The Hidden Power In Karate Movements

Black Belt Thesis

Greg George Sr.

Table of Contents:

Introduction:

There are many opinions about the uses of karate and other martial arts and their real life applications. As a sport, hobby or self defense system, karate students usually have a desire to master their art and do things right and proper, so power in karate movements is important to them. It has long been a help to karate students to gauge their progress in karate training. One of the ways to gauge progress is to measure power.

As a mode of self defense, power in karate is essential. John Vengel, a teacher of Shoto Kan in California has written an "Alphabet of Destruction" relating to the real life application of Karate as self defense. Mr. Vengel has an axiom for every letter of the alphabet. The first two letters of this 26 part guideline are:

A. Protect yourself at all times.

B. Every time you move, hit them, and every time you hit them, hurt them.

Obviously when defending yourself, economy of movement and getting out of the situation as quickly as possible is very important. Power in your karate techniques is essential in self-defense.

Movies, books, magazines and folklore have sometimes alluded to an almost magical or supernatural power that comes from extensive training in Karate.

We will not address the supernatural in this paper, but we will investigate where the physical power comes from, and how to improve our power in the practical application of both dojo study and self-defense.

In discussing this power, there have been many studies conducted over the years with some revealing results. I will attempt to sift through all of the material that I could find and try to glean from others how to increase power. Although there may be some belief and evidence in power being derived from some inner spiritual strength, I would like to examine the mechanical aspects of where the power comes from physically, and how we as Karate Ka can gain more power from refining our movements.

This may seem like refresher course in high school physics, but it is very important to understand where the power comes from if you plan to improve as a karate student. I would imagine that every student has been told over and over again how to involve their hips in certain techniques; I will attempt to show why hips and many other nuances of karate movements are important.

I find it amazing that so many hundreds of years ago, without computer analysis, pocket calculators or advanced math., that such superb movements and techniques were developed to such an extent as to call it an art.

Mathematical Aspects of Karate:

F=ma	Vf=g x t
A=dv/dt	f/m=f/m
A=?V/t	Vf=Vi + a * t

To take karate apart mechanically and analyze where the power comes from, we will use formulas normally used for general physical principles. Applying mathematical analysis to karate can shed a great deal of light on the mysteries of karate.

It is difficult to apply "mechanical" physics to the human body. People are not machines. They are not nearly as consistent as machines at applying the same forces in the same directions with the same movements day after day, or even minute to minute. In order to compare and analyze data we must level the playing field and assume consistent mechanical movement when talking about applying these concepts to karate. In other words, we must assume that the person actually behaves like a machine. The person we are using as an example must perform certain movements the same way (within reason) every time he repeats the movement, everyday. This will allow us to measure, change and measure again to see if there was improvement in power.

Before we start taking apart some basic movements, we must define some terms so that we all understand this analysis the same way.

Definitions (in alphabetical order)

Acceleration: Acceleration is often thought of as movement; however it is actually the rate of change in the velocity of a moving mass. Acceleration is used to measure a speeding up, or slowing down of a moving mass. If a mass is traveling at a steady velocity, it has no acceleration. Acceleration is actually measured as the rate of change in the speed of movement or a=f/m. Another way to calculate acceleration is a= dv/dt, or acceleration equals the difference in velocity divided by the difference in time.

Dynamic Force: This is really the same concept as kinetic energy. Dynamic force is the force a mass has because of both its weight, and the velocity that it is moving.

Force: Force is a unit of exertion, usually measured in pounds, newtons or kilograms per unit of area such as a square inch or square meter. Generally in the United States we use pounds per square inch. In most other countries using the metric system, many variations are used such as: kilograms /square meter and Newtons /square millimeter.

Impulse: Impulse is a product of a mass applying force to another mass with a time component. Usually when using impulse, we are talking about very short periods of time such as milliseconds.

Inertia: This term describes a body or mass resisting movement, or resisting the stopping of movement. In a nutshell, inertia is the tendency of a body to resist changes in velocity. The more inertia a body has, the harder it is to move, and the harder it is to stop. This is

related to Newton's first law of motion; a body at rest wants to stay at rest, and a body in motion wants to stay in motion.

Kinetic Energy: This is energy from a moving mass. This energy is measured in mass multiplied by velocity.

Mass: Mass is really the amount of matter something is made up of. Literally, the neutrons protons, and electrons added together. If you multiply mass times gravity, the product is weight.

Momentum: Newton called momentum the "quantity of motion" or a product of mass times velocity.

