FORCE FIN
[redacted]
Santa Barbara, CA 93101
1-800-FIN-SWIM®
805-966-9628
[redacted]

FIN MAKER FINDS FAULT WITH STUDY

by Bob Evans, President, Force Fin(R)

Controversy surrounding innovative ideas or products is nothing new. It seems to be human nature to want to stay attached to conventional ideas, to the status quo. People are suspicious of change and have a hard time accepting new concepts. This appears to be especially true in the diving industry and with regard to dive fins in particular.

As an example, Force Fin(R) is as revolutionary and innovative today as it was when it was introduced to divers 11 years ago. Although acceptance is growing, there are still those who refuse to believe that Force Fins work for diving because they <u>look</u> and <u>feel</u> different than other fins.

Evaluating Force Fins in comparison to strongly held diver biases about what fins should feel and look like merely reinforces ingrained perceptions. This process does not allow divers to be open to new ideas and to the possibilities of how a different technology like the Force

Fin(R) can help make their diving safer and more enjoyable.

Similarly, researchers sometimes model experiments to measure only the point they want to make. Expert witnesses or scientists representing corporate interests are notorious for this, ignoring or deleting relevant information that may lead to results that either raise questions about or contradict the point that they want to prove. In the end, the untrained or those who don't have the time read study details can be fooled into believing invalid or false conclusions.

This is precisely what was done by UCLA student Michael Yee in his 1991 Masters Thesis study, "A Kinesiological Evaluation of Diving Fin Design and Performance," which was reported on in Sources (September/October 1992, May/June 1993) and Undercurrents (December 1991).

In the condensation of his study in Sources, Yee used figures, illustrations and charts that, to the unwary reader, appear to provide evidence in support of two major conclusions: 1) Surface area is the primary architectural feature in diving fin performance; and 2) Large fins make diving easier and safer. Yet there is absolutely nothing in Yee's data to support either of these conclusions. (Drawing a conclusion not supported by data is the biggest sin a researcher can commit.) In fact, the study says virtually nothing at all about the efficiency or performance of <u>any</u> fin tested including the Force Fin(R), which Yee seems so bent on criticizing.

Publication of this misinformation about our product compels us to offer a rebuttal. However, you should be no less compelled to investigate further. This is not the first time, nor the last, that technological advancement has been slowed by industry propaganda. The only defense we as divers have against our being manipulated by less-than-scrupulous interests is educating ourselves by reading all sides of a controversy, gathering all the information we can, evaluating products thoroughly, and trying to understand innovation on its own terms as well as in comparison to our current concepts and models.

SPECIFIC STUDY CRITICISMS:

Surface Area Measurements Incorrect

Yee failed to correctly measure the surface area of the fins he tested. This is important since these measurements form the basis of many of the study's conclusions.

In trying to reproduce Yee's results, Dr. Alfred Nash, Ph.D., a post-doctoral physics researcher at the University of California/San Diego, took several fins from the study and remeasured them using a high-precision technique where a video picture is broken up into over 300,000 squares or pixels and counted by a computer.

"The results were surprising," says Nash. "The relative sizes of the blades forward of the foot pocket were up to 20 percent different than Yee reported. Even the resulting ranking of the fins according to size was different! Additionally, there was a measured difference in the size of the foot pockets of up to 32 percent, in contradiction to Yee's claims that they were roughly the same."

Yee erroneously measured the Force Fin's surface area at 502 cm2, about 19 percent smaller than our XS size made to fit a child under 10 years old. Nash measured the surface area of a size Large Force Fin(R) (the same relative size as the other fins in the study) at 680 cm2, 80 cm2 more than Yee's magic number of 600 cm2 that he claimed makes diving "easier, safer and more enjoyable."

Also, Yee's conclusion that fin-blade surface area is the primary architectural feature determining performance was unsubstantiated.

"For this conclusion to have been valid," explains Brett Lee, a researcher at Purdue University's Kinesiology

Division, "a comparison between all other fin characteristics (e.g., flexibility, material, venting, etc.) was needed to determine their relative effects on a given variable."

In other words, Yee didn't test for surface area; he didn't compare surface area to anything. He simply measured it (incorrectly, as we've seen). Therefore, his conclusion that surface area is the most important fin feature effecting performance cannot be accepted.

