# Flip or Swim?
## An Analysis of How Elite Level Women's Gymnastics and Swimming Impact Health and Fitness

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05.09.12

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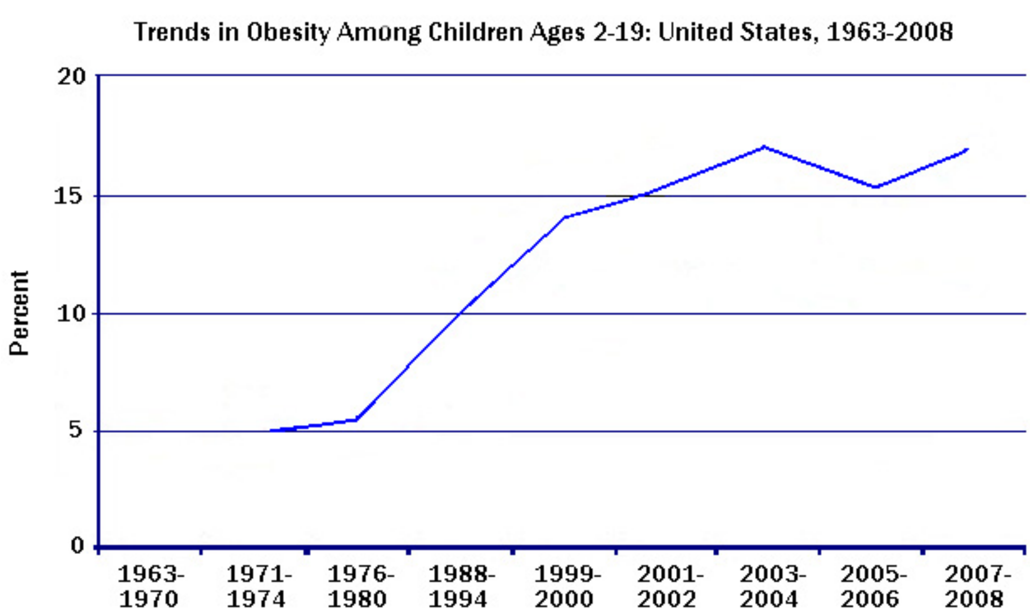
**Introduction**

With today's busy, fast paced world, many find living a healthy lifestyle to be a challenge. We go to school, work more than one job, pay bills, and take care of our grandparents and our children. There is not enough time in the day to cook a healthy meal or go for a run. There is hardly enough money to buy organic food, or hire a personal trainer. Children today are often not allowed to play outside all day because the streets are considered too dangerous. Even if they could go outside, many would prefer to sit home and play the newest videogame or chat with friends online. With lifestyles like this, it is no wonder that organizations such as the American Heart Association are reporting that our children are growing fatter every year (American Heart Association, 2011, p.1). It is alarming to see how many more obese children there were in 2008 compared to 1970 as "Figure 1" indicates.

**Figure 1**




(Adapted from NHANES/CDC, American Heart Association, 2011, p.2)

As the chart demonstrates, in the early 1970s, only five percent of the children in the United States were obese. Throughout the years, those numbers increased through 2008, when they reached approximately seventeen percent. This chart doesn't even include those children that are overweight, which makes up an even greater percentage. It only illustrates the percent of children that are over the ninety-fifth percentile on the age, height, and weight chart provided by the CDC (included and discussed further on page twenty-one).

It is generally understood that regular exercise is important for overall well being, to avoid chronic diseases, and to remain independent for as long as possible. More specifically, it is important to exercise to avoid obesity, which has been linked to coronary artery disease and Type Two Diabetes. Today, one in three children are either overweight or obese. It has also been estimated that obese children are 70-80 percent more likely to remain obese throughout the rest of their lives (American Heart Association, 2011, p.1). Therefore, it is important to stress the necessity of exercise early on in childhood.

One of the easiest ways to get children, or young girls in particular, to be more active is to sign them up for a sport. Many sources agree that participation in sports will provide health and skill benefits including cardiovascular health, weight management, bone health, and power. However, we might ask ourselves, "Which sport offers the greatest benefits?" If the general population was asked to give an example of a healthy sport, swimming would most likely be one of the top choices. Just by watching the Olympics, we can see that swimmers have a strong build with broad shoulders and toned limbs. It is often stressed as a great sport for heart health and for individuals who have joint pain or injuries. On the other hand, if the same group were asked to give an example of a sport that is unhealthy to practice, many might suggest gymnastics. This is not surprising when we consider that when watching the Olympics, we often see teenage girls with their ankles taped and learn about the long list of injuries they have suffered. Nevertheless, when preschool or even pre-teen girls choose a sport to practice, they probably do not worry about whether it will be healthy or not. They want to do something fun and exciting. Gymnastics can be a very appealing sport for these girls, because of all the tricks they expect to learn. Parents in contrast may be wary of allowing their child to begin a sport with so many assumed dangers and may rather encourage their child to take swimming classes.

Many studies have been done on the effects of elite level swimming and gymnastics, but most have not compared them side-by-side. As I will demonstrate, it is beneficial to study them together to distinguish which sport at the elite level will develop a child's fitness better, including curbing obesity and its corollary problems, and which is more detrimental to the body. This essay explores the meaning of fitness and determines which sport matches that definition better. Although these two sports are very different, competitive participation in one of these actually does develop the level of fitness of children of all ages better than the other. After an examination of each sport, it will be evident that contrary to popular belief, gymnastics actually develops fitness more thoroughly and extensively than swimming does.

## What is Fitness?

Before comparing swimming and gymnastics, it is necessary to fully understand the term fitness. This is a word that is used in every-day life, in conversations at the gym, magazines, health ads, and on infomercials. Generally, people have an idea of what a "fit" individual may look like or what they are expected to do. When we hear the term "fit" we may imagine a muscular individual who eats a balanced diet and exercises daily. Though this may be a general image of it, there is a lot more to fitness than just going to the gym. A 1996 U.S. Department of Health & Human Services report defines physical fitness as "the ability to carry out daily tasks with vigor and alertness, without undue fatigue, and with ample energy to enjoy leisure-time pursuits and to meet unforeseen emergencies" (U.S. Department of Health and Human Services, 1996). It is generally agreed that fitness is multidimensional and can be split into categories. The two widely accepted categories are health related and skill related. The five health-related components of fitness are cardiovascular fitness, muscular strength, muscular endurance, flexibility, and body composition. These are important indicators of future injury or chronic disease, in particular cardiovascular disease. It is important to incorporate cardiovascular exercise, muscular endurance exercise, strength exercises, and even flexibility into one's fitness plan in order to maintain good health (U.S. Department of Health and Human Services, 1996).

The six skill-related components of fitness are agility, balance, coordination, speed, power, and reaction time. These relate more to performance and what separates the average athletes from superior ones. However, this does not only apply to athletes. All of these factors are important to improve quality of life (U.S. Department of Health and Human Services, 1996). For example, reaction time is very important for safety when driving a car. One must have a quick reaction if a pedestrian or another car were to come into their car's path to avoid an accident. Balance is needed simply when walking or climbing stairs.

Two other physiological aspects of fitness are discussed in the book Physical

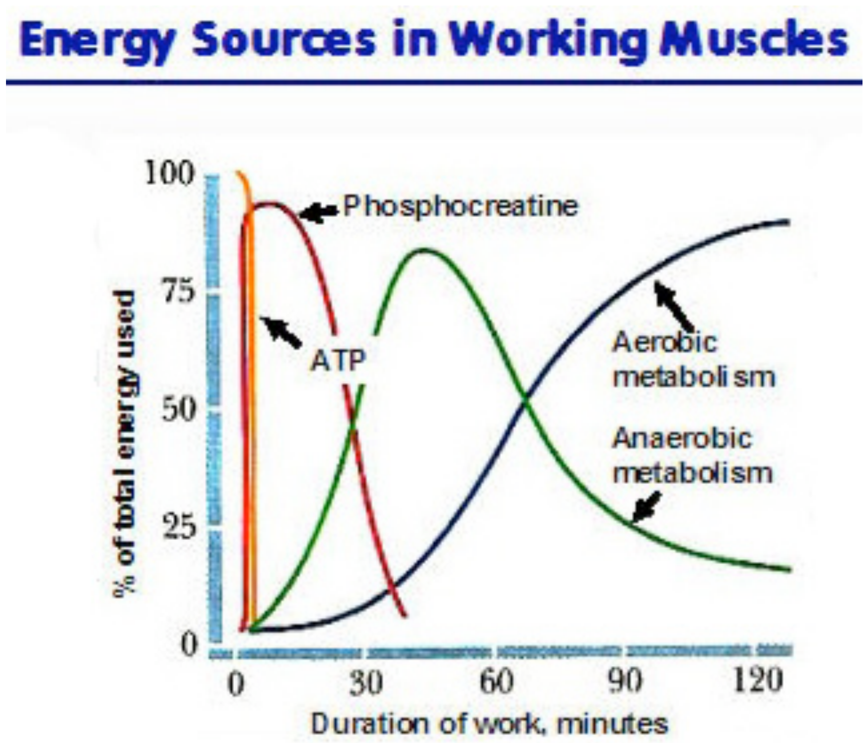
Activity and Health. These include one's metabolic state and their bone integrity (Bouchard, Blair & Haskell, 2007). These characteristics of the body are affected by physical fitness that can be measured and used to predict one's health status. Metabolic fitness relates to the state of one's metabolic system or variables that can predict diabetes and cardiovascular disease such as blood sugar levels, and blood lipid levels. These factors can be improved with exercise. Bone integrity relates to one's bone mineral density, which can be improved with exercise as well. Each of these characteristics can be affected differently by the sport one participates in. Each sport has unique demands and, therefore, will develop the characteristics to a different extent. The first category of fitness I will examine are the health related components.

**Health Related Components:**

*1. Cardiovascular Fitness*

The first component under the health related category is cardiovascular fitness. This is the ability of the body to withstand aerobic activity engaging the large muscle groups for prolong periods of time. Our bodies use two forms of metabolism to generate ATP or energy for our bodies to use: "anaerobic" (short-term) and "aerobic" (long-term). Anaerobic metabolism is the main source of energy for short periods of exercise, while aerobic metabolism is the main source of energy when working for extended periods of time. Anaerobic metabolism is used for power or quick bursts of high intensity such as jumps or sprints and all together doesn't last more than about ninety seconds. At this point aerobic metabolism will have to take over as "Figure 2" illustrates. The green line shows that our bodies use mostly anaerobic metabolism when we work our muscles under one minute. At about a minute or so, aerobic metabolism, or the blue line in the chart, starts to slowly take over until it becomes the main source of energy (MedBio, 2009).

