups, are beneficial in rehabilitation and prevention of injuries.

Women in particular can gain considerable major increase in strength (20-40%) as a result of resistance training. And, contrary to the concern over "bigness" this strength gain is not accompanied by large increases in muscle mass as the larger levels of testosterone in males is what contributes to more muscles (Wilmore & Costil, p. 580,82).

Lower body musculature – stabilization via eggbeater (alternating frog) kick

Succession of Levers for One Leg in the Eggbeater Kick: (see chapter 9 “Goalkeeper” also)

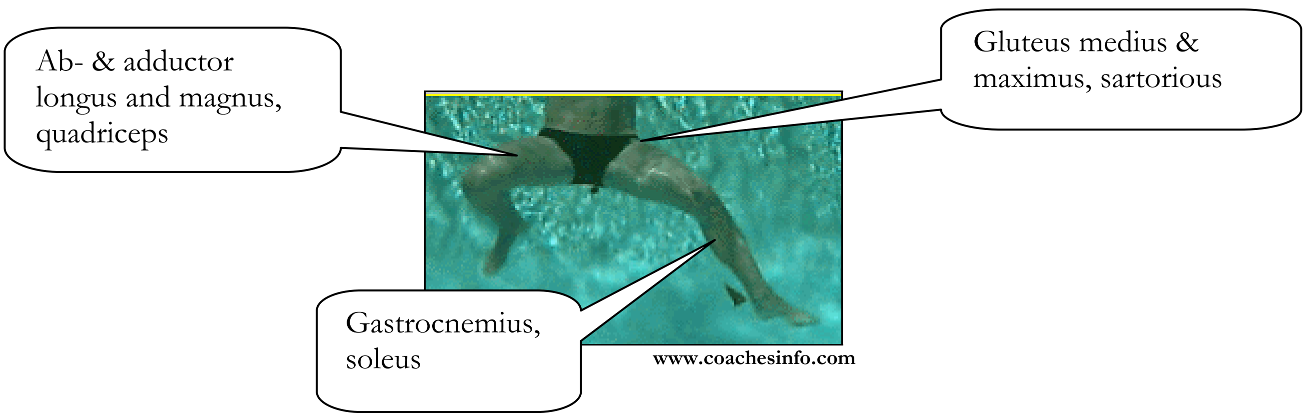
The eggbeater coordination between one leg and another is an important supplement to the pass and shot in water polo. Correct technique with this kick will help provide an adequate base upon which to perform the pass and shot. This optimal sequence is as follows (one leg):

Hip abduction, flexion, & outward rotation ⟹ knee flexion ⟹ ankle dorsiflexion & eversion ⟹ ankle inversion & plantarflexion ⟹ knee extension ⟹ hip adduction, extension & inward rotation.

The timing of the two-leg cycle is such that at full knee extension and plantarflexion for the first leg, the second leg is at maximal knee flexion and ankle dorsiflexion, and vice-versa. (Sanders, p.282).

Major muscle groups used in the eggbeater kick are shown below:

Underwater photos of leg muscles utilized in eggbeater



Eggbeater kick - maximum vertical propulsion, above-water photo

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Nutrition

As with most sports, hydration is of utmost importance. "Fluid balance during exercise is critical for optimal cardiovascular and thermoregulatory function." (Wilmore & Costil, p.178) Fluid loss is not as pronounced in aquatics athletes as in runners, for instance. Most fluid loss for aquatics athletes comes through conduction and convection, therefore there is not the evaporation that takes place on land. For land sport athletes, 80% of heat loss comes through evaporation (Wilmore & Costil, p.311).

The average long distance runner loses .96 to 1.27 L/hour (Juhn, MS & Henehan, p.393). Male basketball players lose 7.97-10.79L/hour (Cox, et.al., p.190) In contrast, the average fluid loss for water polo players has been reported as .51 L/hour.

Aquatics athletes, in general, need .5L/hour in order to be well hydrated during competition. A loss of more than 5% of his or her total body weight will likely result in performance decrements for water polo athletes.

In order to enable efficient muscular contraction, three basic minerals are necessary as part of fluid and/or solid intake: calcium, potassium, and sodium. Calcium can be found in large percentages dairy products and vegetables; potassium is found in fruits, vegetables, and milk products; and sodium can be attained through moderate addition of salt to the diet. (Houtkooper, pp.39-40)

The most essential nutrient necessary for replacement during rigorous exercise is glycogen. Because of the demands on the anaerobic system and glycolic anaerobic system, for muscular efficiency it has been suggested that water polo athletes need 6 grams of carbohydrate intake for 8 servings a day (Farajian, et. al, p.570). Muscle glycogen resynthesis was researched and revealed that it is most rapid when individuals were fed at least 50grams of glucose every two hours after exercise (Wilmore & Costil, p.178)

Injuries

The all-encompassing usage of musculature in water polo makes it very beneficial to the body but at the same time places an extra burden on certain areas. Water polo is the only "true" contact sport in the Aquatics discipline. This aspect, combined with head up swimming, the typical water polo body position, reduces the amount of body roll the athlete can use therefore more forced ab- and adduction movements of the shoulder region.