Air & Oxygen Consumption Never Measured

Yee boldly claimed that larger fins reduce air consumption. What he failed to mention is that air or oxygen consumption was never measured in the study. Instead, Yee counted air bubbles on a video screen to determine how often divers were observed breathing. Number of breaths per minute and volume of air or oxygen consumed are three very different ways to gauge respiration.

Divers care about the volume of air consumed and the amount of oxygen utilized, neither of which was measured by Yee. He only measured breath frequency, which is not necessarily related to diver efficiency. Consequently, Yee's conclusion that large fins reduce air consumption is not valid.

Heart Rate Increases Not Linked to Fins

Yee based his heart rate conclusions (that fins producing higher heart rates were less "effective") on the results of his underwater ergometer exercise tests. Basically, divers were strapped to an immovable device sitting on the bottom of a swimming pool where they tried to produce a given amount of force by kicking against the device while receiving visual feedback to adjust their efforts.

Although heart rate is generally a good measurement of work load, Yee did not examine the link between the heart rate increases and what may have caused them. Because he didn't look at other variables like kick style or diver preference, Yee didn't isolate fin performance from diver performance. With Force Fins, this is a critical issue.

Force Fins are designed to be used with a natural swimming-style flutter kick. This does not pose a problem for diving education and safety since new divers naturally want to use this type of kick. Paradoxically, the problem seems to come from the perceptions of experienced divers and instructors who have been trained to adapt their kick to other fins, and who must de-train and orient themselves to using Force Fins. (We recommend that experienced divers test dive Force

Fins a minimum of 5 to 10 times before rendering an opinion about them.)

As diving instructor trainer Ken Loyst (NAUI #2976L) noticed when conducting a 10-month evaluation of fins for Discover Diving Magazine, "...those fin testers who had not been trained in fin use overwhelmingly (8 out of 10) preferred Force Fins over any other fin tested. However, Force Fins were not generally the fin of choice for experienced fin testers, who had conditioned themselves to using other fins."

From first-hand observation of Yee's study's videotapes, we know that the subjects -- mostly experienced divers and instructors -- used what is frequently called a "drag-dominated" kick when kicking with Force Fins (see Figure XX). This is a deep, pushing-water-backward type kick that brings the diver's fin blade to as close to 90 degrees from the body's line of motion as he/she has the leg strength and flexibility to reach. The fin is then pushed down and against the water to provide forward propulsion.

However, Force Fins are designed to be used with a more efficient "flapping-style" kick that requires a shallow and quick motion. With this kind of low-load/high-cadence kick, the fin blade remains roughly within a 24" to 36" total range of motion.

Moving the leg and foot significantly beyond this optimum range, as Yee's subjects did, increases the drag forces and reduces the propulsive lift forces generated by the fin. Therefore, all the heart-elevating work Yee's subjects did with Force Fins outside this shallow range of motion was contrary to the manufacturer's instructions and was basically wasted energy.

That the subjects' heart rates increased when kicking at higher loads with Force Fins is more likely the result of the fact that they were not properly adapted to using the Force Fin(R) with its streamlined kicking style.

(Using a streamlined kick becomes even more important when confronting a current in open water, as opposed to being strapped down on the bottom of a swimming pool. A deep, drag-dominated kick catches the current like a sail, creating a potential safety concern as the drag forces a diver must work to overcome are increased by the fin blade orientation itself.)

Sprint Velocity Irrelevant to Diving

Yee claimed that larger fins were significantly faster than smaller models. The obvious question is: So what? Testing divers on how fast they can kick for 25 yards is like testing marathon runners to see how many free throws they can make on a basketball court. It's irrelevant.

Sprinting is an "anaerobic" effort that is appropriate for shorts bursts of energy and cannot be maintained, even by Olympic champions, for more than a minute or so. (Yee's subjects averaged about 16 seconds.)

Of course bigger fins will help you go faster in a 25-yard sprint, but at what cost? The larger the surface area of the fin, the more effort is needed and the more of the diver's energy is required. It's like trying to pedal a bicycle that's geared too high (lower RPM, harder gear). Every experienced cyclist knows that struggling to push against big, slow-turning gears is much more difficult and inefficient then "spinning" higher-RPM, easier gears. The underwater equivalent of riding a bike geared too high is kicking with large fins.