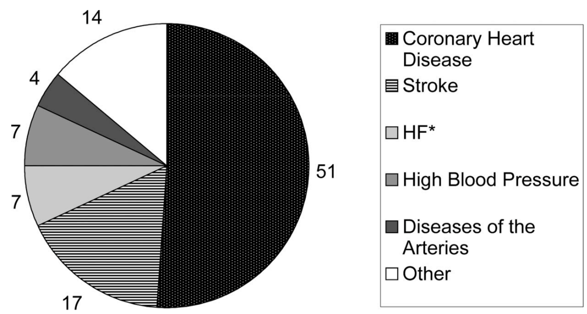
**Figure 2**




(Adapted from MedBio, 2009)

Cardiovascular fitness is targeted once we tap into the aerobic metabolism. It engages the heart, lungs, and vascular system and is often recommended to help prevent coronary artery disease. The National Vital Statistics Report states that heart disease is the leading cause of mortality in the United States (Kochanek, Kung, Miniño, Murphy, & Xu, 2011, p.4). The most common condition under the general term “heart disease” is coronary heart disease, as demonstrated in “Figure 3” (Center for Disease Control and Prevention, 2009).

**Figure 3**




Coronary heart disease is the narrowing of one's arteries caused by a plaque buildup, or cholesterol deposits stuck on the artery walls. This is known as atherosclerosis. The more plaque there is, the more narrow the passageway for the blood to flow. The heart in turn does not receive enough blood, which can cause angina or chest pain. The lack of blood and nutrients getting to the heart can cause the muscle in the heart to weaken, which can cause heart failure or arrhythmias, which is an irregular heartbeat. Also, the plaque buildup can either block an artery completely, or break off into a cluster that blocks the artery completely, which can lead to a heart attack (Center for Disease Control and Prevention, 2009).

Exercise can help to minimize the risk of coronary heart disease because it can lower cholesterol levels and lower one's blood pressure. Exercise strengthens the muscles of the heart and brings more blood to the heart too. The blood that is normally lying stagnant in the body is pushed up through the veins to reach the heart. Therefore, there is a greater volume of blood that the heart must pump, which causes it to stretch and recoil with more force. This is called the Frank Starling Mechanism. (Katch, Katch, & McArdle, 2010). The American College of Sports Medicine (ACSM) requires individuals to exercise at the minimum of walking briskly for thirty minutes a day, 5-7 days a week in order to obtain these benefits. (American College of Sports Medicine, 2010).

One way to measure an individual's cardiovascular fitness is to measure their $VO_{2\max}$ or maximal oxygen consumption. This is the point at which the body is at maximal intensity exercise and consuming as much oxygen as it possibly can. The higher the value, the more efficient the body is at taking in oxygen and distributing it around the body to use for energy metabolism. More specifically, "it provides a quantitive measure of a person's capacity for aerobic ATP resynthesis." It depends on factors such as pulmonary ventilation, hemoglobin concentration, blood volume, cardiac output, peripheral blood flow, and aerobic metabolism (Katch, Katch, & McArdle, 2010, p.166-167).

Swimming is often said to be good for the heart since it requires cardiovascular endurance. In a study done by Vadzyuk, S. N., Il'nitskii, V. I., and Il'nitskaya, U. V., it was shown that aerobic sports, such as swimming, actually make the volume of the left ventricle of the heart larger (Il'nitskaya, Il'nitskii, & Vadzyuk, 2003). The left ventricle of the heart is the chamber that pushes the blood throughout the body. This enlarged ventricle can in turn generate more force and expel more blood per beat due to the Frank Starling Mechanism. It therefore has to beat a fewer amount of times per minute in order to deliver the same amount of blood and nutrients to the rest of the body. The extent of change increases with age, duration of training, and the level of training. From this we can conclude that the longer one pursues endurance training, the more efficient one's heart becomes (Il'nitskaya, Il'nitskii, & Vadzyuk, 2003). This is also exemplified in their high $VO_{2\max}$ levels. Female competitive swimmers between the ages of ten and twenty-five have a $VO_{2\max}$ of approximately 40 to 60 mL per kilogram per minute (Costill, Kenny, & Wilmore, 2008, p.241). Average women at that age have about 31 to 38.9. Anything above 49 is considered excellent (Katch, Katch, & McArdle, 2010, p169).

When trying to think of exercises that are good for the heart, gymnastics is not usually the first sport that comes to mind. This is because gymnastics does not normally focus on cardiovascular endurance training since all of the events require only short bursts of high intensity body movements. Female gymnasts have a healthy $VO_{2\max}$, but only slightly above average. Before puberty, at about age twelve, it is actually quite high at 53± 6.3mL/kg/min. However, as they age it drops to 47.2 ±6.7 mL/kg/min at age 25. That is because they use mostly short-term energy sources for their quick routines that do not last more than ninety seconds. As previously mentioned, this is not long enough to tap into aerobic metabolism as their main energy source. This isn't to say they don't develop cardiovascular endurance at all. They do demonstrate a high metabolic threshold during tests, which means their lactate levels are low at the completion of maximal exercise. High lactate levels are an indicator of fatigue, suggesting that the resistance training gymnasts do enhances fatigue tolerance (Gateva, Holvoet, Jemni, Salmela, & Sanda p.4-6).

*2. Muscular Strength*

The next health component of fitness is muscular strength. This refers to the "ability of the muscle to exert force" (American College of Sports Medicine, 2010). It is demonstrated by exerting one's maximum force over a short period of time. Exercising muscular strength has been said to improve bone mass, which can aid in the prevention of osteoporosis, to improve glucose tolerance, which can aid in the prevention of Type 2 Diabetes, and to improve musculotendinous integrity, which can prevent injury including low-back pain. It also plays a role in increasing levels of fat free mass and one's resting metabolic rate, which can aid in weight management. Lastly, it makes every-day activities easier to carry out, which can lengthen the duration of an individual's independence This is such an important category because at moderate intensities of resistance training, the heart rate is increased. This means the musculoskeletal system is engaged as well as the cardiovascular system (American College of Sports Medicine, 2010).

There are many types of muscular strength, however, and the type of strength one develops is specific to the type of strength one trains for. The two most general types of muscular strength are static and dynamic strength. In static, or isometric strength, the muscle contracts, but stays the same length. For example, if one were to try to lift a table up off the floor that was too heavy to lift, the muscles would contract, but there would be no range of motion. In dynamic strength, the muscle changes length as it moves the body or some external load such as a dumbbell. Dynamic strength normally has two phases of contraction: concentric and eccentric. Concentric contraction is when the muscle shortens to usually lift a force against gravity. An eccentric contraction is when the muscle lengthens to usually lower a force with gravity (Katch, Katch, & McArdle, 2010).

There are also two types of dynamic strength: isotonic and isokinetic. Isotonic literally means, "same tension," though this is somewhat a misconception. In this type of exercise, the participant moves a set force, which does not change, such as a ten-pound dumbbell. However, the force that the muscle uses is not the same throughout the entire range of motion. Isokinetic literally means, "same speed." In this type of exercise, special equipment is needed to provide a resistance that matches the force applied to prevent the participant from changing speed throughout the exercise. In other words, the harder one pushes, the more force will be applied back to make the exercise more difficult. Whichever type of strength one trains, is the type of strength that one will exhibit when demonstrating a strength test. There is very little carry over from one type of strength to another (Katch, Katch, & McArdle, 2010).

It would only be reasonable to assume that swimmers build muscle through the practice of their sport. The latisimus dorsi or the muscle that runs along the sides of the torso are infamously named, "the swimmer's muscle," which would make one assume that swimming in fact does promote muscle growth (Generic Look, 2011). However, in a study done by Demura, Aoki, Yamamoto, and Yamaji, the strength of muscles was tested between swimmers and non-swimmers. The swimmers trained five days a week for at least ten years and the non-swimmers did not actively exercise for three years. Their nonisokinetic, isometric, and isokinetic strengths were tested. The results showed that swimmers only showed significant superior strength in the isokinetic tests. This is because water provides a natural opposing force, similar to isokinetic resistance. This type of strength is very specific to moving in water and is not often applied in every-day activities. Therefore, the carry over into daily living may not be great. (Aoki, Demura, Yamaji, & Yamamoto, 2010).

Gymnasts need a lot of muscular strength to complete any skill. Even holding one's body weight in a handstand requires strength throughout the whole body, especially the arms and shoulders. Squeezing the legs together, which is important in the aesthetics of gymnastics requires strength of the adductor muscles in the legs. Gymnastics in particular works on many isometric contractions. A gymnast must hold challenging poses to show the judges that she has strength, balance, and poise. Isometric contractions are not very practical in day-to-day life because we do not often sustain a contraction at that one specific joint angle. However, it is associated with good posture, joint stabilization, and balance (Borms, Caine & Sands, 2003). A typical training session for a gymnast includes muscular strength exercises. Gymnasts must do strength training to make sure they can put their body through different positions safely without injury. In an interview, Olympic gymnast Alicia Sacramone explained that she has practice every day from 9:00am-12:00pm and then again from 4:30pm to 8:30pm. She also does an hour every day of gymnastics specific strength training. The only way she was able to become an internationally known successful gymnast was to train and continue to build her strength. This is how gymnastics works on the development of muscular strength (Sacramone, 2008).

*3. Muscular Endurance*

Muscular endurance is "a muscle's ability to work continuously against a resistance over a long period of time" (Lunardoni, 2011). This kind of exercise improves the fitness of the muscle fibers that use oxygen when making energy so that they can endure a contraction for as long as possible. They are able to resist fatigue the longest. For this reason, one gains muscular endurance by increasing the amount of time the muscle is contracting against a force, not by increasing the resistance of the force (Lunardoni, 2011). This is important to work on for posture, withstanding physical activity throughout the day, and for the prevention of injuries since muscles are important in the stability of joints. Ligaments hold two bones in place at the joints, but muscles reinforce this positioning and exert a pull on the bones. If one's muscles are subject to fatigue easily, the muscles cannot perform their intended role and the joint is left unstable and can more easily be injured. Also, the muscles need to be well coordinated. There should be a proper balance among the agonist and antagonist muscles. If one exerts a stronger force on one than the other, this can result in misplacement of the bones or improper function for stability in general.

