HIGH VELOCITY TRAINING
IMPROVES BIOMECHANICS, PHYSIOLOGY AND
PERFORMANCE IN ELITE SWIMMERS

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VIII International Symposium on
Biomechanics and Medicine in Swimming

University of Jyvaskyla, Finland
June 28 - July 3, 1998

Background Information on the Symposium

The VIII International Symposium on Biomechanics and Medicine in Swimming was held at the internationally acclaimed swimming research facility in Jyvaskyla Finland. The university is internationally recognized for swimming projects. At the time, the attendance exceeded the symposium organized in Atlanta before the 1996 Olympic Games. This symposium is only conducted every four years. Presenters are invited, and may only demonstrate research or information that has not been previously published. University at Buffalo Head Coach Budd Termin was one of three Americans invited to speak at this prestigious event. Coach Termin gave two presentations. A podium presentation on the testing and successful high intensity training model developed by Coach Termin and Dr. David Pendergast, also of the University at Buffalo, and the Department of Physiology. The second presentation was a poolside training session on how the testing and training methodology is used in a practical manner in an every day practice session. At this poolside presentation, Coach Termin debuted an Underwater Pacing Light Training System that was conceptualized and developed at to train the swimmers of the University at Buffalo swimming program. International and US patents were attained for the pace training light device.

The symposium was a joint venture of the Finnish National Swimming Federation, the City of Jyvaskyla, and the University of Jyvaskyla.

PURPOSE

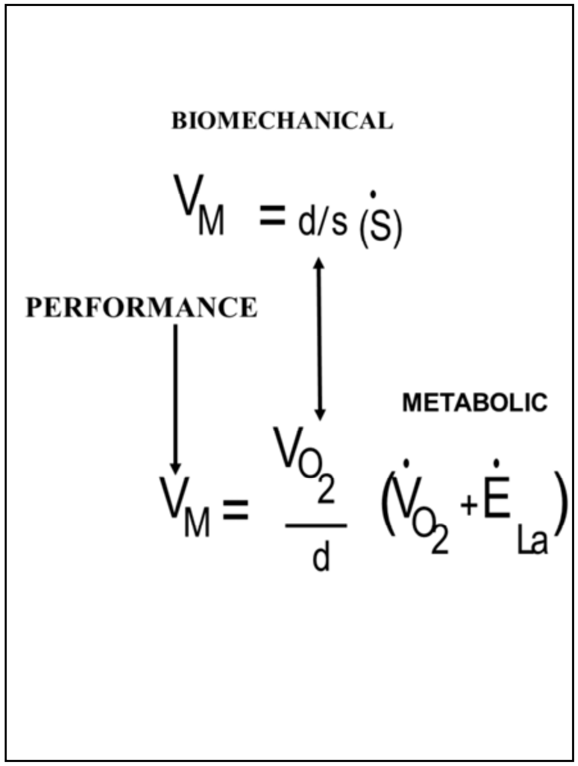
Swimming training typically involves swimming at slower speeds and lower stroke frequencies than used in competition. This is carried out for long distances.

This study tested a training program designed to:

PHASE I - Biomechanics
Improve the maximum distance per stroke at progressively increasing stroke frequencies

Phase II - Aerobic
Increased stroke frequency/velocity to Improve maximal aerobic power and lactate consumption (125% VO2 max)

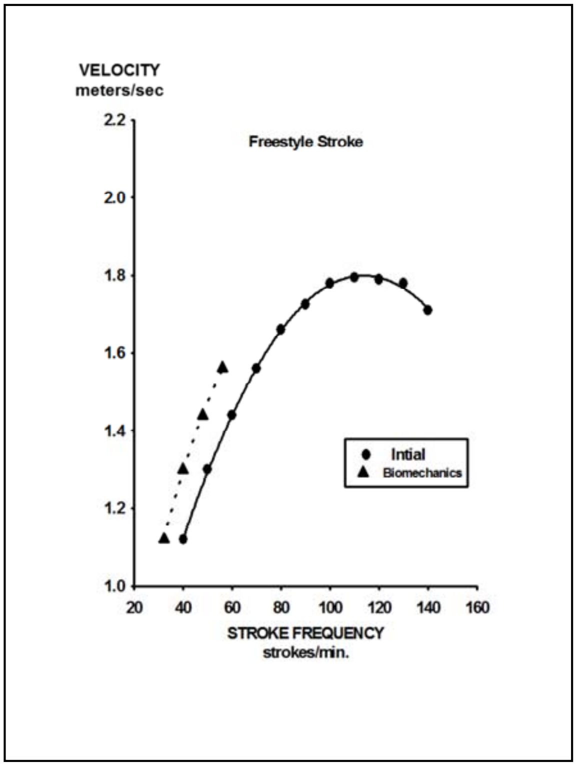
Phase III - High Velocity "Anaerobic"
Progressively shift to higher stroke frequencies and faster velocities while improving anaerobic capacity



Performance In Swimming

Performance in swimming can be expressed as the ability to swim and sustain a maximum velocity over a given distance. This maximal velocity can be expressed as a series of relationships. As the upper formula demonstrates, maximal velocity can be expressed in biomechanical terms as the distance per stroke times the stroke frequency.

