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Introduction

Athletes are constantly looking for ways to increase their lung capacity. The larger the lung capacity, the more air, specifically oxygen, can be taken in by the athlete. Thus, increasing lung capacity increases endurance, allowing athletes to perform at a higher level for longer periods of time without feeling tired. If lung capacity remains the same while duration or intensity of activity increases, oxygen intake remains the same and there is more stress on the heart to get more oxygen to muscles and remove waste (Rathi 2014).

There are distinct techniques used by particular athletes and sports to attempt to raise their lung capacity. Systematic training is a type of training utilized by swimmers, which has been demonstrated to have a positive effect on lung capacity. Systematic training is an approach that utilizes methodological tactics to ensure that training begins and ends with the athlete's needs. The coach or trainer will develop a list of objectives that will be accomplished by the end of the training regimen, so the athlete can clearly see the effectiveness and success of the training. (Quain 2018). Swimmers use this resistance-breathing training protocol in order to help improve respiratory muscle strength and endurance. When underwater, they cannot breathe and must take the force of water into consideration, or hydrostatic force in order to hold their breath (Wylegala *et al* 2007). Although swimmers are at the surface of the water, when holding their breath, they are beneath the surface and the slight hydrostatic force must be taken into account.

On average, swimmers can hold their breath for almost twice as long as sedentary people. (Upadhyaya 2014).

This difference in breath hold time is most likely due to swimmer's increased lung volumes.

	Swimmers	Soccer players
Number of practices a week	7	4
Number of weightlifting sessions a week	2	3
Number of competitions a week	1	2
Distance ran/swam during competition	Varies greatly depending on event- can be from 50 to 1600 meters (0.03 miles to 1 mile)	Average of 7 miles per game

Figure 1. Training schedules of swimmers vs. soccer players (Barro *et al* 2007).

Swimmers' training schedule does vary slightly based on the events they swim. However, an average week of training would consist of seven practices in the pool, with five of them lasting two hours with 5,000-5,500 yards swam and two of them lasting about an hour with 3,500 yards swam, with a total of 32,500-34,500 yards swam per week in practice. The type of swimming differs from using kickboards and snorkels to limiting the number of breaths for a certain distance. The two weightlifting sessions consist of full body workouts. Competition day consists of the swimmers competing in a warm-up, then their event, which are all significantly shorter than the distance swimmers put in to their practices- events are often just 50-200 meters long.

In contrast, soccer players are able to breathe unimpeded as they run up and down the field. In a soccer game, athletes are subject to interval-type running, incremental periods where the athlete will transition between high intensity and much lower intensity running. This causes their respiratory systems to work harder at a higher intensity for brief periods of time, followed by periods with reduced strain during the lower intensity. Freely breathing allows soccer players to sufficiently exchange gas, whereas the swimmers have less time to breathe while competing. Sedentary people do not experience either type of training that swimmers or soccer players do on a daily basis since they do not exercise regularly. Therefore, their endurance is typically less than that of an athlete. Their respiratory pattern is unimpeded, but their body does not experience cardiovascular duress that soccer players do as a result of the physical exercise they endure on the field. Soccer players' training schedule is a bit opposite compared to swimming. Their competition day is when they do the most running, with practice being easier and often focused more on tactics and recovery. The table above displays the training and competition specifics for soccer players, with the information being mostly original data besides the miles per game, gathered from a paper written by Barros et al. The three weightlifting sessions are all full body workouts. For both sports, endurance is an important aspect of being able to compete at the highest level.

Endurance, breath hold time and lung capacity are all connected. Higher lung capacity is tied to a longer breath hold time and better endurance. During a breath hold, the arterial partial pressure of oxygen falls below the normal level of roughly 100 mmHg. Conversely, the arterial partial pressure of carbon dioxide rises larger than the average value of 40 mmHg. The longer the breath hold is, the more drastic the changes in partial pressure are. During a breath hold the CO_2 build-up in the body, not the need for O_2, is the pressing reason for the need to ventilate. The dynamic of CO_2 exchange within a lung during breath holding is observed via the rate of disappearance of CO_2 in alveoli. Hyde et al. showed that at 3 seconds over 50% of the CO_2 within the alveoli has disappeared. The remaining 50% of CO_2 disappeared by half of their current amount per 10 seconds. The initial sharp disappearance of CO_2 within the first 3 seconds indicate that alveolar CO_2 equilibrated with capillary blood CO_2 within 3 seconds.