Swimmers must swim for extended amounts of time. Practices require the athlete to swim for hours in one session. It requires great muscular endurance to pull and kick against the natural resistance of the water for so long. Even during a competition, individuals often have to swim many yards per event and even sometimes, many events in a row. The upper body muscles used during the race are subject to fatigue. They must have great endurance to last throughout the whole race. This is why swimmers develop their muscular endurance. The lower body however, will not fatigue as quickly because it has larger muscle groups. Therefore, swimming may not be enough to improve endurance of the lower body. The only other problem arising here is that the movement is so specific to swimming four different strokes, it may have limited carryover to daily living (Your Health Explosion, n.d.).

Gymnasts also must train long hours at the gym to work on muscular endurance. Gymnastics routines that require thirty seconds to ninety seconds of energy such as the bars, balance beam and floor exercise respectively all require oxidative energy systems to sustain muscular contraction throughout the routine. The uneven bars probably require the most endurance because throughout the whole routine, the whole body must contract to remain stable and to reach and hold all of the positions on the bar. The muscles of the shoulder, wrists, and stomach may fatigue by the end of the intense routine. (Borms, Caine, & Sands, 2003).

*4. Flexibility*

"Flexibility is the ability to move a joint through its complete range of motion" (American College of Sports Medicine, 2010). It is important to have to improve performance in sports and to prevent injury. Perhaps more importantly, it is also necessary to have flexibility in order to carry out daily tasks such as bending down to tie one's shoe, or bringing one's arm behind them to put on their jacket. The longer one maintains flexibility, the longer one can remain independent. However, the only way to maintain flexibility is to keep moving the joints through the largest range of motion one has. Just like exercise, flexibility is also joint specific. For example, stretching one's hamstring muscle will not improve shoulder flexibility. One must stretch the shoulder itself to improve range of motion in the shoulder (American College of Sports Medicine, 2010).

There are also many types of flexibility. Static flexibility relates to range of motion without using speed. This includes slowly reaching down with straight legs and seeing if one can touch the floor with one's hands. Ballistic stretching is when one tries to use a bouncing motion to improve range of motion. This would occur if someone leans forward and once they are near to the floor they make short jerking movements trying to use momentum to touch the floor. Dynamic stretching is similar in that it is not simply holding the stretch, but it goes through a larger movement such as straight leg kicks. The type of dynamic stretch done is usually sport specific. These are all examples of active range of motion because the individual has to use their own strength to reach the full motion. Another type of flexibility is passive flexibility, which is the range of motion one can reach with the help of an external load. One example is if someone lays on their back and a partner lifts one of the subject's legs up and pushes it as far as it can go. Another example is if the subject attaches a strap to their foot and they pull the strap and lift their leg themselves (Alter, 1996).

It is often said that being too mobile can also be dangerous because the joints are unstable and prone to injury. However, this is usually due to heredity or a chronic injury. Exercising the muscles around the hyper mobile joint will promote extra stability. The muscles will be able to hold the joint in place if they are conditioned (Alter, 1996).

Swimmers need great shoulder mobility in order to produce the most powerful stroke. However, if the shoulder is stretched too much, the structures responsible for maintaining shoulder stability can be damaged. In general, though, flexibility training is not generally stressed much in the sport of swimming. In fact, in a study done by Anna Jansson, Tonu Saartok, Suzanne Werner, and Per Renstrom, nine to twelve year old swimmers actually were shown to have less joint laxity than the control group. They were put through tests for joint laxity for the thumb, the fifth finger, the elbow, the knee, and the trunk. They also were tested on internal and external rotation of the shoulder. In all the tests, the swimmers had either equal or less laxity and range of motion than the reference group. Similar studies have obtained results that agree with these findings. However, other studies often show that shoulder external rotation is actually greater in swimmers. The differences may be due to the method of measurement, so we cannot rely totally on these results. However, it is hypothesized that the muscle build around the joint may actually limit the range of motion in the joint (Jansson, Renstrom, Saartok, & Werner, 2005).

Gymnastics puts a great emphasis on flexibility of all the joints. As soon as they begin the sport, young girls are put into the split position and a bridge position and told to keep stretching with no limit to the range of motion. Flexibility is required in gymnastics to first promote a greater aesthetic quality to the movement. Spectators are more astounded by the skills when they see long lines, straight legs, and pointed toes. We want to see a full split when they leap into the air. Aside from aesthetics, flexibility is necessary to avoid injury and actually perform the skills in gymnastics. For example, in “Figure 4,” gymnast Daria Zgoba from Ukraine is doing a side aerial (cartwheel with no hands) on the balance beam. She must swing her top leg up and around as fast as possible in order to have enough time to complete the flip and land safely on the beam. This is only possible if the gymnast can reach a full split in the air in milliseconds. It is amazing to see that her foot that kicked off the balance beam is barely in the air while the other one is already past vertical, on the way down to the beam (Range of Motion! 2009).

**Figure 4**

(Range of Motion! 2009).

Even though the hip joint is probably the most targeted joint, gymnasts must stretch every joint. The wrist must be flexible when landing on one’s hands. Shoulders must be flexible so that when the gymnast flips backwards from her feet to her hands or forwards from her hands to her feet, she has enough range of motion to complete the move. Ankles must also be flexible to ensure the sharpest toe point so that points will not be deducted from their score.

A study done by Gannon and Bird demonstrated just how flexible national and international level gymnasts could be. Their range of motion was measured in degrees and compared to the values of a control group. “Table 1” represents the values in degrees for gymnasts and the control group for the shoulder and hip joint.

**Table 1**

| | | **Left** | | **Right** | |
|---|---|---|---|---|---|
| | **Group** | **Active** | **Passive** | **Active** | **Passive** |
| **Shoulder Flexion** | *Control* | 176.8 + 12.3 | 183.1 + 13.1 | 182.5 + 13.1 | 189.4 + 13.0 |
| | *Gymnast* | 187.3 + 8.6 | 197.8 + 10.8 | 193.6 + 8.9 | 201.1 + 10.7 |
| **Shoulder Extension** | *Control* | 48.2 ± 13.9 | 60.5 ± 13.8 | 56.3 ± 24.2 | 63.3 ± 14.0 |
| | *Gymnast* | 54.0 ± 15.5 | 64.1 ± 19.0 | 53.3 ± 13.6 | 63.8 ± 17.8 |
| **Hip Flexion** | *Control* | 76.2 ± 8.6 | 89.2 ± 12.5 | 81.0 ± 8.6 | 92.3 ± 11.4 |
| | *Gymnast* | 100.4 ± 10.6 | 131.4 ± 18.6 | 103.8 ± 11.8 | 134.2 ± 21.8 |
| **Hip Extension** | *Control* | 39.1 ± 10.3 | 46.8 ± 12.2 | 39.9 ± 12.2 | 47.2 ± 10.4 |
| | *Gymnast* | 48.3 ± 12.0 | 59.7 ± 14.0 | 47.4 ± 12.6 | 57.8 ± 16.2 |
| **Hip Abduction** | *Control* | 70.1 ± 14.1 | 84.1 ± 17.3 | 67.1 ± 15.0 | 80.8 ± 19.7 |
| | *Gymnast* | 99.2 ± 15.6 | 130.1 ± 19.5 | 92.8 ± 21.1 | 127.3 ± 23.9 |

(Adapted from Bird & Gannon, 1999)

It is clear to see that the gymnasts were significantly more flexible in the hip and shoulder joints for both passive and active range of motion with the exception of active right shoulder extension for a reason that is not yet clear. Gymnasts also had approximately 48.8 degrees more range in movement at the lumbar spine from hyper-extension to full flexion. They also had about 8.4 degrees more range of motion in the left ankle and 9.8 degrees more in the right from dorsi flexion to plantar flexion. It is evident, that gymnasts are significantly more flexible than the general population. However, sometimes hyperlaxity or too much range of motion can actually cause injury. The large difference between the active and passive range of motion is most likely due to a lack in strength of the muscle at that range of motion. Therefore, the joint is less stable and more prone to injury. Gymnasts must remember to strengthen around the joint, so that their extra mobility will not cause an injury (Bird, & Gannon, 1999).