This relationship in mechanics as the downward arrow shows, has a direct effect on the cost of swimming, which can be expressed as the VO2 per unit distance. (Aerobic component) This maximal velocity can also be expressed in metabolic terms as the oxygen plus the energy produce from glycolysis, which leads to the production of lactic acid.



Phase I

Biomechanical

In this slide, the velocity of swimming is plotted as a function of the stroke frequency for all velocities.

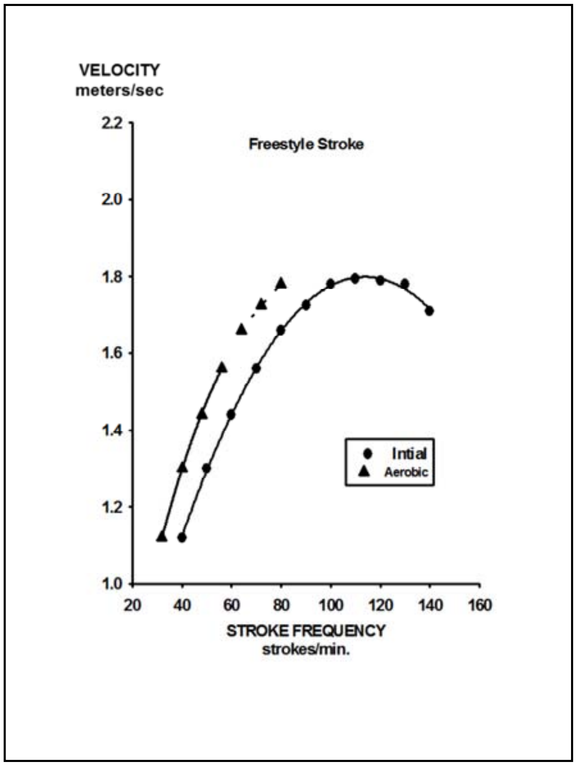
After the initial measurement of velocity for the given stroke frequencies, the curve is shifted 10 % to the left increasing the distance per stroke, and the new velocities are calculated (dashed line). Training involves swimming at progressively increasing speeds form 65% of the new peak velocity to 100 % of VO2 max for one hour on the new training line. The training matrix for this consists of one hour of 50-meter swims in the Long Course configuration. 20 seconds rest is given between each of the interval. The training speeds in time and the corresponding velocity inmeters per second are listed for each stroke progression:

Freestyle - 38 (1.32 m/s) - 36 (1.39 m/s) - 34 (1.47) - 32 (1.56 m/s)

Backstroke - 40 (1.25 m/s) - 38 (1.32 m/s) - 36 (1.39)- 34 (1.47 m/s)

Butterfly - 40 (1.25 m/s)- 38 (1.32 m/s)- 36 (1.39 m/s)- 34 (1.47 m/s)

Breastroke - 46 (1.09 m/s)- 44 (1.14 m/s)- 42 (1.19 m/s)- 40 (1.25 m/s)



Phase II

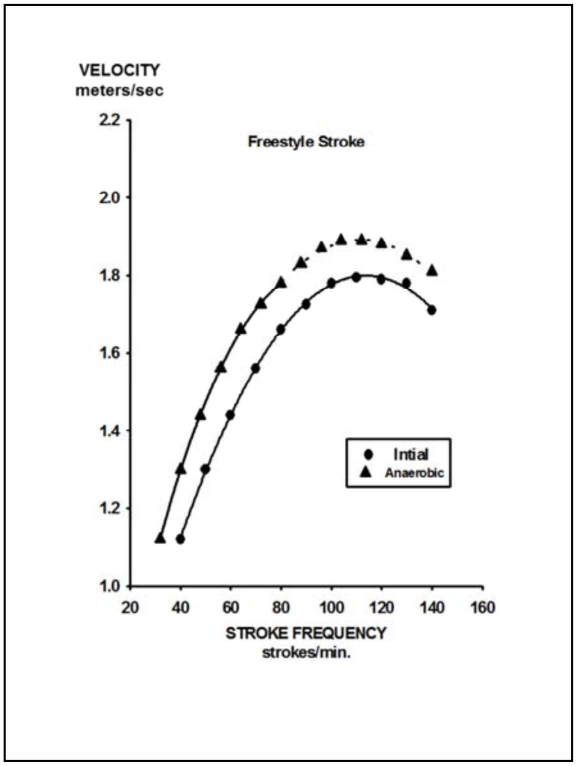
Aerobic

In this slide, the stroke frequency is again plotted as a function of the stroke frequency.

In this training phase, the swimmer trains for 10 minutes at speeds and stroke rates that represent velocities corresponding to a VO2 of 125% of maximum. (dashed line). The swimmer then trains for 10 minutes at a velocity corresponding to 60 % of VO2 max for 10 min and then repeats this cycle three times. The swimmer trains at their VO2 max and maximal lactate tolerance was reached at the end of each 10-minute intense swim. Lactate was fully metabolized during the 10-minute slow swim.