Potential Energy: Basically this is the same as static force. A good example would be a bowling ball sitting on a flat roof. The force that the ball is exerting downward on the roof is potential energy until for some reason it rolls off the roof. As soon as it rolls off, its energy would be kinetic.

Static Force: This is force acting on a mass but not sufficient to move the mass, such as a person leaning against a wall. You exert force on the wall, but the wall doesn't move.

Torque: Torque is the force that causes rotation around and axis. As applied to karate, torque is generated through muscles to cause rotation of shoulders, hips or both.

Work: Work is force applied to a mass sufficient enough to cause the mass to move. Usually measured in units of power and time, generally work is put in units called horsepower or kilowatts.

Force, Mass and Acceleration Explained:

The study of these three terms makes up most of what is called a mechanical or kinematic study. The formula $f = ma$: "force equals mass times acceleration" is the most basic of formulas that we will be discussing here. However, as we will see, there are many factors that need to be considered when measuring mass as well as acceleration and how it applies to karate. We will also use the formula for kinetic energy: $KE=\frac{1}{2}*m*V^2$ where m=mass and V=velocity.

The first thing we need to examine is force. It is good to remember that force is not "work". Force is pressure or energy that is actually transferred from one body to the other. This force may or may not cause motion, but if it does, you can measure the work. Newton, in his three laws of motion covers inertia, movement and interaction of masses. You may have been taught in school about the concepts of "potential energy" and "kinetic energy" as forms of energy used in physics. In this study we are dealing mostly with kinetic energy, or the energy transferred from one mass to another as a result of mass and acceleration in a karate technique.

Dynamic force strong enough to overcome inertia, when applied to a mass causes movement. This is the force transferred when one moving mass comes in contact with

another mass that is not moving, moving in the opposite direction, or moving slower in the same direction. This concept is often called "momentum transfer". In karate application this happens when we strike an opponent or a target. The amount of momentum transfer that you exert on an attacker could be the difference between a long struggle, and a very short fight that may take only one strike to finish. Most karate students are taught that the faster and more powerful an attack is dealt with, the better the chances are for a positive outcome.

Properties of Mass and Acceleration

These two components can be examined together as they are the components that produce force. If the total mass is increased during a movement, then force is increased. The same can be said of acceleration or velocity, the more you increase it, the more force you will exert. For our purposes here, we are generally hitting another mass that is not moving (a target or opponent) with a moving mass (our fist, knee, elbow or foot).

When considering acceleration, most punches and kicks do not leave their home and travel to their target at a constant speed. If technique is proper, a punch or kick will be increasing in velocity the entire time it is traveling to its target. This is especially true of a kick because of the natural whipping action that happens when the foot reverses direction.

We mentioned earlier, that force is not work. Work is done when force is applied over time. When movement or rotation takes place, actual "work" is done. Work can be better described as "Force times distance, divided by time". In America we most

commonly measure work using the term "Pound Feet" or "Horsepower". The term horsepower comes from a man named James Watt. He was an English scientist who lived back in the 1600's. Mr. Watt was trying to quantify the amount of work a horse could do. A simple job of raising pots of water from a deep coal mine was his test bed. He determined through testing that an average horse could pull a 150 pound pot of water, 220 feet vertically out of a mine in one minute. This became known as 33,000 foot/pounds per hour or 550 foot pounds per minute. Ever since then we have been measuring all kinds of work in Horse Power.

In the application of Karate, force alone is incomplete. Force by itself does not fully describe a punch or kick hitting a target or opponent. If the target is hit by a moving mass (a fist, elbow or foot) the moving mass will need to transfer momentum and penetrate the plane of the target. Most likely the target will move or change shape. This is clearly what happens when someone is hit in the torso. The opponent may not move back a great deal, but the strike changes the shape of their abdomen for a short period of time. Eventually this force finds its way throughout the body and the body moves. As the target moves, work is done. When this actual "work" is being performed the target can measure the work by measuring how far it was moved, and how fast it moved.

Application of the Analysis

We will use a Zenkutsu dashi reverse punch for our study. First, let's establish some mass properties that will stay constant throughout this study. We will consider a man's

arm as a projectile with a weight of 53.8 ponds per cubic foot. We arrive at this by taking the specific gravity of human flesh (.90) and multiplying it by the weight of a cubic foot of water, which is 59.8 pounds. We now need to establish the mass of the arm that will be performing our technique. A typical man's arm should be about 288.6 cubic inches and a weight of .0311 pounds per cubic inch. This would give us an assumed arm weight of 8.97 pounds.