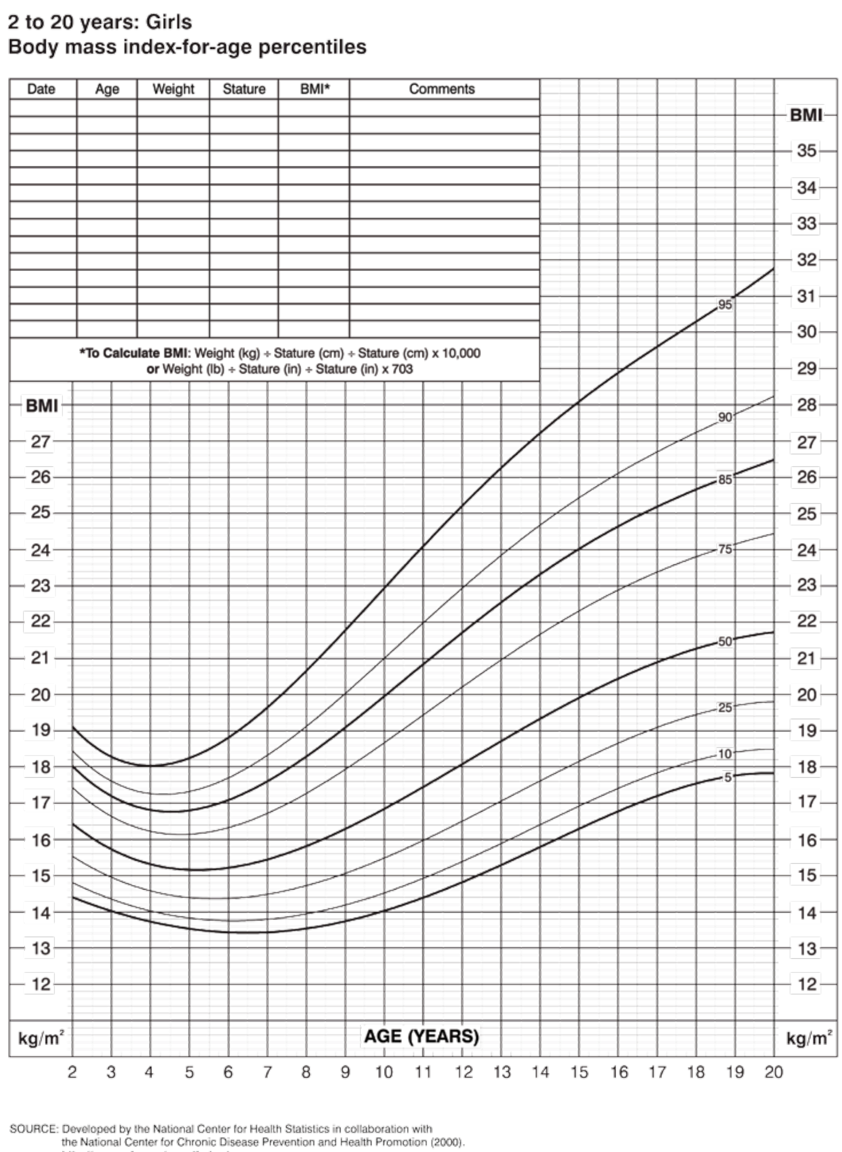
*5. Body Composition*

Body Composition is a measure of what the body is made up of. There is a fat component and a fat free component. The fat component includes three different types of fat. They include, intramuscular (within the muscle), visceral "(torso)" and subcutaneous "(under the skin)" fat (Kravitz, 2010). Intramuscular fat is located within the muscles and is important for fuel for the body during exercise. Subcutaneous fat is the one just below the skin and over the muscle that everyone can see and that many try to lose. Visceral fat is the most dangerous kind because it is found within the body around the organs. This type of fat has certain necessary roles such as providing the blood with free fatty acids that can be used for certain metabolic processes, and secrete chemical messengers that control actions in the body. These messengers are called cytokines and regulate a number of different things, including inflammation response. However, when there are a high level of these cytokines, they can damage the arterial walls. This is the first step to the development of atherosclerosis, which is a type of coronary artery disease. Even though fat cells also produce adiponectin, a protein that promotes insulin sensitivity and reduces chance of atherosclerosis, when a person gains too much visceral fat, adiponectin levels drop. Therefore, the body has a harder time responding to insulin, which can promote Type II diabetes and has a greater chance of developing atherosclerosis (Kravitz, 2010).

It is important to estimate fat component in the body to prevent problems such as these. There are a few different methods of predicting fat levels. These include BMI, skin fold testing, bioelectrical impedance, DEXA, Air Displacement Plethysmography, and Anthropometry. Each of these possesses their own unique positive and negative attributes. DEXA and Air Displacement Plethysmography are the two most accurate measurements, however, the equipment is very expensive and not many facilities have access to them. Bioelectrical impedance analysis requires either a small hand held device or a scale and is fairy accurate depending on the quality of the company that makes it. An alternating electrical current runs through the body and depending on how fast it traveled, it can predict one's body fat percentage. The more fat one has, the more the current is impeded or slows down. If the reading for a female is over 28% body fat, she is said to have too much fat. If a man is over 25% body fat, he is said to have too much fat compared to muscle. However, the reading can be affected by one's hydration levels and can be different if measured by the hand held device versus the scale one stands on. Another method is use of the skin fold caliper to test skin fold thickness. The person performing the test must pinch the subject's subcutaneous fat with a device and measure it to the nearest millimeter. Then they apply it to a certain formula, which gives them the fat percentage. This method is fairly accurate as long as the tester follows the correct procedure and has had a lot of practice. Sometimes the tester may pinch in the wrong area or may include some muscle in the pinch, which makes the value found invalid (Katch, Katch, & McArdle, 2010).

The most common method used to predict fat levels is BMI since it as easy formula that compares weight to height. If the ratio is under 18.5, then the individual is said to be underweight. If it is at or over 25, the individual is said to be overweight. If it is at or over 30, the individual is said to be obese. However, BMI is not a great predictor of fat composition. Because muscle is denser than fat, muscular individuals will have a BMI that is over estimated and in the elderly, who have less muscle mass, it will be underestimated (Kravitz, 2010). Children also have a specific graph represented in "Figure 5" that is applied for different ages. If the child is under the fifth percentile, they are considered to be underweight. If the child is in the 95th percentile or higher they are considered obese. Between the 85th and less than the 95th percentile is considered to be in the overweight range (American Heart Association, 2011).

**Figure 5**



Waist circumference measurements and waist to hip ratios are better than BMI at predicting all-cause mortality, diabetes and cardiovascular disease risk since it can predict levels of visceral fat. Waist circumference is just a measurement taken using a tape measure around the trunk at the umbilicus. One should take the measurement at the end of expiration. Waist-to-hip ratio is also a good predictor of chronic disease. It is a comparison of the girth of one's waist at the narrowest point and one's hips at the widest point. The A ratio of .8 or higher is not good for a woman's health. This is because it means that one's waist is as thick as one's hips. As mentioned earlier, the trunk area is the most dangerous area to store fat. Therefore, waist circumference and waist-to-hip ratio is a better predictor of chronic disease than BMI and should be used as a tool to guide the population into fitness and good health (Kravitz, 2010).

All exercise can help promote a healthy balanced body composition if done properly and incorporated into a healthy diet plan. Competitive swimming can promote fat loss because of the aerobic training it entails. One study was done to see just how much an intense swimming program could cause young women to improve their body composition. The study was done on divers and swimmers aged eighteen to twenty-one. The girth measurements and body fat percentages were taken pre-season and after a sixteen week training period which included dry-land resistance, strength, and flexibility exercises for one and a half hours a day, three days a week and in-water training six days a week for nine, two-hour sessions per week. Even though these are two different sports, it was found their body compositions were similar enough to compare together statistically. It was found that body fat percentage was approximately 22-24% for these young women. Throughout the season, it became evident that the levels of fat were decreasing as levels of lean muscle were increasing. "Table 2" is a summary of some of the measurements taken pre and post season. (Petersen, 2006)

**Table 2**

| Measure | Preseason (n = 24) (Mean ± SD) | Late season (n = 24) (Mean ± SD) | P-value |
|---|---|---|---|
| Present age (median [min, max] y) | 19.5 [18.0, 21.9] | | |
| Height (cm) | 170.1 ± 6.7 | | |
| Body mass (kg) | 64.6 ± 6.5 | 63.3 ± 5.4 | 0.065 |
| Body-mass index (kg/m2) | 22.4 ± 2.4 | 21.9 ± 2.1 | 0.0499 |
| Waist circumference (cm) | 70.2 ± 3.7 | 66.9 ± 3.3 | ≤ 0.0001 |
| Hip circumference (cm) | 95.4 ± 5.3 | 91.7 ± 3.9 | ≤ 0.0001 |
| Waist-hip ratio | 0.74 ± 0.03 | 0.74 ± 0.08 | 0.71 |
| Lean mass (kg) | 47.2 ± 2.7 | 47.7 ± 2.4 | 0.028 |
| Fat mass (kg) | 15.3 ± 4.9 | 14.0 ± 4.5 | 0.0002 |
| Percentage body fat (%) | 24.1 ± 5.7 | 22.4 ± 5.6 | < 0.0001 |

(Adapted from Petersen, 2006)

The 2% decrease in body fat percent after the sixteen weeks of training. demonstrates that a vigorous swimming regimen can improve body composition. (Petersen, 2006) However, 22-24% fat does not qualify as an athletic build. According to ACSM guidelines, a body composition of 20-32% body fat is satisfactory for women and levels should not reach less than 10-13%. However, they also mentioned that based on the patients of Cooper Institute, 24% body fat is at approximately the 30$^{th}$ percentile only and is in the "poor range." It also shows that 22% body fat is in the 40$^{th}$ percentile and moves up in status to the fair range (American College of Sports Medicine, 2010). This body composition is not as athletic as one might speculate for a swimmer. However, their girth measurements do put them in at a healthy category. For waist circumference, 70-89cm is in the low risk category for chronic disease. Fewer than 70cm is considered very low risk though (American College of Sports Medicine, 2010). These swimmers started out with an average of 70.2 and reached 66.9 by the end of the season, which is a significant improvement. The swimmers also had a healthy waist to hip ratio of 0.74, which is under the limit of 0.8 though not much lower (Ideal Weight Charts, n.d.).

The study hypothesized that swimmers have a slightly higher body fat percentage because the fat promotes buoyancy, which can reduce water resistance and can help the swimmers to save energy in the water. However, if the body fat were to reach above 22%, the added surface area may counteract the benefit of buoyancy. Therefore, they need a proportioned balance of lean muscle mass and fat mass.

Gymnastics is an aesthetic sport that requires great strength and power, but also beauty and grace as one soars through the air. The best gymnasts are known to be very small and light or at least have a very low percent of body fat. It is not only more elegant looking to be a thin gymnast, but it is also easier to perform the skills when they do not have extra fat weighing them down. Therefore, gymnasts are pressured to stay thin. Because they start vigorous training at an early age, even as young as three years old, many do not receive the adequate nutrition needed to grow, maintain a proper weight, and reach sexual maturity at an appropriate age. According to a study done by Soric, Misigoj-Durakovic, and Pedisic, prepubescent gymnasts at the national level who have been practicing for at least five years for about twelve hours a week have a significantly lower BMI than control nonathletes. All of the girls were between ages nine and thirteen. The results are expressed in “Table 3”.

**Table 3**

| | Controls | Artistic gymnasts |
|---|---|---|
| Height (cm) | 154.4 ± 8.8 | 139.5 ± 11.7 |
| Weight (kg) | 46.4 ± 10.0 | 32.2 ± 7.5 |
| BMI (kg/m2) | 19.3 ± 2.9 | 16.3 ± 1.1% |
| Body Fat | 24.3 ± 7.5 | 12.4 ± 1.8 |
| Training Volume (min/week) | 180 ± 133 | 1233 ± 263 |

(Adapted from Misigoj-Durakovic, Pedisic, & Soric, 2008).

The artistic gymnasts have a lower BMI and a much lower body fat percentage. This is probably due to the great amount of muscle development needed to be a gymnast. It is easy to see with over twelve hundred minutes, or twenty hours a week of training why these girls have such a low level of body fat. Even though for an eleven year old, a BMI of 16 is at the $25^{th}$ percentile, at twelve percent body fat, the girls are putting themselves at risk of not having enough fat for regular function (Misigoj-Durakovic, Pedisic, & Soric, 2008).