This study will test breath hold time and vital capacity in order to indirectly test endurance. Researchers have not previously explored the comparison between swimmers and soccer players before, so that is what this research intended to do. How long someone can hold their breath is indicative of how much oxygen they can take in which is important in improving endurance. Vital capacity is defined as the largest amount of air that can be maximally expired after a maximal inspiration (Al-Madfai Z. *et al* 2016). Vital capacity can be used to explain breath hold time by measuring the maximum amount of air that can be inhaled and expelled. Additionally, this study will measure respiratory rate. This study will attempt to determine whether systematic training used by swimmers does result in higher vital capacity and breath hold values compared to soccer players who use an interval style of training, and non-athletes, who have no training program. If this is true, the second phase of the study would go on to test whether systematic training is effective in increasing vital capacity and breath hold (and thus endurance) in soccer players and non-athletes. This could inform one group better ways to train and improve their vital capacity and therefore their endurance.

There is a direct correlation between height and vital capacity. As one's height increases, so does the surface area and volume of their lungs. The larger surface area and volume that taller people possess allow them to take in a greater amount of oxygen and blow out a larger volume of air than someone who is shorter and has smaller lungs (Bhatti *et al*., 2014). Therefore, people with greater height are known to typically have a higher lung capacity than people of lesser height. However, there are other factors like BMI, gender and compliance that can affect vital capacity. Height has a significant impact on vital capacity so the statistic used to evaluate vital capacity will be adjusted for the different heights of the subjects

There has been research done on the vital capacity of soccer players and swimmer separately, but this study will add a direct link between the two. This study will compare swimmers' breath hold time and vital capacity to soccer players' breath hold time and vital capacity. It is expected that swimmers will have higher breath hold times and that it can be explained by accompanying higher vital capacity values. Additionally, systematic training will increase the endurance (measured by vital capacity and breath hold time) of soccer players and non-athletes.

Methods

Subjects

Ten college male swimmers and ten male soccer players (all of whom have participated in their sport for at least three years), and nine college males who are not athletes and do not participate in a regular exercise program were recruited by contacting the soccer team via text message, the swim coach via email, and individuals for the control group by word of mouth and text message. Students having respiratory diseases like asthma or COPD, or who play a wind instrument, sing or smoke were eliminated from the study. Participants signed an IRB approved waiver. Swimmers and soccer players were chosen because this comparison had not been made before and it was a convenience sample.

Procedure

All the testing occurred indoors to prevent humidity and temperature from affecting the data.

First, subjects' height and resting respiratory rate was measured. Resting respiratory rate was then measured by recording the number of breaths the subject took in fifteen seconds and calculating the rate (breaths/minute).

Next, vital capacity was measured while the subject was standing by means of a handheld spirometer. Their nose was plugged by nose clips. The subject inhaled as much as possible then exhaled as much as possible into the machine. This process was repeated two more times with a thirty second break in between. The mean of the three measurements was then taken for analysis.

Finally, the subject held their breath for as long as possible. The subject held their nose and released their hand when they could not hold their breath any longer. The time was measured by using a stopwatch. Then, post breath hold respiratory rate was immediately measured using the same technique as described earlier.

Analysis

To account for the significant impact height has on vital capacity the statistic that was used for data analysis is vital capacity/height in centimeters (VCH). Mean vital capacity and breath hold time was graphed to compare athletes for both sports and nonathletes. The vital capacity and breath hold time was analyzed using an ANOVA and a post hoc t-test to determine if there is a difference in vital capacity or breath hold time between any of the groups at a level of significance of 95%. Significance was noted by asterisks on the graph.

Results

As expected, the swimmers had significantly higher VCH's (66.2 $\pm$ 10.1) than soccer players (52.9 $\pm$ 6.93) and the control group (52.2 $\pm$ 10.5) ($F_{2,26}$ = 4.55; p= 0.0203 see Figure 1). Post hoc t-testing indicated that swimmers differed significantly from soccer players (p_{16}=0.0369) and the control group (p_{14}= 0.0207). There is no difference between the soccer players and control VCH values.

No significant difference was found in breath hold time between the three groups, most likely due to large standard deviations (($F_{2,26}$ = 2.11; p= 0.141). However, the trend for breath hold time is almost identical to the trend in VCH (see Figure 2).