The velocity of the punch now needs to be established. Obviously different people will have different speeds for their punch. Also, speed will increase with skill level. We will start with an average speed so that we can increase speed with skill later in the example. We will start with a reverse punch that takes .4 seconds or 400 milliseconds. For an experienced student, this is not very fast, but this will give us room to improve and model the amount of power that can be gained transitioning from a beginner to an advanced student.

We will set the distance of the punch is 24"; we will keep this distance through the entire example. Twenty four inches at .4 seconds is equivalent to 5 feet per second. If we apply our formula, $KE=1/2*m*V^2$, then the force equals $½*8.97 \times 5^2$ or 112.125 pounds. See the chart below to examine the power difference gained through speed alone.

The Effects of Speed on a Reverse Punch			
Time	**Speed**	**Weight**	**Force**
0.4	5	8.97	112.12
0.35	5.71	8.97	146.22
0.3	6.67	8.97	199.53
0.25	8	8.97	287.04
0.2	10	8.97	448.5
0.15	13.33	8.97	796.93
0.1	20	8.97	1794

As you can see, the results are very predictable. As speed is increased, the power to the target increases proportionally. In this theoretical realm, the results are very linear, we increased the punching speed 4-fold and the force increased 16-fold.

In our next model we will connect more mass from the student's body and keep the velocity of the punch constant. We will use the same formula for kinetic energy as before. The same results we see in our speed model can be accomplished by connecting more mass to the punch instead of speed. The increase in mass is being estimated as the skill of the student improves and involves more of his body in the technique. See the chart below for the results of connecting mass to a constant punch speed.

The Effects of Mass For Standard Reverse Punch			
Time	**Speed ft/sec**	**Weight**	**Force**
0.4	5.00	8.97	112.12
0.4	5.00	13.455	168.18
0.4	5.00	17.94	224.25
0.4	5.00	22.425	280.31
0.4	5.00	26.91	336.37
0.4	5.00	31.395	392.43
0.4	5.00	35.88	448.5

Again you can see that increasing weight 4-fold increases the force 4-fold. However, adding this kind of mass to your reverse punch may not seem as intuitive as adding speed. I believe however, that most of the advanced teaching done in the Dojo is helping us to connect mass to our strikes and kicks. It may not seem at first glance that it is easy to connect more mass to karate movement, but we will see later in the report that there are several ways to connect more mass. It may also look like increasing mass four-fold is not achievable, but actually numbers much higher than this are possible with proper teaching.

For the last part of this reverse punch example, we will add mass and speed together to see how it affects the force of the punch. With each progression we will add speed and mass in the same increments as in the other charts above.

The Effects of Speed and Mass For Standard Reverse Punch			
Time	**Speed ft/sec**	**Weight**	**Force**
0.4	5.00	8.97	112.12
0.35	5.71	13.455	219.34
0.3	6.67	17.94	399.06
0.25	8.00	22.425	717.6
0.2	10.00	26.91	1,345.5
0.15	13.33	31.395	2,789.27
0.1	20.00	35.88	7,176.0

Now you can appreciate the power that can be gained by increasing the mass and the speed 4-fold each. The force increased 64-fold as a result of increasing speed and mass.

The resistance to this transference of force is called inertia. Inertia can be described as the desire of a motionless mass to stay motionless, or the desire of a moving mass to stay moving.

A heavy bag or an opponent in a kumite match has inertia that is a product of their mass (we will keep the units in pounds during this study instead of slugs for our calculations) Most mass calculations attempt to ignore gravity. In the application of karate, gravity is constant and equal t all students.

Generating The Power (practical application in movement)

As we saw in the reverse punch model, a great deal of power can be added to a technique by adding mass and speed. It is very easy to throw numbers at these techniques and see how the theoretical power increases, but how do we actually make this happen in our karate technique?

I think that you will be surprised to find out that if you study karate from a good Sensei, you will see that you are already taught all of these principles. We will take a look at the common training techniques used in a dojo and examine how they add mass and speed.

First we will look at adding speed. There are several things that karate students are typically taught to increase speed. We will look at all of these individually:

Pulling Hand:

In applying a punch toward a target or opponent, speed can be increased by pulling the opposite hand into the chamber. The returning mass increases the acceleration through the shoulders to speed up the out-going hand. The faster the returning hand moves, the faster the out-going travels. Newton's third law of motion states that "for every action, there is an equal and opposite reaction". The pulling hand action "reacts" through the shoulders and increases the mass o the punch.