A body fat composition with too little fat can also be unhealthy. Edda Weimann researched gymnasts' Leptin levels, height and weight, body composition, and nutritional intake and found that their Leptin levels were low, their body fat mass was low, and their nutrient and caloric intake was insufficient. It was concluded from the study that Leptin is closely related with the amount of body fat a person has and also with the onset and progression of puberty.  Because it is common for female gymnasts to restrict calorie intake, gymnasts tend to have lower body fat, which causes lower Leptin levels, which appears to be related to slower progression of puberty.  Therefore, elite female gymnasts are at a higher risk for developing the female athlete triad, or late menarche, restricted eating habits, and stress fractures (Weimann 2002, p. 2146-2152).

Therefore, it is important for gymnasts to monitor their nutrition intake and be careful of dieting to the extreme. One sixteen-year-old Chinese Olympic gymnast was monitored before the 2008 summer Olympics. It was found that at 82.34lbs she was unhappy with her weight and tried to diet. Instead of losing weight, she reached 83.51lbs and became depressed. For the next four weeks she had a professional help her lose weight so that she could be 81.66lbs (Haitao, Mei, Peiwen, Shanzhen, Shu, Weiai, & Wenxin, 2009). Unfortunately, the article did not specify how tall the gymnast was, but according to the girls BMI chart, if she was approximately 5 feet tall, she would be under the $5^{th}$ percentile for body fat. It is hard to imagine how someone could be so worried about how heavy they are when they are well below the norms for other girls their age. If a child wanted to be serious about becoming an Olympic gymnast, it would be a priority to make sure she has the proper nutrition and is monitored so that she does not develop a negative self-image or eating disorder.

**Skill Related**

*1. Agility*

Agility is defined as "an effective and quick coupling of braking, changing directions, and accelerating again while maintaining motor control in either a vertical or horizontal direction," (Vescovi, n.d.). Agility is very complex and requires balance, spatial awareness, and visual processing. It is important to develop in order to improve on one's neuromuscular control and motor skill function, to prevent injury, and improve performance in sport. Agility training should begin early on. Even toddlers begin to work on it as they start to run around and learn to coordinate their bodies. Basic skills should be taught, such as basic arm and leg movements, hopping in place, or making them move in a way that requires spatial orientation. Eventually, they master these skills and build upon them particularly with sport specific drills (Vescovi, n.d.). This is obviously helpful as an athlete, but we can incorporate these skills into daily life. We may not realize it, but even walking down the city's crowded streets can sometimes require agility by having to dodge bicycles, cars, and other pedestrians.

Swimming does not require agility in the sense that there are no abrupt stops or changes in direction. Basically, in swimming, one simply swims in a straight line and always starts at the end of the pool and ends at the end of the pool. The one time they may require this type of agility is to get the appropriate timing for doing the flip turn when changing directions. If one is too far from the wall, they won't be able to get enough of a push. If one is too close, they may hit the wall. It requires speed and precision, which are two elements necessary for agility.

Gymnastics requires a lot of agility because one is constantly changing the direction of the body whether on one's feet, on one's hands, or in the air. All of these skills require speed and exact precision or else one will get injured. A release move on the uneven bars requires an incredible amount of spatial awareness and proprioceptive skills to let go of the bar at the precise time so that one can do a summersault and catch the bar again as illustrated in "Figure 6." Even performing different jumps and dance elements on the floor requires agility.

**Figure 6**

(Rogers, 2008)

*2. Balance*

Balance is the ability to maintain equilibrium of the body whether one remains in one place or one is in motion (U.S. Department of Health and Human Services, 1996). Balance is so important to have in order to avoid injury, especially as one ages. Poor balance makes one more susceptible to falls no matter what the age. Unfortunately, as we age, our bodies become less flexible and our bones become weaker resulting in danger of a more serious debilitating injury such as a hip fracture. (Dontas & Yiannakopoulos, 2007)

It is difficult to assess how swimming may influence balance. Swimming may develop the muscles of the trunk particularly of the back. Good endurance of muscles can aid in balance. (Native Remedies, n.d.) However, it does not directly work on balance the way we'd imagine benefitting from on dry land.

Gymnastics requires a lot of positions that require balance. On the balance beam, gymnasts tend to practice many motionless balance poses. Therefore, they may develop static (motionless) balance. However, all of the events including floor exercise, uneven bars, and even the vault require dynamic (in motion) balance. Both types of balance were tested in a study done by Bressel, Yonker, Kras, and Heath and the results found that gymnasts had superior dynamic and static balance as compared to basketball players (Bressel, Heath, Kras, & Yonker, 2007).

*3. Coordination*

Coordination refers to the ability of an individual to use their senses together with their body to perform tasks smoothly and accurately (U.S. Department of Health and Human Services, 1996). It takes coordination to do everything in life, which we may take for granted at times. Buttoning a shirt takes coordination of the fingers. Hopping over a puddle in the street takes coordination of your legs, your posture muscles, and your sense of how far you have to jump. These are things we may have a harder time doing as we age and lose a sense of coordination. That is why it is important to work on it at a young age.

Swimming is a sport that requires a sense of coordination. When learning to swim, one of the most challenging feats to overcome is to coordinate the arm stroke, the leg kicks, and the breath. When young children learn to swim, it is interesting to watch how they can do each skill very well when isolated. For example, they can kick well when their arms are holding a kickboard, and they can stroke well when they are using a flotation device at the legs. However, when they attempt to put it together, children often lose the technique. During the front crawl or freestyle, the child might consistently kick their legs while slowly reaching out their arms in front of them, taking too many kicks per stroke. Other children stop kicking rhythmically and hover their arm in the air when trying to take a breath. It takes a lot of coordination and rhythm to piece the three components together for every stroke. Possibly the most challenging stroke to coordinate is the breaststroke. The technique is constantly being revised and the timing is very precise when trying to gain maximal velocity. Not only is it difficult to do the actual stroke, but swimmers must adjust their technique according to the distance they are swimming. Swimmers have to slow down when they are swimming long distances. The glide of the breaststroke becomes longer and more energy efficient as the distance increases (Ikuta, Miyashita, Nomura, Ogita, Okuno, Sugimoto, Takagi, Wakayoshi, & Wilson, 2001).

Gymnastics requires just as much coordination. Most of the skills in gymnastics requires the muscles of the entire body to coordinate together. One must be able to know when to tighten which muscles especially when learning an advanced skill. Even something as simple as a handstand is highly coordinated. The fingers and wrists have to adjust weight distribution as the rest of the body attempts to stay vertical. A study was done to show that coordination develops as one progresses through the levels of gymnastics. In this study high level gymnasts and intermediate level gymnasts had to track a target with their ankles while maintaining a handstand position. Although the skill is relatively simple and both groups could do it well, the higher-level gymnasts were able to maintain body position and accuracy better. This shows that practicing gymnastics can improve coordination.

*4. Speed*

Speed is simply the ability to perform a movement as quickly as possible (U.S. Department of Health and Human Services, 1996). Having speed is not a necessity to live out a high quality life, but it certainly is appreciated throughout the day such as when one must run to catch the bus. Speed is unfortunately influenced by the amount of fast twitch muscle fibers that one has. These fibers fire at a quick rate, though they fatigue quickly. If an individual has a higher proportion of these fibers as compared to the slow twitch (slow to react, but have greater endurance) they will be naturally quick. Anyone can nonetheless, improve their speed with technique and muscle training, even if not naturally predisposed to be fast. (Katch, Katch, & McArdle, 2010). However, like everything else, speed is sport specific and has little carry over from sport to sport. (American College of Sports Medicine, 2010)

The whole point of swimming competitively is to be the fastest. Therefore, it is generally assumed that swimming develops speed. This is true in the sense that as one practices swimming, the time it takes for them to swim across the pool decreases. This is mostly as a result of better technique and more power. This however would be practical in very few situations unless one is often in or near water as a hobby or profession. Regardless, it is still a useful skill to have in case of emergency.

Gymnastics only presents typical speed during the sprint before the vault or a tumbling pass. The faster the gymnast runs, the more power she will have to complete the skill. However, one may not realize the speed necessary to do a double back flip. Without speed in the flip, the gymnast will not have enough time to rotate. A double back flip take only three quarters of a second to complete if executed properly. Speed is even needed on bars. The added friction of the bar against the hands slows the athlete down. They need to get past that and speed up enough to gain the momentum necessary to swing around the bar (Borms, Caine & Sands, 2003).

*5. Power*

Power relates to explosive force production. It is the measure of the force one can generate at the quickest speed. We may not think of using power much in our every day lives, but it keeps us efficient and swift. It is a result of high neural activity, recruitment and coordination of muscles, and anaerobic (without oxygen) metabolism. (MacLean, n.d.)

Swimming requires a lot of upper body power in order to propel oneself as fast as possible through the water. The most significant factor of predicting how fast a person can swim is their maximum swimming power (Miura Shimonagata, & Taguchi, n.d.). Some power is also needed to spring off the starting block or the pool's wall as far and fast as possible to gain a few millisecond lead. A study was devised to test the anaerobic power of different athletes including swimmers. They each performed the Wingate test for anaerobic power, the squat jump, the countermovement jump, and a drop jump from 0.20m and 0.40m. It was found that the swimmers had a lower fatigue index, or better result in the Wingate test, since swimmers often must swim at full speed for about thirty seconds. However, the results of the different jumps were not as impressive (Bencke, Damsgaard, Jorgensen, Jorgensen, Klausen, & Saekmose, 2002).

Gymnasts were a part of the same study. Their Wingate test results were not as good as the swimmers, since they normally have short bouts of explosive movement in their routines, and do not have to sustain high speeds for more than a few seconds. However, because of this, they had better results in all of the jump tests indicating more power in the quick explosive movements (Bencke, Damsgaard, Jorgensen, Jorgensen, Klausen, & Saekmose, 2002). In gymnastics, most of the skills and components last less than fifteen seconds. A tumbling pass, a vault, or a dismount off the balance beam are all quick moves that require a tremendous amount of force in a short amount of time. These skills all use anaerobic metabolism. Therefore, the performance level of these gymnasts depends on their level of power, which they must train and develop in their weekly training plan (Borms, Caine, & Sands, 2003).

*6. Reaction time*

Reaction refers to the time it takes for the body to respond after a stimulus has been given. (U.S. Department of Health and Human Services, 1996). As mentioned earlier, reaction time is important in daily life such as while driving.