In an open-water, strong-current situation, as an example, having large fins that provide you with more short-range velocity won't do much good when you quickly exceed your body's ability to maintain that kind of anaerobic effort.

Rather, it's your ability to maintain a continuous, "aerobic" effort that will get you out of such a jam. What divers need is the ability to create long-term, sustainable velocity, something that Force Fins were expressly designed to provide, and something that Yee did not test for.

Sprinting is not a true measure of what a diver faces. Arguments for or against specific fin choices should be made on the basis of practical intensities that are commonly used by divers in the real world.

Another point about speed: Even if you are a speed demon and demand it in your fins, consider the following.

In Yee's sprint tests, the subjects only went between 11-29 percent faster with fins that were between 27-52 percent larger than Force Fins. Said another way, the Force Fins actually performed 15-35 percent better than the other fins in the study relative to size.

Wouldn't you be willing to give up only 11-29 percent of anaerobic sprint speed in order to have a fin that's one-half the size, easier to maneuver and keep off reefs, and that significantly reduces fatigue and cramping over longer distances?

CONCLUSION

In the final analysis, where did this UCLA student project go wrong? We could on and on pointing out its fallacies, but the most important issue is scientific objectivity.

Yee apparently never looked critically beyond what his assumptions were, one of which was that all fins are basically the same. But Force Fins don't fit the mold. They're different because they're designed to change shape more dramatically than other fins during the kick cycle.

Yee obviously had a large fin bias and set up his study and interpreted the results to support that bias. Instead of attempting to learn something by doing a complete, objective study, testing different variables to determine the most critical factors in fin design and letting the chips fall where they may, Yee pre-judged the issue and was merely trying to validate his assumptions.

The study's methodology, testing protocols and statistical analyses are very questionable. Most of Yee's characteristics, factors or parameters had little to do with fin efficiency or performance, and most of his conclusions were not supported by his data. In fact, Yee would have to be Indiana Jones to have made the Leaps of Faith that he did in drawing his conclusions from the study. What conclusions were supported were either not reported, were misreported or were not relevant to diving.

And in addition to the fact that a 10-year old pre-production prototype Force Fin(R) was used during the tests where more current models from the other companies were evaluated, one has to wonder about a study that had more subjects than the number of variables examined (in this case, seven subjects were used to examine four variables at multiple exercise levels using six different fins). The validity of the conclusions are even more suspect when considering that two of the seven subjects were none other than Mr. Yee himself plus his project supervisor. The observer loses all objectivity when he himself is being studied!

What Yee failed to understand was that, for the most part, he wasn't testing <u>fins</u>, he was testing <u>people</u>, and the difference is enormous.

How a diver moves his/her fins through the water can be a much bigger factor in the fins' resulting performance than the design of the fins. Efficiency and propulsion are effected by many factors including kicking style, physiological characteristics, and individual preferences in addition to the choice of fins.

A great disservice is being done to the diving community by those promoting or endorsing this study. The losers are the divers and the diving instructors who have been kept from learning about truly innovative products and technological advances. Products that not only make diving more enjoyable but safer as well. Products like the Force Fin(R).

#######

<u>About the Author:</u>

Bob Evans is a dive industry pioneer who was originally certified by the County of Los Angeles in 1966. He was recently issued an SSI Pro Certification, an honorary certification given to divers who have logged over 5,000 dives and have made significant contributions to diving over the past 10 years.

FORCE FIN.