Muscle Tension:

The individual muscle groups of the body work together to apply the proper movement as your brain directs them. The stiffness of the arm muscles are required to transfer the momentum from the fist to the target. Without muscle stiffness in the arm, the fist would only transfer the mass of the arm to the target. Muscle stiffness aligns bones and connects the arm to the rest of the body. Keeping the muscles in the arm relaxed until the moment of contact increases speed. This technique also conserves energy. The muscle tension is only required at the very end of the punch. The downside to this tension is that when you tense the arm during the punch, the punch slows down. This is why the muscle tension should be saved until the end of the punch. This practice takes extensive training but when applied to a punch it will increase power and speed greatly.

We have already seen mathematically how adding mass to a technique will add power. I believe that more time is spent in training, adding mass to technique than any other

teaching in karate. There are several ways to add mass; and we will discuss them individually below.

Pulling Hand:

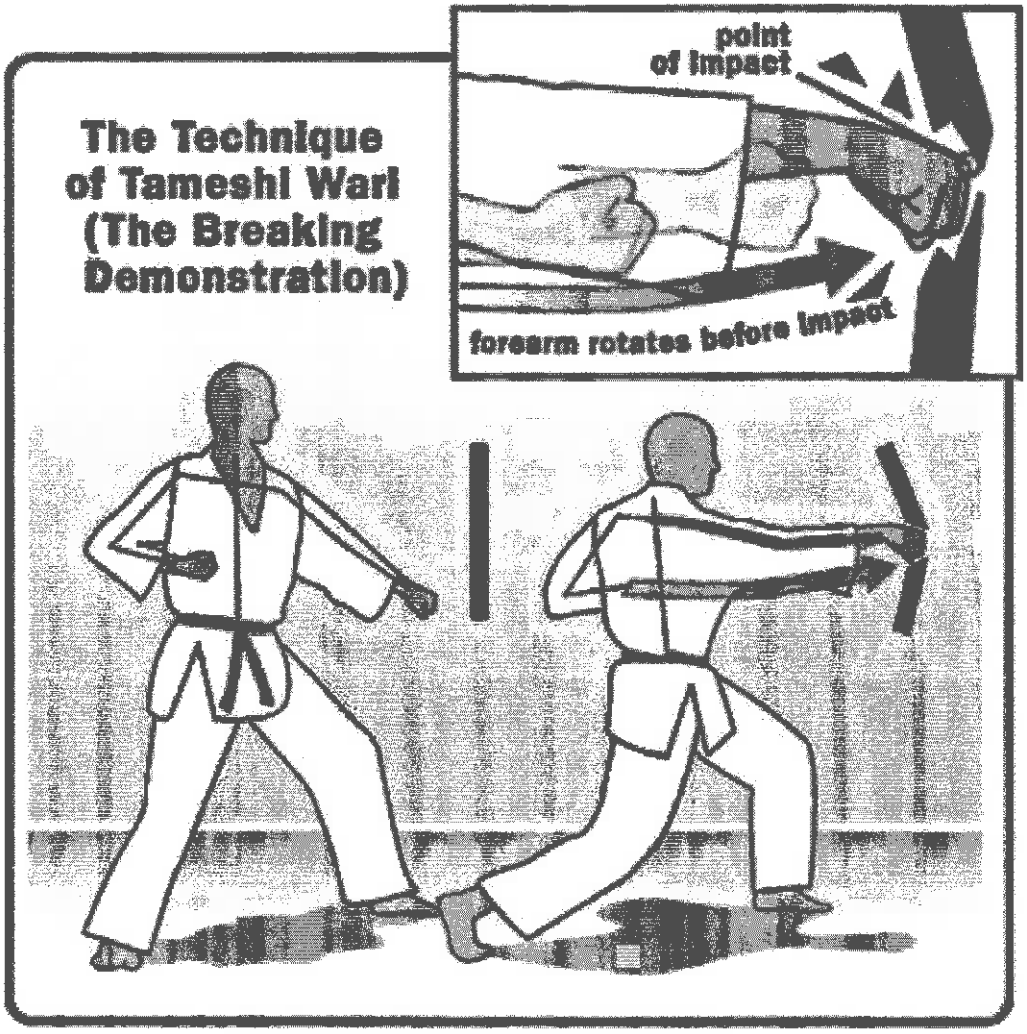
We have already discussed how the pulling hand can increase speed, but even more importantly you can add mass by involving other parts of the body in the technique. One of the easiest opportunities to add power is to involve the pulling or returning hand. This hand returns as the primary punching hand is moving out. Remember our average arm weight is 8.97 pounds. If we take an average punch speed of .25 seconds we see a force of 717.6 pounds exerted to the target. If we could add the entire mass of the returning arm efficiently through the shoulders, the mass of the punch doubles. If the mass doubles and the speed stays the same, then the force at the target doubles to 1435.2 pounds. We need to keep in mind that these techniques for adding mass are theoretical and based on perfect timing. In order to get pure efficiency from the added mass, it would need to be perfectly timed to the movement of the other hand. This timing and focus is called "kime". This kime also requires extensive training to teach your body to move fluidly and tense the proper muscles at the instant of impact.