When a race is so close in swimming that the winner only out-swims her opponent by a few milliseconds, the start can make a big impact on the outcome of the race. This is why swimmers often work on reaction time during practice. It is not the most important part of the race, but an improvement in the time it takes for the swimmer to propel off the block after hearing the gun being shot by the official can make the difference between a win and a loss. Therefore, swimming can develop reaction time of an individual. (Tanner, 2001)

Gymnastics has specific cues that the gymnast must react to with swift timing. For example they must be able to grasp the uneven bar after a release move. They have to realign their body after landing a move on the balance beam. They must bend their knees at the precise point in time in order to complete a back tuck If they tuck too early, the flip will be too low. If they tuck too late, they might not rotate. As a result, the body learns to respond to a stimulus at a faster rate when practicing gymnastics (Borms, Caine, & Sands, 2003).

**Physiological**

*1. Metabolic state*

The composition of one's blood can be a good indicator of an individual's health and future disease. Lipid and glucose levels are only two factors that can be looked at to evaluate one's health, but high quantities of either of the two is a common and dangerous issue. High blood lipid levels, such as LDL cholesterol can increase one's risk of different diseases of the heart and arteries. It can contribute to plaque buildup, atherosclerosis, heart attack, or stroke. High glucose levels are an indicator of insulin sensitivity or that the body is no longer processing sugars as efficiently as it should. If it is not controlled, this can develop into Type 2 Diabetes. However, it has been found that exercise can control levels of both. Exercise helps to prevent or slow the progression of Type 2 Diabetes by increasing insulin sensitivity and aiding in glucose metabolism. Studies show that exercise such as Hatha yoga or conventional physical training can decrease fasting blood glucose levels by 29.48% and 27.43% respectively (Brock, Chandler-Laney, Fernandez, Gower, Hunter, & Lara-Castro, 2009).

Gymnastics has been shown to decrease total cholesterol, triglycerides, and LDL cholesterol. Also, it can raise the HDL cholesterol, which is a positive change. Gymnastics may improve these lipid levels by regulating lipid metabolism in the blood and by increasing fat oxidation (Aburjai, Ata, & Mansi, 2008). It was also shown that swimming has the same effect on plasma lipid (Castillo, Mesa, Mingorance, Rodríguez-Cuartero, & Ruiz, 2004). Therefore, both swimming and gymnastics can help control cholesterol and triglyceride levels.

*2. Bone integrity*

Bone integrity refers to the density of the bones. If bone density reaches dangerously low levels, one has a condition known as osteoporosis. The sport that a young girl practices may in the future have an effect on the progression of osteoporosis in later years. In many studies, it has been proven that the more active an individual is, the higher their bone density become. This is because physical activity affects bone metabolism. Specifically, it triggers osteoblast activity, and inhibits osteoclast activity. In other words, there is a stimulation of bone growth instead of bone resorption. It is important to build up bone density at an early age, so that when it does eventually start to degrade after menopause, one has a thick density that won't reach dangerous levels as quickly as sedentary, low-density individuals (Courteix, Lespessailles, Peres, Obert, Germain, & Benhamou, 1998).

In a study done by Courteix, Lespessailles, Obert, Peres, Germain, and Benhamou, the bone mineral density of gymnasts and swimmers was compared. Gymnasts were shown to have statistically higher mean bone mineral density values than the other two groups. The values for their bone density at different areas of the body were between 11% and 33% higher than controls. There was no difference between swimmers and controls. The distal radius (the wrist) has such a high percent probably because gymnast put a lot of impact on the wrists, which is very unusual in regular day-to-day life. This experiment supports the idea that intensive weight bearing loads are a powerful osteogenic stimulus. In particular, it suggests that the anabolic effect is specific to only the part of the skeleton that is under stress. When one is in the pool for so long however, one experiences a decreased "gravitational component." This takes away a lot of the load on the weight bearing bones. This is why there was no difference in the bone mineral density of the swimmers as compared to the control group even though they are training so intensely. In fact, in some experiments done with rats shows that bone loss can even occur when one trains often in water. Overall, the high impact sport of gymnastics helps to stimulate bone growth where as the low to almost no impact sport of swimming does nothing to affect it (Benhamou, Courteix, Germain, Lespessailles, Obert, & Peres, 1998).

**Injuries**

As mentioned previously, parents often sign children up for sports for the physical benefits it provides. However, once the child is enrolled, a fear that always exists for parents are sports injuries. Parents are right for showing some concern. More than 3.5 million girls and boys ages fourteen and under receive medical treatment for sports injuries each year. They account for twenty one percent of all traumatic brain injuries among children in the United States. It absolutely essential to always use the necessary safety equipment and to take proper safety precautions required by the particular sport. These precautions must always be taken, even during practice, which is when sixty two percent of all injuries occur.

It is common to think of an injury as an accident such as a fall or getting hit by an opponent or some equipment. However, it is also important to remember that athletes can get injured simply from overuse. In fact, nearly half of all sports injuries to middle-and high-school students are from overuse, or repeated motions over time. Factors that can add to the risk are immature bones, insufficient rest after an injury, and poor training techniques. It is therefore necessary to rely on only competent coaches with the necessary knowledge and certifications. They should be able to recognize their athletes' limits and also educate their team about what is normal and what is not normal to feel in the body and when to speak up about pain (Safe Kids USA, 2012).

1. *Gymnastics Injuries*

Gymnastics is usually seen as a very dangerous sport. However, gymnastics injuries in children are actually not as common as in other popular sports such as basketball, football, and soccer (Keller, 2009, p.1299-1300). Nonetheless, each year approximately 86,000 gymnastics-related injuries are treated in hospitals, doctors' offices, clinics, and ambulatory surgery centers. Most are not serious and are usually due to overuse and stress. However, like all injuries, if left untreated, they may lead to chronic pain or even bone fractures (Stop Sports Injuries, 2010, p.1,). Children that practice the sport recreationally, see the least amount of injuries. The higher in level the child goes, the more complex the routines are and the more subject they are to injury. Also, twice as many of the injured gymnasts taken into the emergency room are between the ages of twelve to seventeen as compared to children between six and eleven years old.

The most common injuries are of the upper extremities, making up about forty-two percent of the cases (Keller, 2009, p.1299-1300). This is because the upper body is used as a weight-bearing joint in gymnastics, which is unusual for our bodies. Some common upper extremity injuries include elbow dislocation, wrist sprains, and superior labrum, anterior-posterior lesions in the shoulder (Stop Sports Injuries, 2010, p. 1). Second to that are the lower extremities making up thirty-four percent of the cases (Keller, 2009, p.1299-1300). The most common injuries to the lower limbs involve the knee and ankle such as Anterioir Cruciate ligament (ACL) injury or Achilles tendon injury. They usually result from landing and dismount activities (Stop Sports Injuries, 2010, p.2). Thirteen percent of injuries are of the head and neck. Ten percent are of the trunk and one percent is of other sites (Keller, 2009, p.1299-1300).

Of the type of injuries noted, forty-four percent were sprains and strains, while thirty percent were fractures and dislocations. The other remaining percentages were abrasions, contusions, lacerations, and closed head injuries respectively. Also, ninety-seven percent of the gymnasts taken to the emergency room were discharged rather than admitted into the hospital. Of the three percent remaining, ninety percent were due to fractures and dislocations. This shows that most of the injuries caused by gymnastics are not very serious, especially if the child is young and at a low level. Furthermore, the injury rate actually declined by twenty-five percent between the years of 1990 to 2005, implying that safety measures are being applied to a greater extent than before. This means that gymnastics may not be as dangerous as many might believe (Keller, 2009, p.1299-1300).

Like in any sport, injuries are nonetheless inevitable in gymnastics. One particularly common body part that gymnasts injure are the wrists. Seventy to eighty percent of all gymnasts at one point had a wrist injury due to the repetitive stresses of handstands, bar swings, and floor exercise (Keller, 2009, p.1299-1300). In gymnastics, the wrists are frequently put into the extremes of extension, pronation, and supination. Normal wrist extension is about sixty to seventy-five degrees. However, many gymnastics skills require wrist extension of ninety degrees or more. The wrists are not designed to be weight-bearing joints, yet in gymnastics they are just that. Studies have shown that when eleven to thirteen-year-old gymnasts perform back handsprings, the compressive forces applied on their upper extremities are approximately 2.37 times their body weight. When this pressure is applied daily, for hours at a time, it is no wonder the wrists begin to hurt. One problem this may lead to is distal radial physeal stress injuries (Ray, 2006).

The two bones that run parallel each other in the forearm down to the hand are the radius and ulna bones. This condition tends to affect the distal radius in particular. Studies have shown that gymnasts that train on average only twelve hours a week often may have physeal stress injuries that can be found through radiographic imaging (Keller, 2009, p.1299-1300). The physis is the segment at the end of a bone, which is responsible for lengthening. It is more commonly referred to as the growth plate. Gymnasts who repetitively put a strain on their wrists risk physeal widening. "Figure 7" is an image of what a normal wrist joint looks like, while "Figure 8" depicts radial physis widening.