The training matrix for this consists of one hour of 50-meter swims in the Long Course configuration. 20 seconds rest is given between each of the intervals, whether training fast or during the 10-minute recovery phase. The training speeds in time and the corresponding velocity in meters per second are listed for each stroke progression:

Freestyle Range - 27 (1.85 m/s) to 31 (1.61 m/s)
Backstroke Range - 29 (1.72 m/s) to 34 (1.47 m/s)
Butterfly Range - 29 (1.72 m/s) to 34 (1.47 m/s)
Breaststroke Range - 36 (1.39 m/s) to 44 (1.14 m/s)



Phase III

Anaerobic

During this phase the swimmer trains at progressively increasing stroke rates and speeds up to the maximum velocity. These swims were 25 or 50-yard intervals with decreasing rest intervals (15 to 30 sec.) over a one-hour period.

Training Matrix

A series of different training matrix have been developed to address the different parts of the upper region of the stroke curve, (dashed section) and are outlined below.

25's and 50's

4 x 25 - 15 sec. rest

4 x 50 - 30 sec. rest

4 x 25 - 15 sec. rest

Rest 1:30 sec and repeat

All 25's

16 x 25's - 15 sec. Rest
Rest 1:30 sec.
Repeat for 1 hour

High End Combo Pack

12 X 12.5 meters on 15 sec. rest
Rest 1:30 sec. and repeat for a
half an hour, followed by
All 25's matrix for second half-hour

Moncion's Mix Matrix

All 25's matrix for first half hour
30 X 25's on 50 sec.
Rest and repeat – second half-hour

PROTOCOL

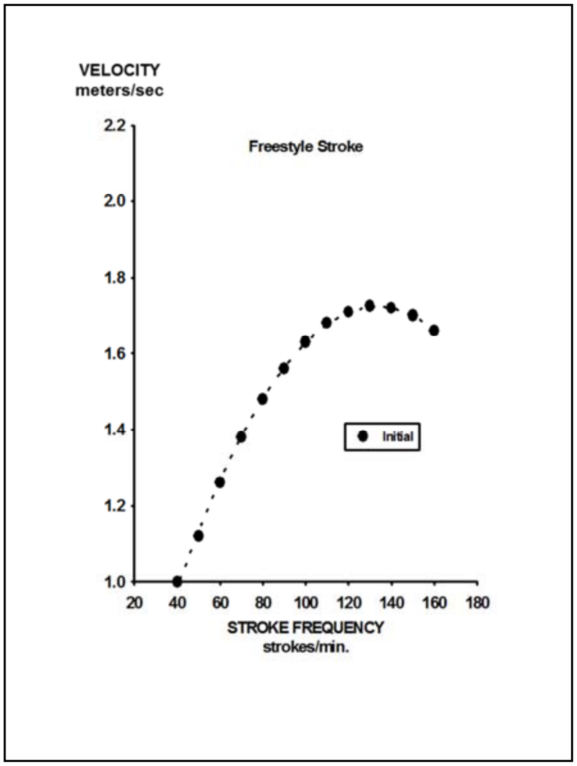
Subjects
Men: n = 22; age = 17 - 22 yrs.
Wt. = 73.5 Kg; Ht. = 181 cm

Groups
High Velocity - UB
High Volume - 17 other teams in the Conference

Testing
September, December, and March
of years 1,2,3,and 4

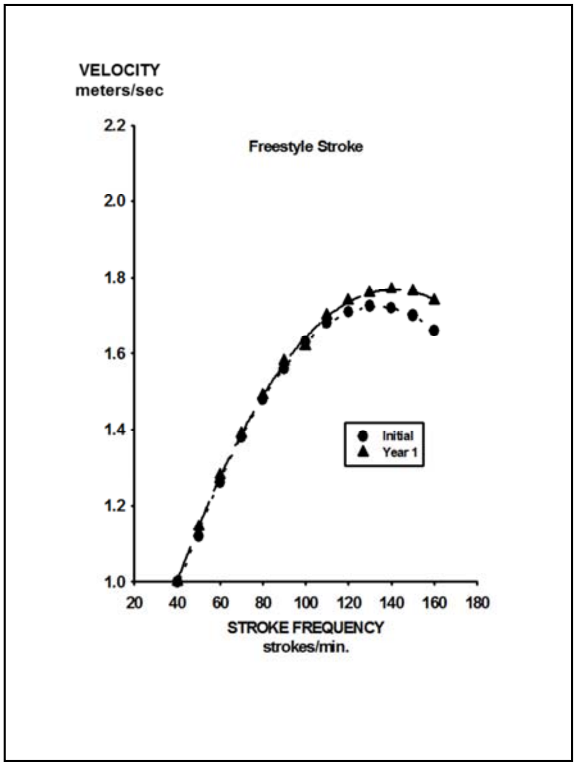
Training
September through March
26 weeks