28 Anacapa Street
Santa Barbara, CA 93101
1-800-FIN-SWIM®
805-966-9628
Fax 805-564-8240

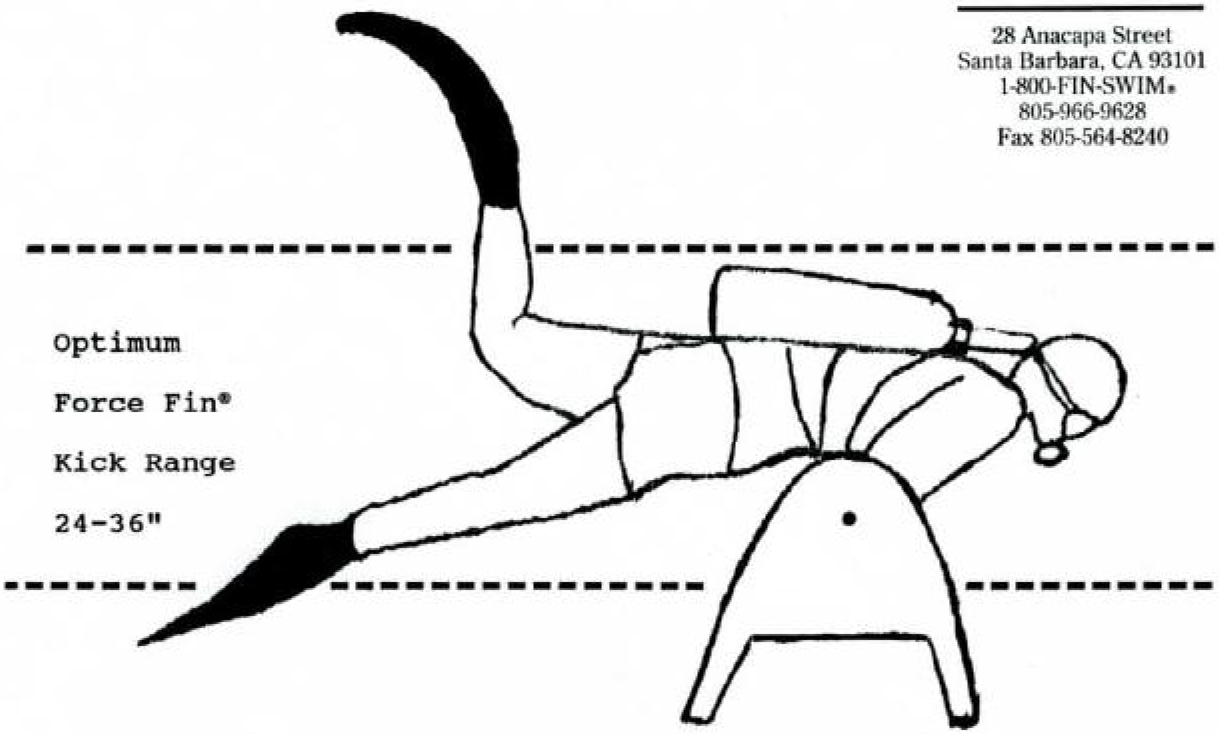


Illustration Caption:

This is a tracing of a photograph shot from the actual video images taken during the study. The subject is kicking with the Force Fins. Note how the left leg is in an exaggerated position in relation to the body's line of motion. This is the WRONG way to kick with Force Fins, creating more drag due to poor streamlining and reducing needed propulsive lift forces.

An Evaluation of Diving Fins
REVISITED

by Michael T. Yee, M.S., NAUI# 11414

Ed. note: This article was submitted by the author as a partial response to, "A Review: 'A Kinesiological Evaluation of Diving Fin Design and Performance'," by Fred Calhoun, P.E., which appeared in Sources, Nov./Dec. 1992.

The origin of diving fins dates back to 1690, when Borelli invented a pair of claw-like fins. However, footwear for the swimming diver disappeared until they were re-discovered by Commander de Carlieu in 1930. Since then, diving manufacturers have been busy redesigning Borelli's fins and proclaiming their new products to be the best fins ever developed. Naturally, these conflicting claims have caused a tremendous amount of confusion within the diving community, and numerous attempts have been made to clarify the situation.

Comparative fin studies began as early as 1954, but it was not until 1974 that an exhaustive study of diving fins was performed. With a highly innovative experimental design, Picken and Crowe eliminated the individual differences found between divers (such as height, weight, leg strength, and endurance) by completely eliminating the diver. Instead, they constructed a motorized leg to which they attached a variety of fins. Force applied to the artificial leg was converted into thrust, which propelled the entire assembly across a tank of water.

In 1977, McMurray used physiologic parameters to determine fin efficiency. Workload, heart rate, and aerobic capacity were measured for five fins and followed by a series of sprint trials. His work immediately suggested that fins with large surface areas were more aerobically efficient than smaller models. In another study, Mekjavic, Rowe, and Morrison (1982) arrived at the same conclusions. They found that their large fins (940 cm^2) performed better than a smaller (540 cm^2) fin. The large fins produced a significantly lower VO_2 value than the smaller fins (46.99 mL kg^{-1} min^{-1} and 50.85 mL kg^{-1} min^{-1} respectively). These smaller fins also required higher kick frequencies and rates of respiration.

