The Cost of Using Dive Fins

by

Alfred Nash, Ph.D.

Over the years, there have been many articles written about the relative efficiency of various diving fins. Several research studies[1] have claimed to find a relationship between fin surface area and oxygen uptake. In particular, these studies have all proposed that fins with a large surface area were more aerobically efficient than fins with smaller surface areas.

If only it was that simple. In the case of dive fins, factors including, but not limited to, the kicking style, physiological characteristics, and individual preferences of the subjects in a study can greatly influence the measured efficiency of diving fins. How a diver moves their fins through the water can be a bigger factor in the fins' resulting efficiency than the design of the fins. That is why two divers can use identical dive fins and get very different results.

There is, however, an inherent energy cost to moving any dive fin through the water. This is the energy that must go into fighting hydrodynamic drag forces on the fin as it moves back and forth through the water. The larger the surface area of the fins, the larger these hydrodynamic forces are. Therefore, more strength is needed to be able to kick with larger fins. Not only does one need to be stronger to move a large surface area fin, it uses up a diver's energy *faster* to kick at a given rate with larger fins than with smaller fins.

These are just simple facts due to the laws of physics.

The force necessary to move a flat object (such as a dive fin) through the water is given by the formula

$$F_D = C_D \frac{1}{2} \rho A V^2$$

where

- V = the speed with which the object moves through the water
- A = the surface area of the object
- ρ = the density of water
- C_D = a "coefficient of drag" that depends on the shape of the object, and the angle at which it moves through the water.

The rate at which a diver must expend their energy fighting hydrodynamic drag forces acting on their fins is equal to the product of the drag force on the fin and the velocity of the fin through the water.

$$P = F_D \cdot V$$

Experiments to determine C_D for various objects[2] indicate that the values of C_D should not vary more than a few percent between different models of dive fins. Therefore, kicking style, kicking speed, and everything else being the same, the surface area of the fin is what determines the strength required of, and the rate energy is drained from, a diver. The larger the surface area of the fins, the more strength that is needed to be able to kick with them. The larger the surface area of the fins, the faster it uses up a diver's energy to use them.

In addition, it should be noted that the more parallel a fin blade is to the direction it moves through the water, the smaller the drag forces on it will be. Therefore, the stiffer a fin is, the larger the drag forces on it will be and the faster it uses up a diver's energy to use them.

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[1] R.G. McMurray, *Comparative Efficiencies of Conventional and Super-Swimfin Design*, Human Factors. 19 495 - 501 (1977).

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

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

[2] See R.D. Blevins, Applied Fluid Dynamics Handbook, Van Nostrand Reinhold, pub. (1984).

Adjustable Calculation

Kick Cycles/Minute	25.00	Cycles/Second			0.42		
(+/-) Kicking Angle (degrees)	45.00	(radians)			0.79		
Hip to Fin Distance (inches)	36.00	(meters)			0.91		
Angle Between Leg & Fin (deg	0.00	(radians)			0.00		
Arc Length (meters)	0.72						
Foot Velocity (m/s)	0.60						
Density of water (kg/m^3)	1000.00						
						← HP FIXED →	
		KICK CYCLES FIXED →				hp limit	
			Est.			0.125	
	Area	Aspect	Coeff c	Power	Power	Est. Kicking	Limit Kick
Fin	(cm^2)	Ratio	Drag	(Watts)	(hp)	Speed Limit	Cycles/Minute
Force Fin	680.00	0.67	0.97	7.07	0.01	1.41	59.0692177
Scuba Pro Sea Wing	864.00	0.34	1	9.26	0.01	1.29	53.9862946
Sea Quest Accelerator	997.00	0.34	1	10.69	0.01	1.23	51.4702624
Tekna Spectra-Fin	1003.00	0.35	1	10.75	0.01	1.23	51.3674244
Mares Power Plana Graphite	1019.00	0.34	1	10.92	0.01	1.22	51.0971534
Wenoka Reflex	1032.00	0.33	1	11.06	0.01	1.22	50.8816909
Mares Plana Avanti	1038.00	0.33	1	11.13	0.01	1.22	50.7834635
						hp limit	
			Est.			0.125	
	Area	Aspect	Coeff c	Power	Power	Est. Kicking	Limit Kick
Fin	(cm^2)	Ratio	Drag	(Watts)	(hp)	Speed Limit	Cycles/Minute
Force Fin	680.00	0.67	1	7.29	0.01	1.40	58.4725181
Scuba Pro Sea Wing	864.00	0.34	1	9.26	0.01	1.29	53.9862946
Sea Quest Accelerator	997.00	0.34	1	10.69	0.01	1.23	51.4702624
Tekna Spectra-Fin	1003.00	0.35	1	10.75	0.01	1.23	51.3674244
Mares Power Plana Graphite	1019.00	0.34	1	10.92	0.01	1.22	51.0971534
Wenoka Reflex	1032.00	0.33	1	11.06	0.01	1.22	50.8816909
Mares Plana Avanti	1038.00	0.33	1	11.13	0.01	1.22	50.7834635