Performance
End of Season Conference Championships



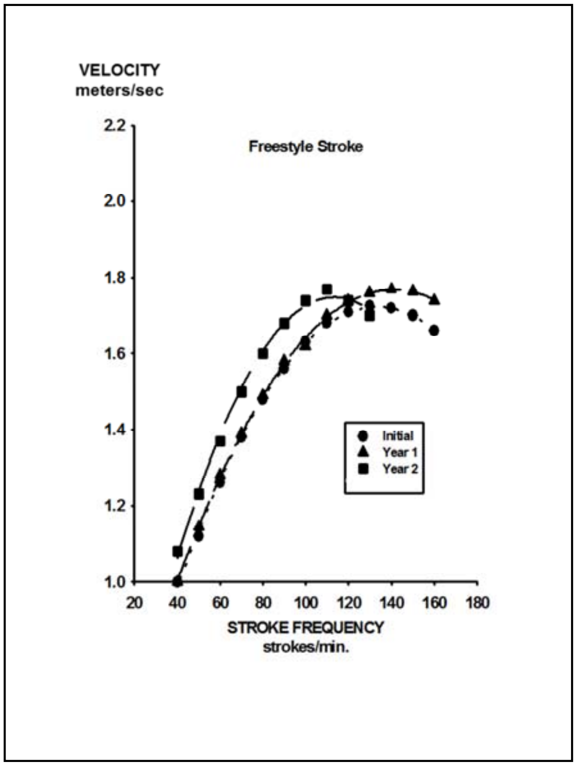
Initial Stroke Curve
First Season

A starting stroke curve was collected for each swimmer. Training was designed for short distances with high velocities and stroke frequencies not normally associate traditional swimming training. Short distances of 25 yard intervals were used to allow the swimmers to train at high velocity. This method also allows the coach to give constant feedback to the swimmers about the mechanics of swimming using the above stroke frequency velocity curve. Swimmers had the whole season, and are trained to work as far up the curve as possible.



Year 1

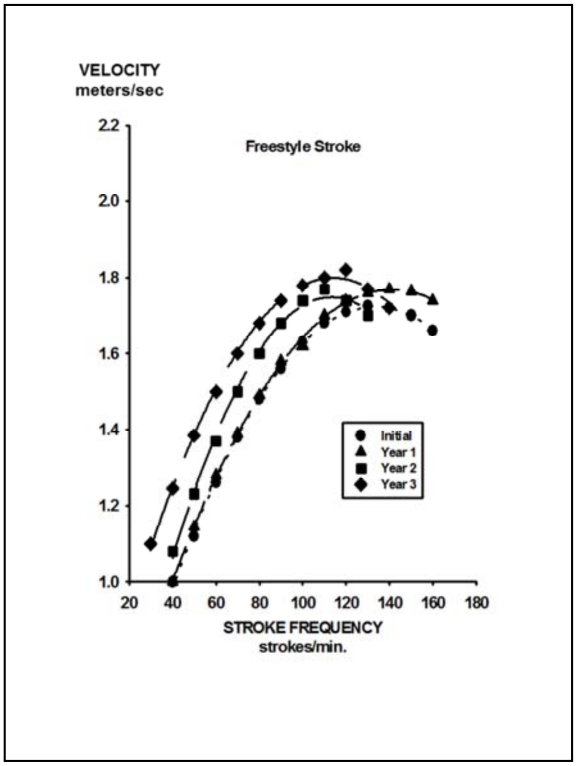
The above curve demonstrates how the swimmers shifted after a season of training at high stroke frequencies and velocities not normally associate with traditional training. Since all of the training concentrated at or near the peak, only a shift occurred in that region. This curve demonstrates an important concept never shown in swimming before this time. Using a high velocity training method, the distance per stroke can be shifted or increased at peak velocity.



Year 2

Now that the swimmers demonstrated the ability to shift the curve a training program was developed to address all parts of the curve. Because it has been shown that the fastest swimmers have the longest distance per stroke at low velocities, from the initial data collection, a shift of 10 % was constructed, in order to increase the distance per stroke. The swimmers began to train at velocities that represented 65% of the new peak velocity. A systematic increase in the velocities and corresponding frequencies was achieved when the swimmer was able to master mechanically a particular speed for an entire training session. The swimmer was given the whole season to progress from the starting point, all the way to the peak velocities, always maintaining proper mechanics.

This graph clearly demonstrates a swimmers ability to shift the curve across all frequencies and velocities. Once again, this curve illustrates for the **first time ever shown in swimming**, the distance per stroke for all velocities can be changed through training.



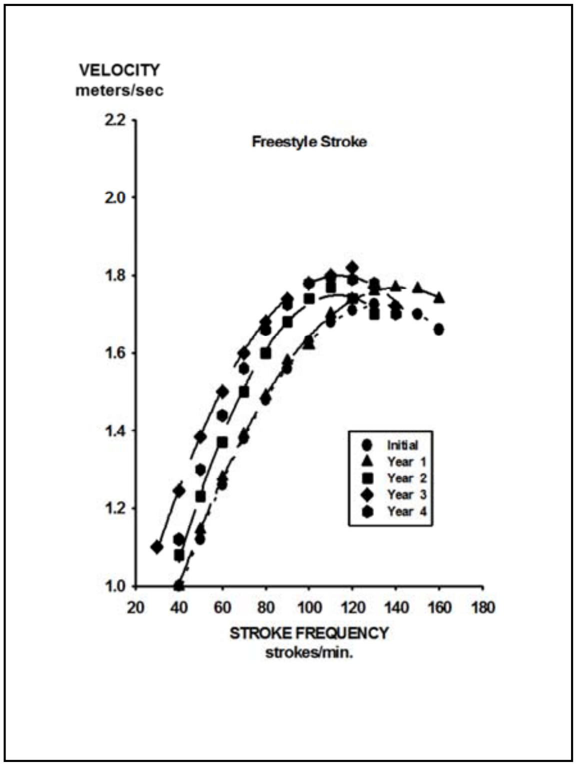
Year 3

In year three, the findings from the two previous seasons were incorporated to develop a training program, which addressed the distance per stroke ofthe swimmers and the peak velocity. Early season training consisted of concentrating on improving the distance per stroke at the lower velocities. Mid to late season training consisted of high velocities and frequencies used in the training outlined for Year 1. This combination produces another significant shift in the distance per stroke of the swimmer, while the peak velocity also significantly increased.