In addition, the water polo athlete must **throw** from many different body positions without a firm base upon which to balance – i.e. there is no fixed point around which to rotate against. **Good mechanics are essential in order to avoid injury.** In the shoulder joint, abduction and external rotation, combined with maximum forward flexion of the glenohumeral joint places a large amount of force on the rotator cuff area. (Colville & Markman, p.307, Chalmers & Morrison, p.761)

Shoulder pain in water polo can most often be attributed to the following:

- A strength imbalance between the internal rotators and adductors of the shoulder in contrast to the deltoid and rotator cuff muscles.
- Biomechanics that place undue stress on the shoulder as part of the succession of levers (i.e. <90º or >120º at the elbow joint)
- Inadequate warm-up of musculature and tendons prior to high degree of acceleration and kinetic energy on the body used for shooting.
- Combinations of head up swimming and passing/shooting done in excess prior to the supporting musculature being strong enough to support these activities over a long term.

Even good throwers are susceptible to injury due to the transfer of torque through the succession of levers.

At a minimum, water polo players should work to establish a remedial program to rebalance the rotator cuff with exercises that work on the abductors and external rotators in order to equalize the musculature strength in this area. (McMaster, et. al., p.75)

The elbow area is another common injurious site for water polo players. Pain in correlated with the overhead throwing motion, during which stress can occur in the ulna collateral ligament complex (Colville & Markman, p.309). Once again, the lever angle at the elbow joint, if >150º, is a contributor to increased amounts of stress on the ligaments and tendons in this region. Goalies in particular can experience hyperextension injuries at the elbow joint, largely the result of improper absorption of contact with the ball.

In the hand and wrist region, commonly encountered injuries include lacerations, dislocations and fractures of the bones and joints (Richardson, p.370). There is a lot of hand contact with the ball and other players, and the strength and flexibility of these muscles and tendons is important in order to be prepared for this contact. (Colville & Markman, p. 310) Goalkeepers in particular are susceptible to trauma in this ulna collateral ligament region – particularly when coming in contact with the post of the goal.

The eggbeater kick contributes to possible lower body injury – specifically at the knee and hip joints. The pattern of the legs in eggbeater with abduction and internal rotation at both of these joints places stress on the medial collateral ligament and can become inflamed (Brooks, p.318). Due to the turning and twisting motions of the torso, the spine and extremities have been identified as common regions for injury (Chalmers & Morrison, p.761). Again, strengthening and flexibility exercises for both of these regions, particularly with goalies and center players are beneficial preventative steps.

Finally, most water polo players rarely take preventative measures for the mouth area. Studies have shown that a mouthguard would be advisable prevention for contact to this region. (Brooks, 316)

At this point we would note that specific stretching exercises are included in Appendix #3 at the end of the book, and specific strengthening exercises are in Appendix#4.

Gender Differences

The rapid advance and proliferation of girls and women's water polo has stimulated research regarding female development in the sport. Recent research has pointed towards the following comparisons between genders:

- There is **no** significant difference in the beginning and duration of the menstrual cycle between female water polo and non-water polo players. (Sambanis, et.al., p.401)
- Women have lower sweat rates than men for the same heat stress – with no effect on women's ability to tolerate heat (Wilmore & Costil, p.597)
- Female water polo players have more shoulder injuries, generally, than males. (Sallis, et. al., p.421), (Brooks, p. 318)
- There have been gender differences for the elbow and wrist angles during the overarm throw, with women not able to get quite the range of motion for the wrist (Elliott & Armour, p.110). It is speculated that this disadvantage was due to the lesser hand to ball size ratio. And, it has been found that the angle at the elbow joint is a critical variable for females, with the necessity of approaching 100º so that there is less strain placed on the shoulder rotator muscles.
- The female athlete triad which includes disordered eating, secondary amenorrhea, and bone mineral disorders is more distinct among women athletes in general.(Wilmore & Costil, p.596)

Females adherence to efficient biomechanical leverage in passing and shooting motions is therefore maximized in order to prevent the possibility of injury mentioned above.

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