Hip Movement:

Probably no other movement outside of actual techniques is taught more in karate. Probably no other body involvement technique is more difficult to master than involving hips. Hip rotation and advancement of hips can add more mass than any other mass

adding technique. Just as adding mass through the shoulders from the pulling hand, your hips add mass through your lower body. A large percentage of the mass of your lower body can be added to your technique by rotating hips through the axis of your pelvis. See the graphic below to illustrate the paths of force through the axes of the hips and shoulders.

This transfer of mass through the shoulders or hips is called "rotational dynamics". This same concept is used in rotating machinery to balance and add mass to a rotating arm doing work. You could imagine how unstable a lawnmower would be if the blade was one-sided. This would be a very unbalanced condition. Imagine a lawnmower blade coming in contact with a tree stump. One end of the blade comes in contact with the immovable object, the opposite "balancing" side of the blade that is not hitting the tree stump, adds all of its mass through the rotational axis to the other blade and doubles the force.



As you can see in the above illustration, our student at the beginning of the technique has his hips open, somewhere around a 45 degree angle to the target. At the end of the technique the hips have rotated to a perpendicular (or 90 degree angle) to the punch. When this can be accomplished efficiently, a large percentage of the student's torso mass is connected to the punch. You will also notice that the student's opposite hand is pulled back into the chamber at the focus point of his punch.

Lester Ingber states in his book "Karate: Kinematics and Dynamics" that this relationship of mass and speed is very important:

> *To achieve both mass and speed, the arm or leg which has been just previously shot from the torso and stance can be tensed just before impact, then reconnected to the torso, and thus to the large mass of the lower body which is connected to the ground by the stance leg(s).*
> *However, while this technique attaches a large mass to the limb, it eventually slows the limb down. There is a compromise possible such that a large momentum (mass x velocity) is available upon impact with the target. Depending on the target and the strategy, various proportions of mass and velocity may be selected to contribute to produce large momentum. This is the essence of "focus".*

Mr. Ingber brings up a point that we have not discussed yet. How does our connection to the ground affect all of this power or vice versa? Is our stance important, and are there stances that provide more power than others?

This connection to the ground or floor is very important. It only stands to reason that if you weigh 200 pounds and you exert a force of 400 pounds dynamically in a punch, on a horizontal plane, that you would be knocked back by the force of your own punch. There are a couple of reasons why this does not happen in typical application. One reason is that a punch force is applied for a very limited time. This reactive force is usually passing through your body for less than .5 seconds. This is not enough time to accelerate your body in the opposite direction of the punch. This reactive punch force ends up being "shock" to the person doing the punching. This shock is expected, muscles are tensed, bones are aligned and therefore the force is channeled through the body to the

floor through a good stance. The other reason that we don't fall over when we exert a powerful punch is that we generally lean toward the target and lower our center of gravity. When a stance like a Zenkutzu Dashi is used, the mass of the striking person and the shock of the blow takes a different path to the floor than a straight up punch. The force of the striking person changes to a two component force. The standard formula used for this problem is Cosign times the angle times the force of the blow. For example if a student leaned toward his target at a 45 degree angle, the 45 degrees multiplied by cosign is .707. You then multiply this product by the force of the punch. When using a 400 pound punch this equates to 283 pounds backward and 117 pounds upward (this is the force that would try to stand him back up straight). Thus the backward reaction of the punch is reduced by almost 30% just due to leaning forward.

Kiai:

A kiai is a short loud scream from the lower abdomen. It is a long held belief that the kiai adds power to your attack. Besides scaring an opponent, power actually does come from this exercise. As part of this action a proper kiai incorporates muscle tension through the abdomen at precisely the right time to transfer mass. This kiai helps to add the mass of the lower abdomen to the technique by attaching large muscle groups to the technique.