Also during this season, a training program was developed to address the aerobic power of the swimmers. A training program where the swimmertrains for 10 minutes at speeds and stroke rates that correspond from between 100% to 125% of the measured VO2 max. The swimmers then trains at 60 % of VO2 max for 10 min and then repeats this cycle three times. The swimmer trains at velocities above the VO2 max and maximal lactate tolerance was reached at the end of each 10-minute intense swim. Lactate was fully metabolized during the 10-minute slow swim.

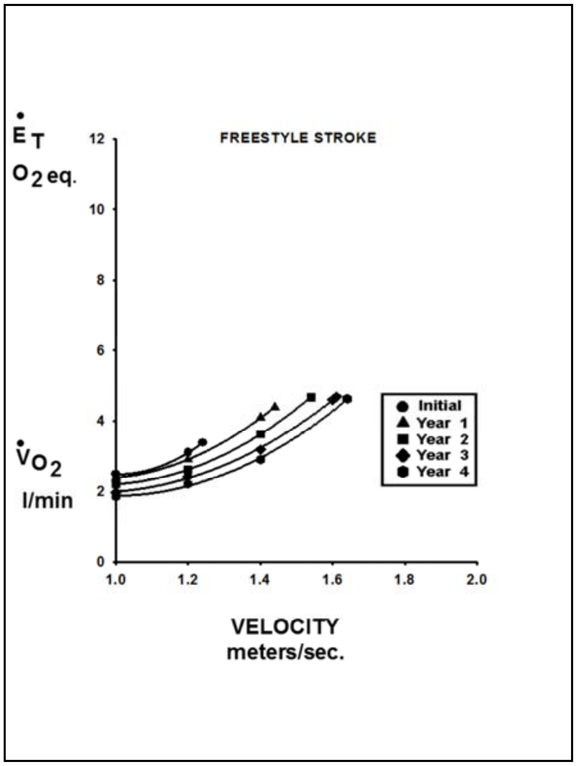
The training matrix for this consists of one hour of 50-meter swims in the

Long Course configuration. 20 seconds rest is given between each of the intervals, whether training fast or during the 10-minute recovery phase.



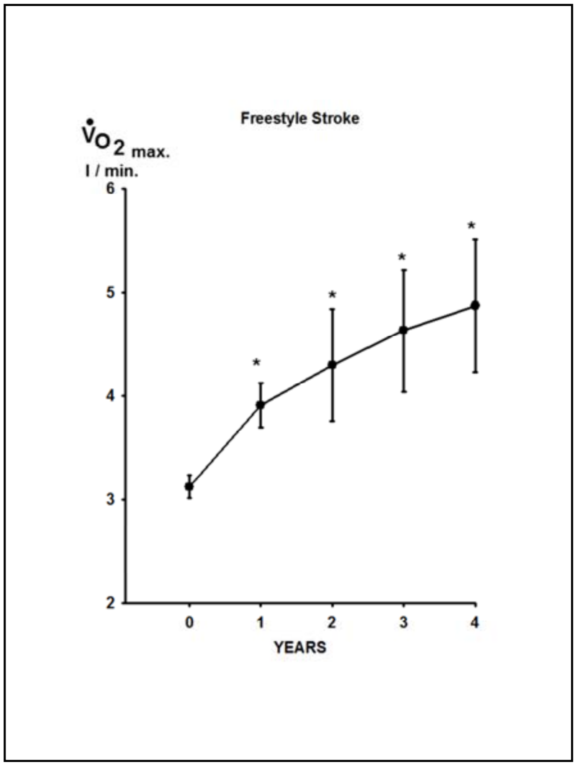
Year 4

In year four, the same training program used in Year 3 was incorporated with similar significant changes in the distance per stroke and peak velocity. The mean changes that can be made throughout the training period from Year 1 to Year 4 is between 20 to 30 percent. These “shifts” in the mechanics of swimming have a direct effect on the energy cost of swimming, which will be described, in the next section of this paper. **The systematic changes in mechanics described over the four year time period are the first ever shown in swimming.**