During the past decade, however, space-age plastics have radically altered diving fin design. In 1991, I conducted a study that reevaluated the modern fin. Seven experienced divers, including two NAUI Instructor Trainers and three Instructors, participated in this research project at UCLA. My goal was to compare a group of six fins and identify the primary architectural characteristics that determined propulsive efficiency. Each subject tested the fins listed in Table 1 in a 25-yard underwater sprint and on a submerged diving ergometer (see Figure 1). Tests with the ergometer (the scuba world's equivalent of a treadmill or stationary bicycle) provided heart rates and respiration rates for three increasingly intense exercise workloads.

Statistical analysis of the data (paired dependant T-tests, 1-tailed, alpha = 0.05, 95% confidence interval) indicated that significant differences in diver heart rates occurred as the exercise workloads increased (see figure 2). While no differences were observed at the lowest workload (9 lbs), significant ones did appear during the moderately intense, 12-pound workload. Trials with the largest fins (fin #1) produced significantly lower heart rates than the trials with the smallest design (fin #6). And, during the highest workload (15 lbs), fins #1, #3, #4, and #5 produced lower heart rates than fin #6. The larger fins reduced the amount of effort required to maintain a given workload, especially at higher exercise intensities, and can reduce fatigue significantly.

Larger fins also reduced air consumption at every exercise workload (see figure 3). Respiration rates fell significantly while using fins #1, #3, and #4; but rose during the testing of fin #2 (the stiffest model) and fin #6 (the smallest). Obviously, reduced air consumption results in longer dives and greater air reserves at the end of a dive for emergency situations.

The strongest evidence for the superiority of larger fin surface areas over smaller models was observed during the 25-yard sprint, a test of maximal effort. The results of this test appear in figure 4. Statistical analysis confirmed that the large fins were significantly faster than all four of the medium length models, and that all

Table 1: Fin Surface Areas

	Name	Area**
Long fins:		
Fin #1	Plana Concorde	935 cm^2
Medium fins:		
Fin #2	Spectrafin	665 cm^2
Fin #3	Reeflex	641 cm^2 (3 soft battens)*
Fin #4	Reeflex	641 cm^2 (3 firm battens)*
Fin #5	Sea Wing	631 cm^2
Short fins:		
Fin #6	Force Fin	502 cm^2

* The Wenoka Reeflex was the first fin designed with interchangeable battens which allowed divers their choice of fin stiffness. Three soft battens represented the most flexible configuration while three firm battens specified the least flexible.

** Calculation of fin blade surface areas excluded foot pocket region.

of these were faster than the small fins. In fact, fin #1 was the fastest model for 6 of the 7 divers, and fin #6 was the slowest for EVERY subject.

Thus, fin-blade surface area appears to be the primary architectural feature determining the overall performance characteristics of a diving fin. Larger models had higher maximum velocities, reduced air consumption, and had lower heart rates during intense exercise than their smaller rivals. Fin flexibility also seemed to be a major factor and may explain why fin #2, the stiffest fin to be evaluated, performed below expectation. Lastly, architectural features, such as vents, had an even smaller influence on fin efficiency. The only significant differences between a vented fin (fin #5) and another medium-length fin design (fin #3) was found in the rate of respiration at the 15-pound workload.

McMurray (1977) and Mekjavic *et al.* (1982) were the first people to show that small fins could not perform as well at larger fins. What was true then is still true today. Contemporary designs reduced heart rates and breathing rates, and increased the maximal swimming speed for divers. Most importantly, the difference between these fins increased in high performance situations and during heavier exercise workloads. As a result, fins with surface areas exceeding 600 cm^2 made diving easier, safer, and more enjoyable.

The author holds B.S. and M.S. degrees in Kinesiology from UCLA. He was the UCLA Scuba Program Coordinator from 1987 through 1989 and oversaw recreational and instructional scuba affairs there, under the supervision of Dr. Glen Egstrom. At UCLA, he had the opportunity to investigate diving accidents and also to do research on DCS, dive tables, and diving computers in laboratory conditions.