746 watts per HP

.125 = 90 watts

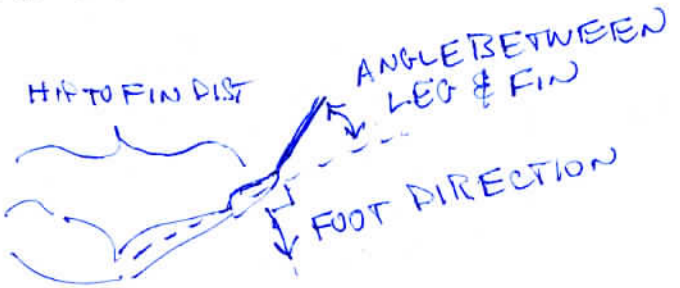
BICYCLISTS

RECREATIONAL

1/8 HP

ELITE

1/4 – 1/2



Adjustable Calculation

Kick Cycles/Minute	25.00	Cycles/Second			0.42		
(+/-) Kicking Angle (degrees)	45.00	(radians)			0.79		
Hip to Fin Distance (inches)	36.00	(meters)			0.91		
Angle Between Leg & Fin (deg	30.00	(radians)			0.52		
Arc Length (meters)	0.72						
Foot Velocity (m/s)	0.60						
Density of water (kg/m^3)	1000.00						
						hp limit	
			Est.			0.125	
	Area	Aspect	Coeff c	Power	Power	Est. Kicking	Limit Kick
Fin	(cm^2)	Ratio	Drag	(Watts)	(hp)	Speed Limit	Cycles/Minute
Force Fin	680.00	0.67	0.97	6.12	0.01	1.48	61.970406
Scuba Pro Sea Wing	864.00	0.34	1	8.02	0.01	1.36	56.6378349
Sea Quest Accelerator	997.00	0.34	1	9.25	0.01	1.29	53.9982276
Tekna Spectra-Fin	1003.00	0.35	1	9.31	0.01	1.29	53.8903387
Mares Power Plana Graphite	1019.00	0.34	1	9.46	0.01	1.28	53.6067934
Wenoka Reflex	1032.00	0.33	1	9.58	0.01	1.28	53.3807484
Mares Plana Avanti	1038.00	0.33	1	9.63	0.01	1.28	53.2776965
						hp limit	
			Est.			0.125	
	Area	Aspect	Coeff c	Power	Power	Est. Kicking	Limit Kick
Fin	(cm^2)	Ratio	Drag	(Watts)	(hp)	Speed Limit	Cycles/Minute
Force Fin	680.00	0.67	1	6.31	0.01	1.47	61.3443996
Scuba Pro Sea Wing	864.00	0.34	1	8.02	0.01	1.36	56.6378349
Sea Quest Accelerator	997.00	0.34	1	9.25	0.01	1.29	53.9982276
Tekna Spectra-Fin	1003.00	0.35	1	9.31	0.01	1.29	53.8903387
Mares Power Plana Graphite	1019.00	0.34	1	9.46	0.01	1.28	53.6067934
Wenoka Reflex	1032.00	0.33	1	9.58	0.01	1.28	53.3807484
Mares Plana Avanti	1038.00	0.33	1	9.63	0.01	1.28	53.2776965

Adjustable Calculation

Kick Cycles/Minute	25.00	Cycles/Second			0.42		
(+/-) Kicking Angle (degrees)	45.00	(radians)			0.79		
Hip to Fin Distance (inches)	36.00	(meters)			0.91		
Angle Between Leg & Fin (deg	60.00	(radians)			1.05		
Arc Length (meters)	0.72						
Foot Velocity (m/s)	0.60						
Density of water (kg/m^3)	1000.00						
						hp limit	
			Est.			0.125	
	Area	Aspect	Coeff c	Power	Power	Est. Kicking	Limit Kick
Fin	(cm^2)	Ratio	Drag	(Watts)	(hp)	Speed Limit	Cycles/Minute
Force Fin	680.00	0.67	0.97	3.53	0.00	1.78	74.4225508
Scuba Pro Sea Wing	864.00	0.34	1	4.63	0.01	1.63	68.018469
Sea Quest Accelerator	997.00	0.34	1	5.34	0.01	1.55	64.848467
Tekna Spectra-Fin	1003.00	0.35	1	5.37	0.01	1.55	64.7188993
Mares Power Plana Graphite	1019.00	0.34	1	5.46	0.01	1.54	64.3783792
Wenoka Reflex	1032.00	0.33	1	5.53	0.01	1.53	64.1069135
Mares Plana Avanti	1038.00	0.33	1	5.56	0.01	1.53	63.9831546
						hp limit	
			Est.			0.125	
	Area	Aspect	Coeff c	Power	Power	Est. Kicking	Limit Kick
Fin	(cm^2)	Ratio	Drag	(Watts)	(hp)	Speed Limit	Cycles/Minute
Force Fin	680.00	0.67	1	3.64	0.00	1.76	73.6707564
Scuba Pro Sea Wing	864.00	0.34	1	4.63	0.01	1.63	68.018469
Sea Quest Accelerator	997.00	0.34	1	5.34	0.01	1.55	64.848467
Tekna Spectra-Fin	1003.00	0.35	1	5.37	0.01	1.55	64.7188993
Mares Power Plana Graphite	1019.00	0.34	1	5.46	0.01	1.54	64.3783792
Wenoka Reflex	1032.00	0.33	1	5.53	0.01	1.53	64.1069135
Mares Plana Avanti	1038.00	0.33	1	5.56	0.01	1.53	63.9831546

3% less drag not significant

optimum cadence for cyclists = 75 rpm

cannot reach optimum w/other fins

Need to measure radian max for fins*

up to 50% differential