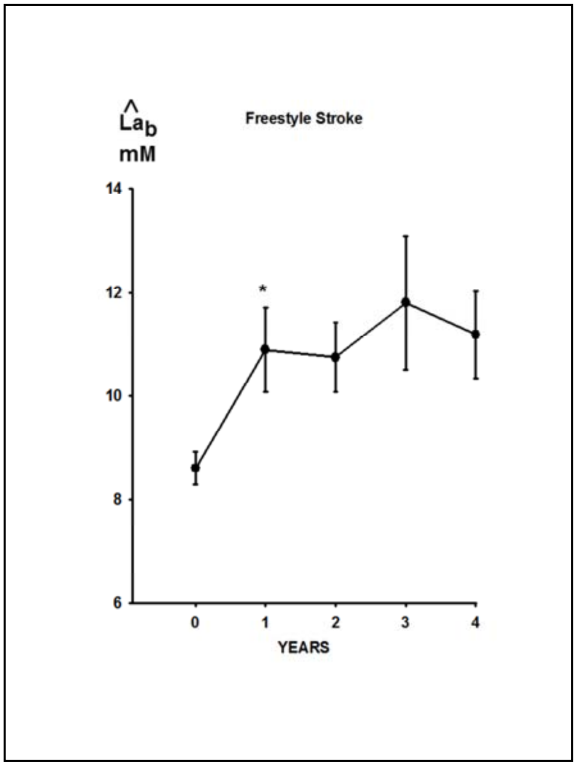
Oxygen Consumption and Energy Cost

The shifts in the mechanics observed from the stroke frequency curves of the swimmers during this time period had a significant effect on the cost of swimming. During the four-year time period, swimmers were measured in an annular pool 60 meters in circumference for changes in oxygen consumption. Testing began at 1.0 meters per second and progressed in one tenth of a meter per second in velocity until exhaustion. When theoxygen consumption is plotted as a function of velocity, these curves show the decrease in energy cost at speeds over the series of years at any given speed.



Peak Measured VO2 Max

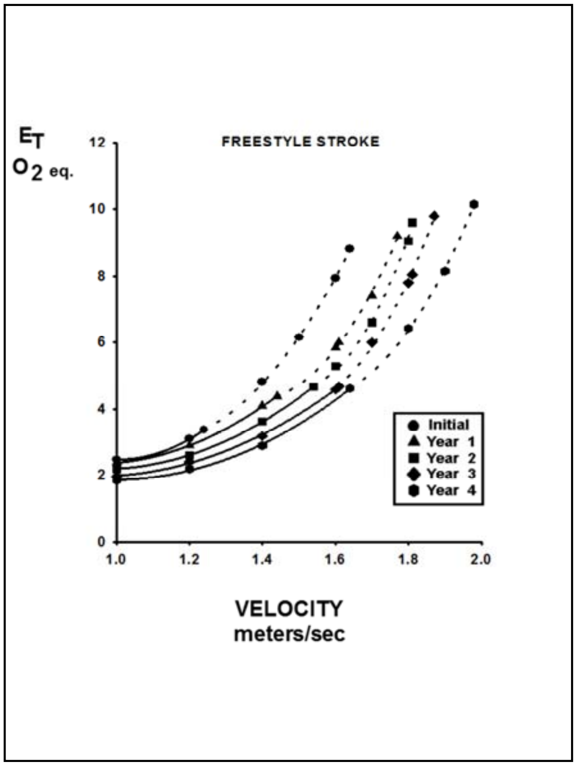
Maximum aerobic power is plotted as a function of four years of training. The values are mean and Standard Deviations of the data from the swimmers. The * indicates a significant change from the previous year. Initial values collected at the beginning of year one were below those expected for this caliber of swimmer. The overall improvement was 56 % while the improvement back calculated from years 2 and 4 would be 38 %. This improvement is greater than reported in all other studies on swimmers of this caliber that trained with lower velocities and high-volume.



Peak Post Exercise Lactate Acid

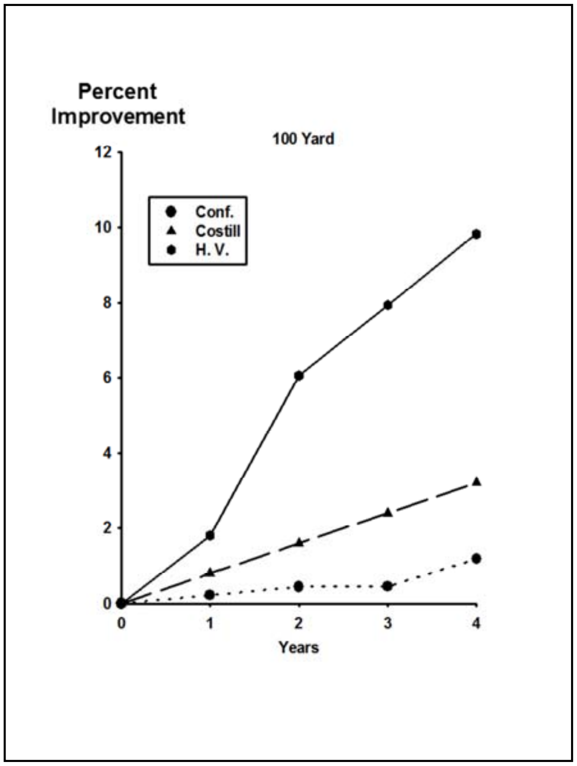
Peak post exercise lactic acid is plotted as a function of the years of training. There was a significant change in the first season of training, with no significant changes in the subsequent years.