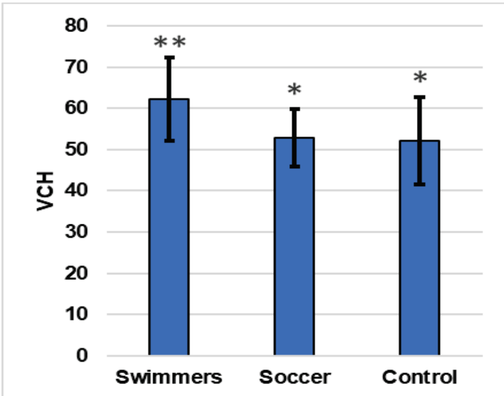

Figure 1. Vital capacity adjusted for height of swimmers is significantly greater than that of soccer players, and the control group. ($F_{2,26} = 4.55$; p= 0.0203)

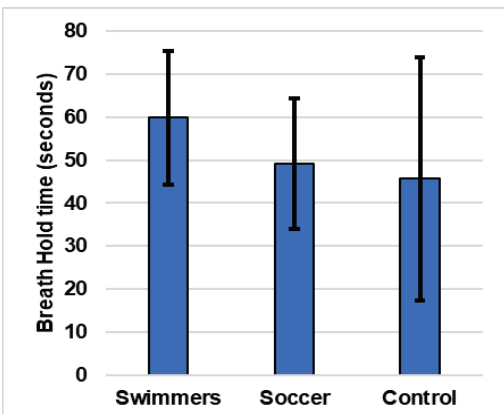

Figure 2. Breath hold time of swimmers, soccer players, and the control group. Showing no significant difference.

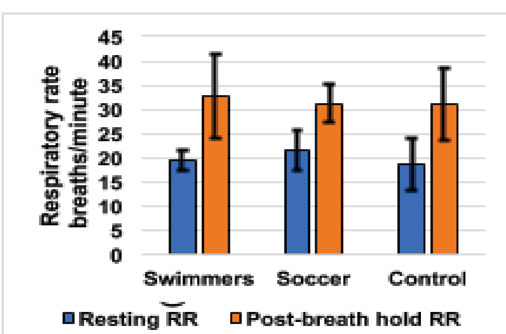

Figure 3. Resting respiratory rate and post-breath hold respiratory rate of swimmers, soccer players, and the control group. Showing no significant difference between groups.

Discussion

Swimmers have an increased ability to bring oxygen into their bodies compared to soccer players and the sedentary group, as demonstrated by the swimmers' higher vital capacities. Vital capacity is directly related to endurance (Rathi 2014). As vital capacity increases, endurance will increase as well. Additionally, swimmers trended toward higher breath hold times than soccer players and the sedentary group, but the results were not statically significant. Soccer players also had slightly higher vital capacity readings and breath hold time than the sedentary groups but both of those data points were not statistically significant.

The VCHs obtained are similar to values obtained previously in a previous study which discovered that swimmers have a superior FEV1 compared to land-based athletes (consisting of athletes who participated in basketball, canoeing, and rowing) and a sedentary group (Doherty, Dimitriou 1997). An additional study corroborated that swimmers had higher vital capacity values than other athletes (football players) and the sedentary control group (Lazovic-Popovicag *et al.* 2016).

Based on our data and the similar results obtained from other studies, swimmers increased vital capacity is likely due to the specific way they train. Swimmers did practice more times per week than soccer players, but Lazovic-Popovicag, *et al* (2016) controlled for training period and determined it did not have an effect on lung volumes. Therefore, the swimmers' high lung volumes can likely be attributed to their technique of systematic training with a focus on limited breathing time and extended periods of time spent not breathing utilized in order to strengthen their respiratory muscles.

A limitation in this study was obtaining truly sedentary people for the control group. Since the subjects were all college students, at the minimum they are walking to and from class and around campus. The important aspect we focused on when recruiting subjects for our control group was that they did not participate in any regular cardio-focused exercise regimen. Another limitation was that we were measuring swimmers' vital capacity and breath hold time during their season of peak performance, while we were measuring soccer players during their offseason when they are not regularly practicing and may not have as good endurance as during their season. Of additional concern was how subjective breath hold time can be. Some subjects may push themselves to the point of passing out until they began to breath, whereas others may have begun to breath when it became mildly uncomfortable. The insignificant differences in breath hold time is not as much of a concern for that very reason and does not undermine the claims previously made.

The future of this research could be to conduct a study where a group of soccer players participate in a systematic training regimen similar to what swimmers use. The subjects' vital capacity and breath hold time would be measured before and after the training program to determine if the systematic training program is truly effective at increasing vital capacity and breath hold time, and therefore endurance. An increase in the vital capacity and breath hold times after the training program would indicate that athletes of different sports would benefit from utilizing systematic training, at least periodically, to increase their endurance and allow higher quality performance for longer periods of time. Alternatively, a study could be done to test the endurance of swimmers and soccer players while having them use an exercise bike while measuring respiratory measures such as VO_2 max.

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