solely explained by improvement of aerobic capacity indicated by VO\(_2\)max, not by changing of stroke efficiency that was indicated by SL at various velocities and SL@OBLA in well trained varsity swimmers. Results shown in Figures 2 and 7 illustrate that VO\(_2\)max improved considerably by endurance training from pre-test to mid-test and post-test. Because VO\(_2\)max is the most accurate method for measuring aerobic capacity (4), the present results suggest that aerobic capacity was improved by endurance training from pre-test to mid-test, and post-test. Results of the relationship between swimming velocity and blood lactate concentration in intermittent progressive swimming test (Figure 3) show that blood lactate concentrations at higher velocities were significantly lower in the post-test, despite identical swimming velocity. Moreover, V\(_{0.5}\)OBLA values measured at the mid-test and post-test were significantly higher (p < 0.05) than those measured at the pre-test (fig. 5). Previous studies suggested that endurance training would engender reduced lactate production and enhance the efficiency of lactate removal (2, 3). Therefore, it can be inferred that, in the present study, lactate concentrations in muscle and blood decreased at the same submaximal velocities by endurance training. No significant differences of both SL at the same velocities and SL@OBLA were found between the three tests (Figures 4 and 6). Moreover, the rate of SL@OBLA change did not correlate significantly to the rate of V\(_{0.5}\)OBLA change (fig. 8). Toussaint and Beek (8) suggested that SL gives a fairly good indication of propelling efficiency and might be used to evaluate individual progress in technical ability. Previous studies (1, 9) have demonstrated that endurance training increased SL. They suggested that endurance training engenders improved stroke efficiency. However, the present results were not consistent with those of previous studies. Apparently, this factor was responsible for the difference in the subjects. The present subjects were well-trained male varsity swimmers, including elite swimmers; seven were finalists at national level competitions. Therefore, it seems that the stroke efficiency of such elite swimmers would be already nearly maximized, even at the beginning of the season. On the contrary, the rate of VO\(_2\)max change significantly (p < 0.05) correlated to the rate of V\(_{0.5}\)OBLA change (fig. 7). These results suggest that, in this study, stroke efficiency would not be likely to improve by endurance training. Therefore, increasing V\(_{0.5}\)OBLA through endurance training was influenced not by stroke efficiency, but by improved aerobic capacity. Similar investigations using various subjects, such as age group swimmers, are necessary to elucidate this point. In conclusion, this study demonstrated that increased V\(_{0.5}\)OBLA by endurance training might be caused not by stroke efficiency improvement but almost entirely by improved aerobic capacity.

REFERENCES

ANALYSIS OF USA SWIMMING’S ALL-TIME TOP 100 TIMES

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The purpose of this study was to investigate the performances of elite level swimmers based on the USA Swimming’s All-Time Top 100 times. We analyzed participation of 17-18 years old swimmers at Top 100 from age 10-under until the age of 15-16 years in various events by girls and boys. The data shows that the older the elite swimmer, the more likely he/she will be ranked in the Top 100. About half of the elite swimmers in the Top 100 at age 17-18 were new swimmers who were never ranked in the Top 100 at any age. Most of the future elite swimmers swim slower than age group champions, especially at ages until 15-16 years. Many participant ranked in the Top 100 as age groupers are not present in the Top 100 in the 17-18 age group. We speculate that the two reasons for losing these young Top 100 ranked champions may be related to their early biological maturation and/or an inappropriate training volume at a young age.

Key Words: age group, top 100, performance, swimming event.

INTRODUCTION

There is a paucity of studies on effects of early high-level performances on athletes’ progression later in their career (1, 2). The analysis of the all-time Top 100 at different ages may provide valuable information about the long-term progression of elite level swimmers. There is constant debate in the swimming community about high-level performances at a young age in swimming. We still do not know if early high-level performances may limit a swimmer’s progression later in their career. Many famous swimmers came from vastly different training programs. Unfortunately, coaches and scientists have speculated about the advantages of low-level or high-level performances at a young age based on a few examples of elite level swimmers. Some elite level swimmers were already ranked in the Top-100 as a 10-under, while other elite level swimmers only reached the Top 100 at age 18. Which strategy is better? The
lack of scientific investigations on long-term performance progression only increases speculation on this topic. The purpose of this study was to investigate the performances of elite level swimmers based on the All-Time Top 100 times.

METHODS
In order to understand the progression of elite swimmers during competition, we analyzed USA Swimming's All-Time Top 100 age group times by girls and boys. All-Time Top 100 age group times are divided into five groups according to the age of the swimmer: 10-under, 11-12, 13-14, 15-16, and 17-18. For the purpose of this study, we considered elite level swimmers the group of All-Time Top 100 at age 17-18. The following swimming events were analyzed: 100, 200, and 500 freestyle; 100 and 200 backstroke; 100 and 200 breaststroke; 100 and 200 butterfly; and the 200 individual medley. The groups of All-Time Top 100 were examined by calculating the percent of participation.