As could be seen from the previous slide, the VO2 max of the swimmers not only increased, but the velocity at which VO2max was achieved had also changed significantly. Due to a higher VO2 max, the onset of lactic acid production was not as high as in the initial first year of the training program, to attain maximum velocity.



Total Energy Output

The estimated total energy output is plotted as a function of speed for the initial test and the four years of training. The solid line represents the directly measured values of oxygen consumption. The dashed lines represent the data estimated from the end-swim lactic acid and observed VO2. The data are the average values of all swimmers. As can be seen the energy cost of swimming significantly decreased over the four years over the entire range of speeds. Both the maximal VO2 and the maximal energy output were significantly increased and resulted in increased maximal velocity progressively over the four years.

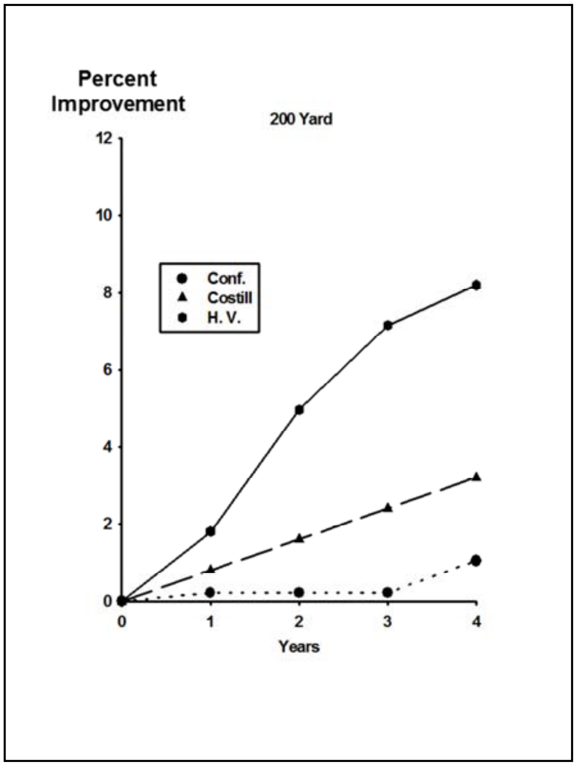


Rate of Improvement

100 Yard Freestyle

The changes in mechanics and metabolism using this training method had a significant effect on the competitive performance of the swimmers over the 4 year training period. Swimming performance is expressed as the percentage decrease in swimming time for the competitive distances (Delta % Improvement). The average data are presented for the high-velocitygroup and the low velocity and the high-volume group (Conf.) during freestyle swimming for the 100 yards freestyle. Data previously published by Costill on elite national level Division I swimmers are also presented for

comparison. The * indicates that the values for the HV group were significantly different from the conference data. As can be seen the improvement was significantly greater in the HV group than the Conference group. The HV groups data were also greater than that previously reported, by Costill for elite national level Division I swimmers.

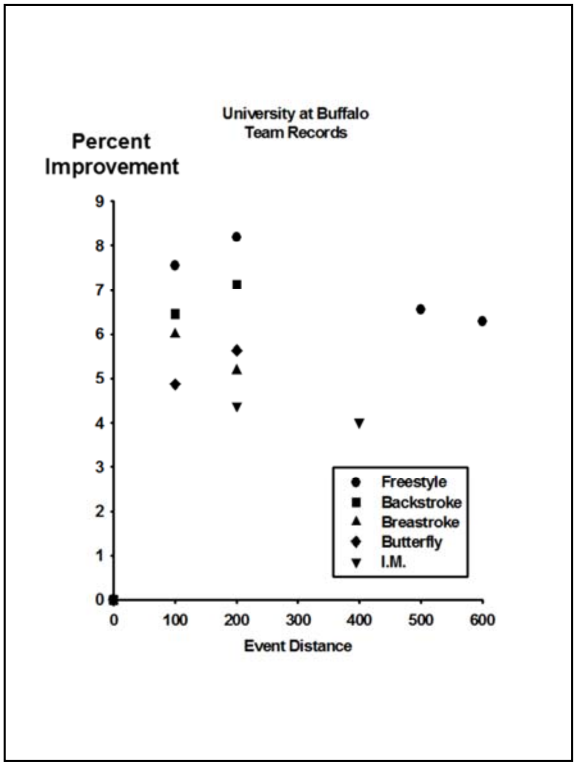


Rate of Improvement

200 Yard Freestyle

The percentage of improvement in freestyle for the 200-yard distance is plotted for the HV group and the low velocity and high volume group (Conf.)as well as the Costill data from the literature. The * indicates that the HV groups values were significantly greater than the Conf. values. It was also greater than previously reported (Costill) for elite national level Division I swimmers. The magnitude of the percentage improvement was similar for the 100 and 200-yard swims. Values for the other distances and strokes were similar to that reported for the 100 and 200 yard distances, and will be

shown in the next slide.



UB School Records Improvement
All Events and Distances

As was previously shown for the 100 and 200-yard distances for freestyle the rate of improvement was greater than the Conf. Group of the data reported by Costill for elite swimmers. The HV group also demonstrated a uniform rate of improvement for all strokes and distances. Changes in the Delta rate of improvement progressed at the same rate over the 4-year training period for the UB school records as was shown for the individual events.