Figure 1: Diving Ergometer

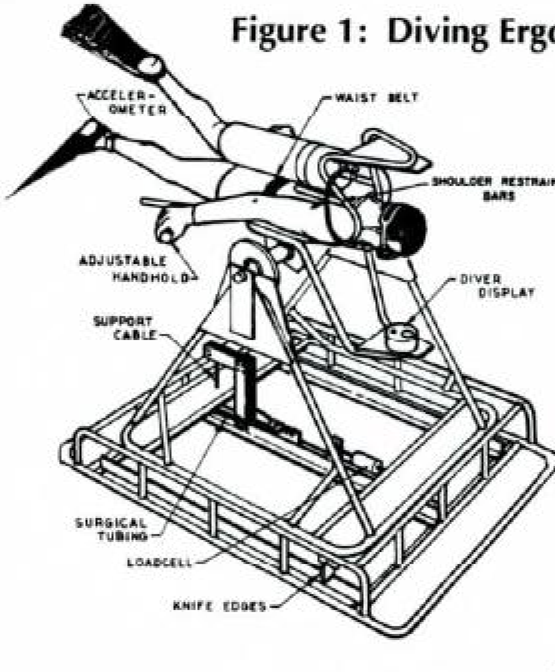


Figure 2. Average Heart Rates

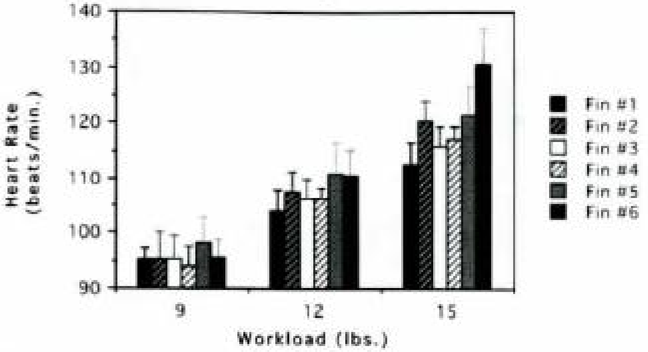


Figure 3. Average Rate of Respiration

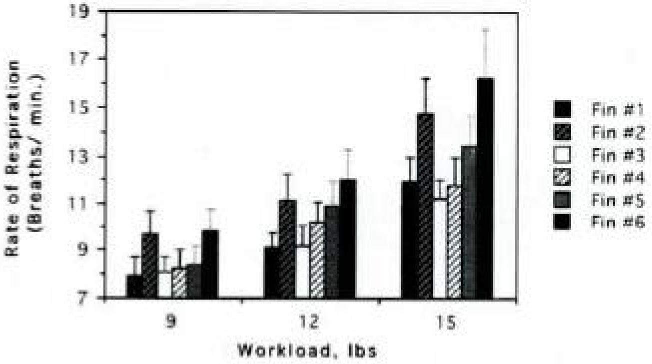
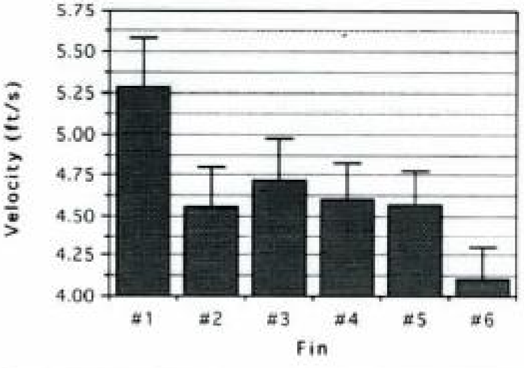


Figure 4. Average Sprint Velocity



References

McMurray, R.G. 1977. "Comparative Efficiencies of Conventional and Super-Swimfin Designs." *Human Factors.* 19: 495-501.

Mekjavic, I.B. 1986. "Evaluation of Diving Fins on the Basis of Physiological Responses during Incremental Exercise." *Annals of Physiological Anthropology.* 5: 197-203.

Mekjavic, I.B., P.A. Rowe, and J.B. Morrison. 1982. "Ergonomic Considerations of Fin Size for Working Divers." *Proceedings of the Human Factors Society — 26th Annual Meeting,* Seattle, Washington, USA. p. 525-529.

Yee, M.T. 1991. *A Kinesiological Evaluation of Diving Fin Design and Performance.* Unpublished Master's Thesis. University of California, Los Angeles.