**Figure 7**

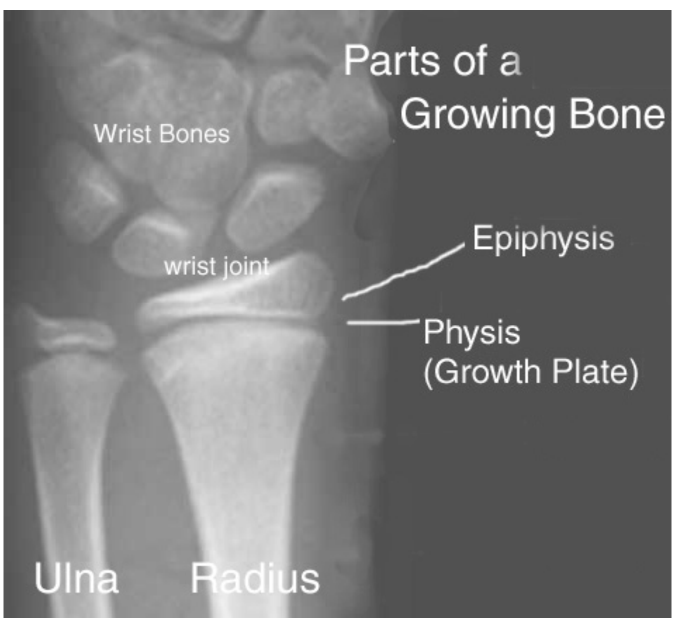
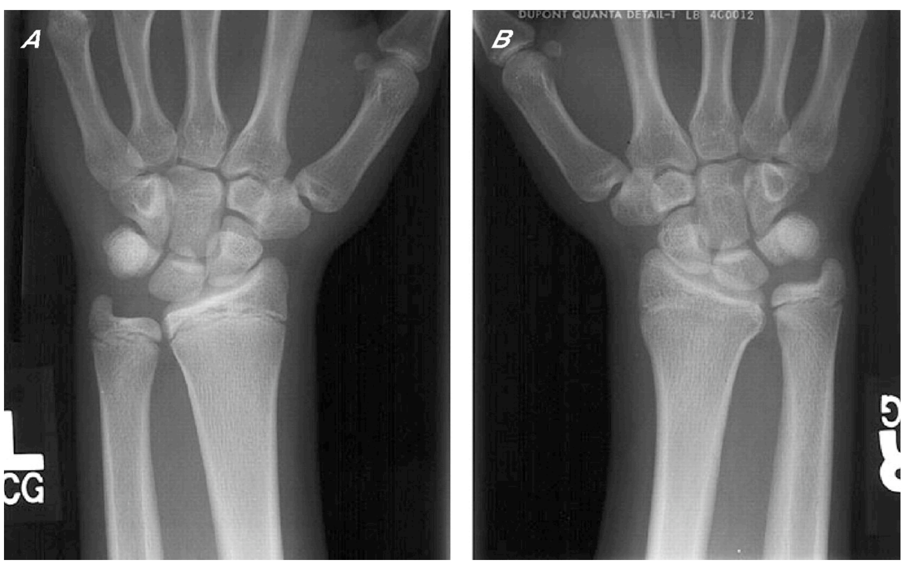



**Figure 8**


(Left: Nelson 2007, right: adapted from Keller, 2009, p.1301)

It is very important for a gymnast with wrist pain to rest the joint and avoid putting pressure on it until the pain subsides. Some gymnasts may not call attention to the problem to their coach or chose to continue to practice despite the discomfort. This can be detrimental to the integrity of their wrists. Repetitive injury to the joint can cause the distal radial physis to close early, which means the bone will not grow longer. The other arm bone, which runs parallel to the radius, is the ulna. Since this bone receives less of the stress, the ulnar physis remains open and would continue to grow. This can lead to syndromes of ulnar impaction (Keller, 2009, p.1300-1301). "Figure 9" is an X-ray image of a fourteen-year-old gymnast who suffers right wrist pain. Partial closure of the physis is evident in the radius, yet the ulnar physis remains open. Both the physis of the radius and ulna of the left wrist remain open.

**Figure 9**



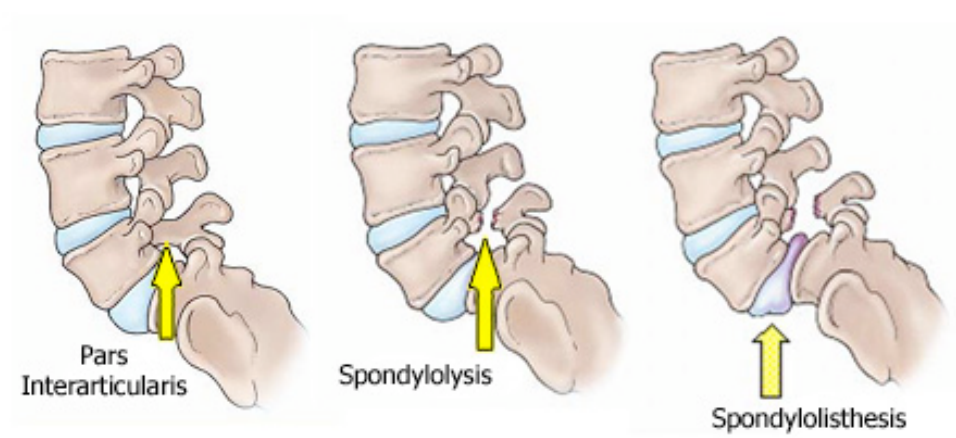

(Caine, DiFiori, Maffulli, 2005)

Another very common condition is anterior ankle pain or pain in the front of the ankle. Many people are familiar with ankle pain from rolling their ankle laterally. However, anterior pain is often caused by stress from overuse of the lower extremities such as when tumbling in gymnastics. The pain is caused by the Talus bone pinching against the Tibia. An individual with anterior ankle pain will feel discomfort when the foot is forced into dorsiflexion or when thee toes move towards the shins. The individual most commonly feels soreness in the area first, which then may develop into significant pain, swelling, and loss of function. It is important to educate gymnasts to notify a coach when they feel pain during landings, stretching the calf, or even if they cannot feel a stretch in the calf because they feel like the front of the ankle is stuck and will not go any further. This injury can be specifically caused by landing short, which can bruise the surface of the bone. Also, it may be caused by chronic irritation due to repeated tumbling, landing, and jumping. Lastly, it can be due to a tight calf muscle caused by an over emphasis in working on toe point or plantar flexion. It is important to maintain balance in strength and range of motion in the ankle through both plantar and dorsiflexion to prevent this and other injuries. Ankle dorsiflexion should be at least ten to fifteen degrees with the knee straight and fifteen to twenty degrees with the knee slightly bent. A lack of calf flexibility can make it difficult to squat while keeping the feet flat on the ground. This position is crucial to ensure a safe landing. If the calves are too tight, this will cause a gymnast to land with knees over the toes and caving inward, while the toes turn out. Repetition of this sort of position can later increase the risk of knee, hip, and back pain. If a gymnast does develop this problem, she should reduce the swelling with ice. Also, she should rest the ankle until pain is minimal in which case, she should begin strength and flexibility exercises for the joint. (Barnes, 2008, p. 30-32)

Another body part many people tend to assume is left vulnerable to injury during gymnastics is the spine. It is not unusual for a girl to be too scared to perform a skill because she is afraid she will “break her neck” or have some catastrophic injury to the spinal cord. However, this sort of event is actually very uncommon. Spinal cord injuries occur under a very particular set of circumstance in which the athlete is of an elite or very competitive level and occurs when the athlete is much higher than ground level. In order for there to be enough force to sustain such an injury, her energy potential is most likely increased by the use of a trampoline or springboard in preparation for some complex skill. This means that children who are practicing gymnastics at a low or recreational level have a good chance of never having to experience this sort of injury (Keller, 2009, p. 1301-1302).

It is not uncommon however, for these girls to experience low back pain. They constantly put their backs into hyper extension, which can cause stress to the spine and may even lead to spondylolysis (Keller, 2009, p. 1301-1302). This condition is one of the most common causes of back pain in children and can be congenital, from a stress fracture, or from some trauma. In these cases, the child has a defect or stress fracture in the pars interarticularis of the verebra. This may even further cause spondylolisthesis or the slippage or displacement of the vertebra (Mass General Hospital for Children, 2012). Both conditions are illustrated in "Figure 10."

**Figure 10**




(Killian, n.d.)

The exact causes of these conditions are unknown though spondylolysis is most common in athletes that participate in sports that require hyperextention of the spine such as gymnastics. The repetitive trauma may weaken the pars interarticularis, which can lead to the spondylolysis. If a gymnast suffers from this, she must take time off from the sport to rest, use a brace for her back, and start physical therapy to improve flexibility and strength (Mass General Hospital for Children, 2012).

2. *Swimming Injuries*

Although there are many incidences of drowning during recreational swimming, competitive swimming isn't normally thought of as a dangerous sport. This is very sensible since swimmers do not do any aerial moves that can lead to painful falls as in gymnastics. They do not use any equipment that can hit them such as a fastball in baseball. Swimming is also not a contact sport such as soccer so they are not subject to collisions with opponents. Additionally, the buoyant properties and light resistance of water are often recommended for individuals who have sustained an injury since it is low impact and does not stress the joints much. However, not many people consider the hours of repetitive stroking and kicking and what kind of overuse injuries it may cause if not properly monitored.

One joint that is particularly susceptible to an overuse injury in swimming is the shoulder. It is made up of a small ball and socket joint supported by the collarbone or clavicle in the front and the shoulder blade or scapula in the back. The rotator cuff muscles that provide stability of the shoulder, including the supraspinatus, infraspinatus, teres minor, and subscapularis, all originate on the scapula and insert around the head or top of the humerus bone. The large trapezius muscle is located on the back in opposition to the clavicular strut in the front. On the anterior or front of the shoulder are the pectoralis major and minor, and the serratus anterior. To the sides are the latissimus dorsi and the teres major. Most of the injuries seen in the shoulder are caused by an imbalance of these muscles causing improper alignment of the humeral head in relation to the socket or glenoid cavity (Becker, n.d. p.1).

One condition that may arise is Multi-axial Dysfunction Syndrome, which is caused by an inability of the muscles of the shoulder to control normal positioning while doing arm strokes in swimming. When considering the shallowness of the shoulder socket, it is evident how important it is for the muscles of the rotator cuff to be strong. This syndrome is characterized by abnormal laxity in the joint, which can cause passive separation in the joint that will but stress on the surrounding and supporting structures. Swimmers are vulnerable to this condition because of their acquired hyperlaxity. When warming up, swimmers aim to stretch the large muscles of the shoulder as depicted in "Figure 10." However, what often happens is that the humeral head is placed in such a way that puts stress on the anterior fibers of the capsule and nearby ligaments. Therefore, if done too much, this stretch can do more harm than good (Becker, n.d. p. 1-2).

**Figure 10**

(Saycoperformance, 2011)

Another factor that may further progress this problem are errors in stroke mechanics. This may include the straight-arm pull, unilateral breathing, poor body roll, late breathing, and dropped elbow. Aside from this, poor deltoid and rotator cuff strength and muscular imbalances will further amplify this syndrome.

A second shoulder problem that may arise falls under the general term of tendonitis. This is a result of repetitive irritations of the long head biceps tendon as it passes over the humeral head. This condition is also related to the naturally shallow shoulder socket and the strength of the stabilizing muscles around it. If the capsule is abnormally loose, the supporting structures are able to move in irregular ways. When the swimmer is fatigued and begins to demonstrate poor technique, the structures are subject to added stress. Tendonitis most often is developed when a swimmer has poor symmetry in their stroke mechanics making the body develop disproportionally. Other risky techniques as mentioned earlier are breathing only to one side, breathing too late in the stroke, or pulling the arm only to the chest instead of down through to the legs (Becker, n.d., p.2-3).