SUMMARY

BIOMECHANICAL

distance per stroke and maximum stroke frequency can be increased

energy cost of swimming can be significantly reduced by improving stroke mechanics

PHYSILOLGICAL

maximum aerobic power and lactate consumption can be increased by high velocity training

PERFORMANCE

percentage improvement in swimming time from high velocity training exceeds that from low-velocity and high-volume training

Summary

The information contained in this manual was collected on a group of University at Buffalo swimmers that competed from 1988 to 1992. In that time period, the swimming program upgraded from Division III through Division II and finally in 1992, to Division I. This manual demonstrated the physiological, biomechanical, and performance data over that time period. Along with all those improvements, some remarkable history was made during this era. Men's swimming was recognized officially as a varsity sport in 1949. In all of that time, the program had never won a team title of any kind. For 40 years the program competed in the Upper NY State Swimming Conference, which in 1989 captured for the first time.

In conjunction with this remarkable training method, are the accomplishments of the swimming teams from 1988 to 1992

Conference Championships: 1992 E.C.A.C. Conference, 1992 East Coast Conference,

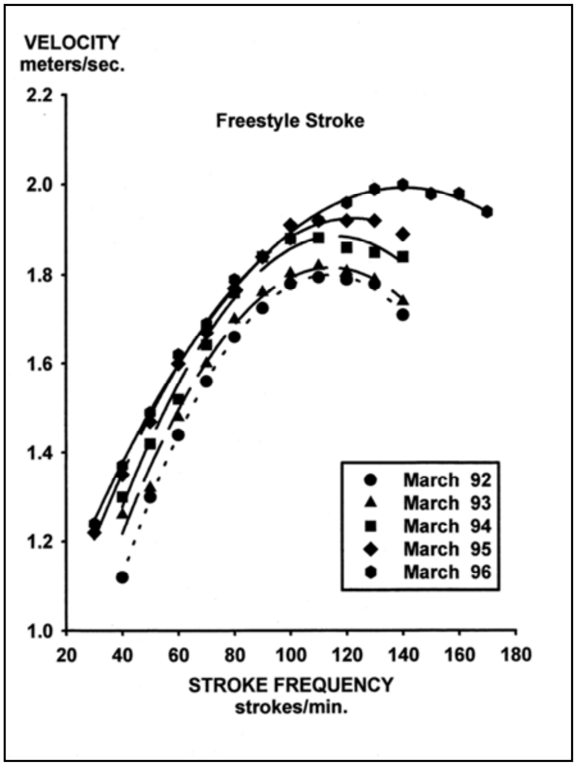
1991, 1990, 1989 Upper New York State Conference.

Individual Conference Records: 9 E.C.A.C. Conference, 13 East Coast Conference, 22 Upper New York Conference Records, 40 University at Buffalo Team Records.

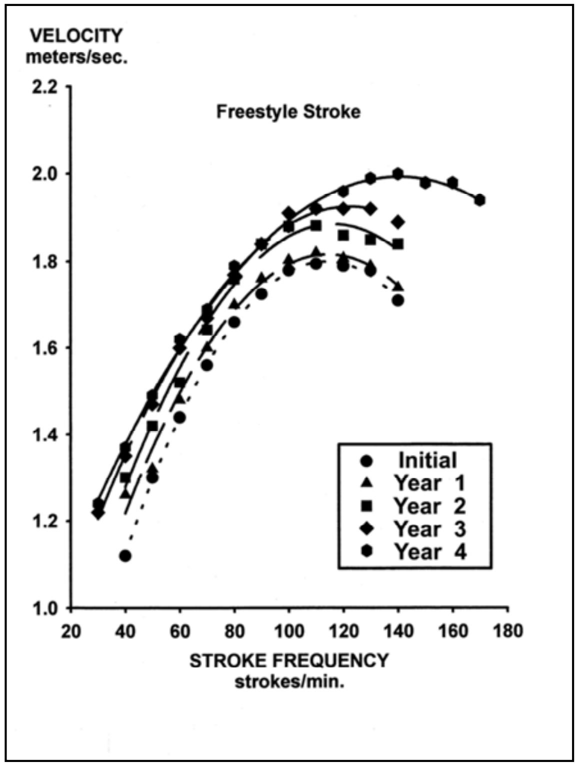
Conference Coach of the Year: 1992 E.C.A.C. Conference, 1992 East Coast Conference,1989 Upper New York Conference.

Outstanding Coaching Achievement Award: 1992, 1991 American Swimming Coaches Association of America.

Swimmer of the Year: 1992 E.C.A.C., 1992 East Coast Conference, 1991 and 1989 Upper New York Conference.



This 4 year high intensity training model was repeated with a new population of swimmers. The next two graphs demonstrate positive repetitive nature of a training model that features high intensity training and attention to swimming mechanics. The changes in metabolism and mechanics continued to produce a mean performance improvement of 6% in 96 weeks of training.


VELOCITY
meters/sec.
Freestyle Stroke
2.2
2.0
1.8
1.6
1.4
1.2
1.0
20
40
60
80
100
120
140
160
180
STROKE FREQUENCY
strokes/min.
Initial
Year 1
Year 2
Year 3
Year 4