Kime:

All of these mass-adding techniques we have discussed require body timing to make them effective. Kime is what ties everything together. If hips, shoulders or a kiai are

early or late in a karate technique, the advantage is lost and power suffers. Timing or "kime" is an essential aspect of transferring maximum momentum to a target on impact. Tensing muscle groups and involving shoulders and hips has to be done at precisely the right time for these to be effective. All of the muscle groups involved need to tense together and all motion needs to stop at the same time for proper kime. This is a skill that is not easy for many students; it is possible that mastering this skill is a life-long study. If timing is wrong, you not only loose the mass you are trying couple to the technique, but you can actually take power away from the movement by adding mass in the wrong direction making part of the technique counterproductive.

Bone Alignment:

Students are taught from their first class that the focus of a punch is the first two knuckles on the punching hand. This may not seem very important, and in a good karate school this becomes habit as students are reminded regularly about this technique, but this is very important to the power that you generate in a punch. As you can see in the illustration above, our student at the point of impact has his bones in his shoulders aligned with his arm and the rotation of his whole torso is added to the strike. "Momentum transfer" is the technical term for applying force to a target. This transfer is made possible because of proper bone alignment. Here is another quote from Lester Ingber about bone alignment, and the muscle control needed around the joints to transfer this momentum.

> *A single technique typically requires at least two stances, one at its beginning and one at its end focus.*
> *The before-stance at the beginning is used to initiate large accelerations to gather up speed for the technique. The after-stance at focus is used to connect mass to this fast moving technique. If the body hardly moves, then the before-stance and after-stance may appear to be the same. But, more obviously, if a large shifting motion takes place, the before-stance and after-stance can be quite different.*
>
> *A rather subtle point is: What happens between before-stance and after-stance? Actually, this is the most important part of the technique, during which most of the work takes place while power is generated. The art is to somehow smoothly change the body kinematics, to go from stressing acceleration, to stressing mass connection, to maximize the momentum at focus. In general, each technique in the martial arts requires some special feelings to get this most efficient transition. Any small change of a joint angle and distance relative to neighboring joints changes the strengths, weaknesses, and maximal use of muscles across that joint. Although only the few basic physical principles discussed in this chapter are required to analyze and to help correct all techniques, each technique must be carefully and regularly practiced many times to achieve excellence.*

Conclusions:

We have examined a lot of concepts for connecting mass, adding speed and timing to increase the power to your karate movement and techniques. We have mathematically looked at how this happens and shed some light on how to increase hitting power. As we conclude this study, it would be good to summarize what we have learned.

Although we have proven that adding mass and speed coupled with timing is the key, there is nothing new or different about how to achieve this. If you study karate from a reputable Sensei at a reputable school you will be taught all of these concepts on how to increase mass and speed. Through repetition and instruction, starting very early by establishing good habits for incorporating hips, shoulders, pulling hand, muscle tensing, bone alignment, proper use of timing and the kiai to connect more mass.
Regular workouts and exercise will increase strength, flexibility and endurance so that you can master muscle tensing techniques and quickness that can increase your speed.

The power that can be achieved in martial arts can seem amazing and sometimes super-human, but once you understand the physics, the power is more believable. The most impressive skill in all of this study is the ability to control muscle groups in such a way as to amplify simple and complex movements to thousands of pounds of force.

Sources

Physics, Principles and Application **Harris, Hemmerling and Mallman**

Karate: Kinematics and Dynamics **Lester Ingber**

This thesis was accepted by the Japan Karate Association and the All-American Karate Federation as one of the requirements for their prestigious Instructor's degree, which he became the first Westerner to receive. By 1970, he integrated these studies with research into yin and yang attention processes, creating a scientific and practical teaching methodology promoting efficient in-depth learning of all aspects of this martial art. These concepts were published in 1976, in The Karate Instructor's Handbook and in its 1981 revision, Karate: Kinematics and Dynamics.

"Marks Handbook for Mechanical Engineers"

"Machinery Handbook for Mechanical Engineers"

JKA Shotokan Magazine Articles:
www.shotomag.com/content.asp?contenttype=Article&page_no=2&sortby=
"Physics of a Punch I" -Some Basic Physics
"Physics of a Punch II" –Utility of Physics Approach
"Physics of a Punch III" –Rationale for Other Training