It is important to catch tendonitis in the early stages. At first, the swimmer will feel some pain during the warm up, no pain during practice, and then extreme pain, which subsides several hours later. If this goes untreated, the symptoms will progress to a secondary stage in which the swimmer experiences pain during the warm-up, which continues through the initial stages of practice, but then eventually becomes a tolerable subdued ache. After practice the pain is again extreme. Eventually it may progress to where there is pain all the time and where the dull aching pain can even hinder the ability to carry out normal activities such as sleeping. Again, this condition can be prevented and treated using proper exercises and stretches (Becker, n.d., p.2-3).

One last shoulder injury is a rotator cuff impingement. The rotator cuff is made up of four different muscles including the subscapularis, infraspinatus, teres minor, and supraspinatus. The first is responsible for internal rotation of the arm. The second two work together to perform external rotation of the arm (Zeigler, 2010). The last performs external rotation when the arm is abducted ("Supraspinatus," 2011). A rotator cuff impingement is a narrowing of the subacromial space. This is the gap between the acromion process of the scapula and the head of the humerus in which the tendons of the rotator cuff run through. This narrowing results in an increase in pressure on the rotator cuff, usually the most on the supraspinatus tendon. This pressure can cause inflammation on the tendon, which causes greater pressure resulting in even greater inflammation. Eventually, one can get a chronic wearing and even tearing of the tendons. It is painful to lift the arm because this inflamed tendon becomes impinged between the acromion process and the head of the humerus when you do so (Zeigler, 2010). Normally, the supraspinatus tendon prevents the deltoid muscle from pulling up the humerus (Brotzman & Wilk, 2003). The deltoid has an upward pull, while the supraspinatus tendon provides a downward force on it to keep the subacromial space open. An improper balance of these muscles is one cause of a shoulder impingement. Other causes include lack of flexibility and strength in the rotator cuff and biceps brachii muscles or even hypermobility. A common cause is overuse of the over-hand motion. This is because the muscle is constantly trying to stabilize the joint during this motion. Eventually, the muscles will become fatigued and are no longer able to maintain stability. This will then cause improper positioning of the scapula in relation to the humerus. There are also some primary causes such as abnormalities in the bones or tendons of the shoulder (Brotzman & Wilk, 2003). This is why, in order to prevent a rotator cuff impingement, one should exercise the shoulder in all ranges of motion including internal and external rotation, scaption, abduction, adduction, and extension.

It is no wonder that swimmers often develop this when you consider how many times they repeat the overarm stroke during practice. Because of this repetition, many often get a slumped posture resulting in the impingement of the ligaments. Swimmers with this problem may feel tight when they try to clasp their hands behind their backs and as a result will try to do this stretch. As mentioned earlier, this stretch only harms the surrounding tissue and causes hyperlaxity in the capsule if done too much. As with the other two conditions, the best way to prevent and treat this is to balance out the strength of all opposing muscle groups (Becker, n.d., p.3-4).

Another overuse condition that happens in the knees is "swimmer's knee." The knee also has a shallow socket and relies on the ligaments and muscles around it to keep it stable. Since it is a hinge joint, it is suppose to see a relatively limited range of motion. The large hamstring and quadriceps muscles provide the force in a swimmer's kick by pulling on the tendons which move the lower leg. The tendons of the hamstrings go around the knee, while the tendons of the quadriceps stabilize the patella or kneecap. Patellar tracking disorder is a result of irregular patellar movement. One reason for this is that swimmers often have hyper extended knees from the constant stress imposed by their powerful kicks which can overstretch the posterior cruciate ligament. This means the kneecap has move free space to move up, down, and side to side. Female swimmers additionally are at risk because they have a tendency of having smaller patellas and also have a slight angle in the knee because of the width of their hips (Becker, n.d., p4-5).

One problem that the knees of swimmers are vulnerable to is Patellar-Tracking Disorder. This is because they have a tendency of having tight hamstrings, tight low back muscles, an increased lumbar curve or lordosis, and hyperextension in the knees. This all adds extra stress to the tendons. The motion of the legs then can produce micro-trauma to the fibers of the ligaments while causing irritation to the overlying tendons. The tight hamstring muscles of swimmers develop as a result of adaptation to the functional position required to kick while swimming (Becker, n.d., p.5).

Another problem may be what is known as “breaststroker’s knee,” which is a sprain of the medial collateral ligament, but can also affect the hamstring tendons on both sides of the knee. Again, this is partly due to the lack of flexibility in the hamstrings. Another factor is the extreme quadriceps muscle development of breaststrokers. They become very strong and start to cause a forward tilt of the pelvis, which will cause a noticeable increase in the lumbar curve. This puts an added stress on the hamstring muscles since they are attached to the back of the pelvis. Additionally, the whip kick that breaststrokers demonstrate can cause injury to the ligaments of the medial knee since the lower leg is rotated outwardly which makes the medial knee susceptible to micro tears in the ligament fibers (Becker, n.d., p. 6).

Lastly, the spine can be affected as well. The spinal column is an upright rod stacked with skeletal disks, each separated from the other by a dense sponge-like cushion. The column’s role is to transmit nerve impulses through openings from the sides of the bone to provide communication throughout the body. Three problems that are often seen in swimmers are thoracic outlet syndrome, the Scalenus Syndrome, and scoliosis, which are all caused by the inability of the muscles of the back to develop equally while accommodating for the requirements of a swimmer's proper technique (Becker, n.d., p. 7).

Thoracic outlet syndrome occurs when the muscles of the neck and chest shorten, pulling the head forward and decreasing the amount of space available for blood vessels to pass through. Additionally, as the swimmer does an overhead stroke the area is compressed even more. As a result, major arterial vessels leading to the arm are partially closed and cause abnormal sensory feeling in the arm or hand which is often described as "pins and needles" or "falling asleep." The Scalenus Syndrome is similar, but the structures that are being compressed are nerves and it causes a variety of sensory changes such as "heaviness," "burning," "cold," or "electric shocks" (Becker, n.d., p. 8).

Lastly, Scoliosis is a condition in which the spine curves abnormally as the muscles of one side of the back grow more than the other and exert an unequal pull on the vertebral column. The shape and magnitude of the curve all depends on where and how much of a muscular imbalance there is. This condition can also be caused by or affected by heredity, age, sex, and developmental growth levels. If it is present before the child begins swimming, the coach, parents, and swimmer must take care that the condition does not worsen due to poor stroke mechanics. A swimmer is likely to develop scoliosis if they have a stronger arm pull with one arm, breathes toward the weaker arm, and shows a longer finish with the strong arm. This is what leads to a unilateral overdevelopment of the Latissimus Dorsi and Erector Spinea muscles which may cause one shoulder to be higher than the other, one arm that hangs closer to the body than the other, and a noticeable curve in the spine (Becker, n.d., p. 8-9).

**Other Potential Dangers of Swimming**

After looking at all of the benefits of gymnastics and swimming and some of the common injuries that occur, it is still important to note one other possible danger that swimming may bring rise to. Lately, society has become concerned with exposure to chemicals and other potentially harmful substances. Hygiene too is stressed to prevent the spread of infection. The conflict that arises in swimming is that the environment in which the athletes train in can easily spread bacteria. Unfortunately, the way that is has been prevented is by adding the chemical chlorine into the pool water. It appears that even though swimming is great for cardio respiratory endurance, it may be detrimental to the respiratory system. When organic substances such as hair, sweat, skin cells, and urine and inorganic substances such as dirt from under the nails mix with the chlorine, the reaction creates toxic substances known as disinfection by-products or DBPs. We can be exposed to them in three ways including water ingestion, inhalation, and dermal absorption. One particular type of DBP is called a Trihalomethane, which according to the International Agency for Research on Cancer is a carcinogen. Another type of DBP, Choloramines, are what is responsible for the well known smell of the swimming pool, mucosa soreness, and dry skin. High concentrations of it can be dangerous. When a pool is indoors and does not have proper ventilation, the concentration can be at very high levels. The concentration grows still with an increase in number of swimmers, the temperature and turbulence. All together, DBPs “increase the permeability of the pulmonary epithelium,” which will make children more prone to asthma and panting (Zarzoso, Llana, & Perez-Soriano 2010). It may even be associated with hay fever, rhinitis, and atopic eczema. It was also shown that swimmers had higher incidence of dental stains, xerosis of the skin, dermatitis, and an increased production of grease caused by prolonged skin hyperhydration. In the nasal passage, they also had more obstruction, itching, nasal discharge, sinusitis, and allergies. Also, it was found that the B2 microglobulin concentration in the urine of young swimmers was significantly higher than normal values. This is an indicator of kidney damage. It was also found that THMs and possibly other DBPs are associated with development of bladder cancer through ingestion, inhalation and dermal absorption in indoor swimming pools. Baby swimming, which is very popular recently, increases the risk of infection in the respiratory tract and the middle ear. (Zarzoso, Llana, & Perez-Soriano 2010). More research needs to be done, though even the notion that these could be possible is frightening. Overall, the question to ask is whether the great cardiovascular benefits outweigh the risk of toxin exposure.

**Conclusion**

After looking at each individual health component, skill component, physiological components and the injuries that may occur in each, I am able to conclude that gymnastics develops fitness more extensively than swimming. Although it does not stress cardiovascular endurance as much as swimming, the resistance training that gymnasts do actually may aid in reducing the risk factors of cardiovascular disease. It also specifically develops balance, coordination, muscular strength, and muscular endurance, which are skills needed to prevent the leading cause of hospitalization: falls and breaks (Bone and Joint Burden, 2008). In general, it exceeds swimming in most of the health related components, and especially in the skill related components. It is important to note however, that elite participation in any sport can become risky and detrimental to one's body. The sole overuse of the body can easily cause injury. Swimming is a great sport to practice for general health, especially cardiovascular health and is great for individuals who cannot jog due to pain in the joints of the lower extremities. However, if one is looking to improve all aspects of fitness from balance and agility to flexibility, body composition, and power, then gymnastics can be a good choice in sport for them. Of course, it is important to monitor a child's diet and look for signs of eating disorders in all sports, especially aesthetic ones such as gymnastics. Nonetheless, with the appropriate nutrition, rest periods, and safe environment, gymnastics can be a great sport for children to develop overall fitness.

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