RESULTS
Analysis of Female Top 100 Athletes
All-Time Top 100 in freestyle, backstroke and breaststroke events for females are presented in Figure 1. Data presented for age groups include elite swimmers from Top 100 at age 17-18 in all events. It means that if an elite swimmer from Top 100 at age 17-18 was ranked in other Top 100 events she would be included. For example, if a swimmer was ranked in the Top 100 for the 100 freestyle in the 17-18 age group and was not listed in the Top 100 for 100 freestyle as a 10-under, but was ranked in the 100 breaststroke, she would be included. The 500 freestyle event wasn’t included in Top 100 at age 10 and under.

As was expected, the older the elite swimmer is the more likely they will be ranked in the Top 100. However, there were a relatively small number of 17-18 year-old swimmers from the Top 100 who were also ranked as a 10-under. For example, only nine swimmers at age 10 and under were listed at age 17-18 in 100 freestyle. Seventeen swimmers at age 10 and under were listed at age 17-18 in 200 freestyle. The number of elite swimmers slowly increases with each age group in all freestyle distances. Similar tendencies occur in the stroke events as well. The low numbers of elite female swimmers are listed in backstroke, breaststroke, and fly events (see Figures 1 and 2). These numbers are even lower than in freestyle events and don’t reach 50 at age 15-16. Fifty-eight 15-16 year-old girls elite level swimmers were listed in the 200 IM (see fig. 2). These numbers are higher than in other events.

Analysis of Male Top 100 Athletes
Participation for the USA Swimming All-Time Top 100 in male freestyle events is presented in fig. 3. As the data shows, participation of elite male swimmers is relatively low in each age group until the age of 17-18.

Similar tendencies appear in other males' events (see fig. 3 and 4).

DISCUSSION
The analysis shows that most of elite level swimmers were unknown at young ages. Most of the future elite swimmers swim slower than age group champions, especially at ages until 15-16 years. Many participants ranked in the Top 100 as age groupers are not present in the Top 100 in the 17-18 age group. We speculate that the two reasons for losing these young Top 100 ranked champions may be related to their early biological maturation and/or an inappropriate training volume at a young age (1, 6, 8, 9). Higher participation on 500 compared to 100 and 200 freestyle events in the 11-12 group may be attributed to larger contribution of aerobic energy system at younger ages (1, 2, 11). Young athletes have lower anaerobic power and are not able to accumulate high blood and muscle concentrations (3, 4, 5, 6).

Surprisingly, there were still a low number of elite swimmers
at age 15-16 for girls and boys. About half of the elite swimmers in the Top 100 at age 17-18 were new swimmers who were never ranked in the Top 100 at any age. This statistic shows that most of the future elite swimmers swim under Top 100 times until age 15-16.

There is a small difference between elite female and male freestyle swimmers at age 11-12 and 13-14, where it appears that higher numbers of female freestyle’s were ranked in the Top 100. Higher numbers for females may be related to earlier biological maturation in girls (6, 7, 10).

It was investigated how many elite level swimmers change their events at Top 100’s. With that goal in mind we analyzed participation of elite swimmers from age 17-18 in Top 100’s at various ages in the same and other events. For example, how many elite swimmers from age 17-18 were listed in the same or other events at age 10 and under, 11-12, 13-14, and 15-16. It is better to look at these numbers relative to the total number of elite swimmers. At age 10 and under many elite female swimmers are listed in other events. As data shows, 51.6% of elite female swimmers are listed in other events at age 10 and under. This number decreases with age and reaches 37.9%, 26.6% and 24.9% at age 11-12, 13-14 and 15-16, respectively.

It shows that most of elite female swimmers select their event at age 13-14. The analysis of elite male swimmers shows that 69.6% of elite male swimmers are listed in other events at age 10 and under. This number decreases with age and reaches 55.6%, 40.8% and 26.7% at age 11-12, 13-14 and 15-16, respectively. Thus, the elite male swimmers select their events at age 15-16 or about 2 years later than elite female swimmers.

CONCLUSIONS

1. A small number of elite swimmers from the Top 100 at age 17-18 were ranked in the Top 100 at a younger age. Typically, a little over 10% were ranked as a 10-under, about the same figure as a 11-12 year old, a little over 30% as a 13-14 year old, and a little over 50% as a 15-16 year old. Similar numbers were found for female swimmer’s, however, they have a little higher percentages in the 11-12 and 13-14 age groups.

2. The analysis shows that most of elite level swimmers were unknown at young ages. About a half of elite swimmers at Top 100 at age 17-18 are new swimmers, which never were listed at Top 100 at any age. This leads to conclusion that most of future elite swimmers swim slower than age group champions, especially at ages until 15-16 years.

3. Many participants ranked in the Top 100 as age groupers are not present in the Top 100 as they become an elite swimmer in the 17-18 age group. We speculate that the two reasons for losing these young Top 100 ranked champions may be related to their early biological maturation and/or an inappropriate training volume at a young age.

4. Elite level swimmers change their events during long-term training. Elite female swimmers tend to change their events until the age of 13-14. Elite male swimmers tend to change their events until the age of 15-16.

REFERENCES