# Parting The Clouds

The Science of the Martial Arts

A Fighter's Guide to the Physics of Punching and Kicking for Karate, Taekwondo, Kung Fu and the Mixed Martial Arts

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# INTRODUCTION

'The mind needs to be freed'
*Master Funakoshi*

## Purpose

I have been privileged to spend decades training amongst the mass of karateka who simply practice the art. These men and women just train. Year in, year out, they just train. They don't aspire to be high-ranking masters, they don't hope for any financial gain, trophies or recognition—ego has long since been beaten into its proper place. They train for their own reasons: karate has become part of them and they a part of karate. There is no point in asking why they do it, why they are apparently obsessed, for as the saying goes:

> *'To those that know, no explanation is necessary.*
>
> *To those that don't know, no explanation will suffice.'*

This book is for them, it is for you and for me. This book is for the martial artists who will spend months or even years struggling with the minutest detail—trying to get a foot, hand or body position right when performing a certain technique, working to co-ordinate the breathing in a particular kata but failing and accepting that perfection is elusive—yet nevertheless they continue to strive for that perfect moment. It is for those that thereby come to understand that there are no goals, no objectives, and the revelation is therefore clear: this is simply a journey, a way. It's a journey that takes a lifetime, no matter how long the life; there is nothing more—'Mu' or 'Wu'—nothing, no mind.

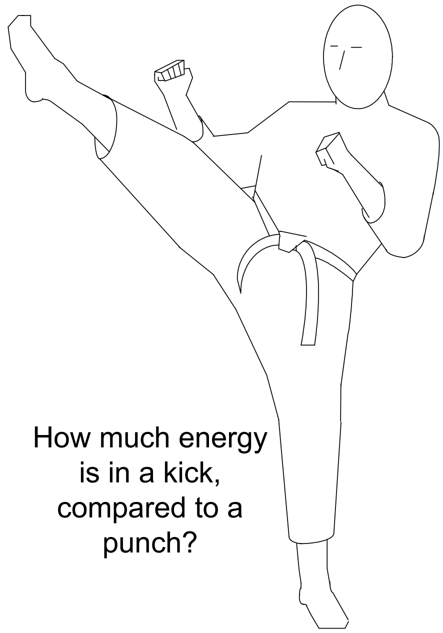
This work may be of interest to others but it is essentially for those that want to supplement their years of dedicated training. No book can ever be a substitute for training under expert tuition but books can provide help. This one aims to help those in the martial arts to better understand the laws of physics as they relate to the fighting techniques being practiced. In so doing it can help an instructor explain why a technique is taught in a particular way and help a fighter understand what's important to its effectiveness. Science has many purposes, perhaps the most important is to provide explanations of the way things are.

If this book helps just one person to better defend themselves against an evil intent then it will have served a fundamental purpose. Fighting is an extremely important matter. Fighters know that there is no room for empty promises and that the teaching of techniques that probably do not work in real circumstances is unacceptably dangerous. Those that pass on knowledge that could be used in hazardous conditions must do so with an understanding of the associated responsibility.

## Background

The traditional martial arts invite passion in the pursuit of excellence. Often where there is passion there is controversy - and conflict is at the very essence of the martial arts. Throughout the centuries there has been debate and discussion about the effectiveness of one technique or another. Arguments have raged over the particular ways of applying a move, about the consequences of training a certain way or the advantages of a specific body position when engaged in a strike, block or evasion. Different styles and schools have emerged from the heat of these discussions. Progress has been made, and sometimes stilted, because of differing views on the optimal way of training or fighting. Examples of these questions and debates could include:

- What's the maximum impact that can be attained by a trained fighter?
- How do I become more powerful?
- How do I know that the style I am studying is effective?
- Does a mixed martial art provide the ultimate fighting skills?
- How much more force is felt from a kick, compared to a punch?
- Which has more force: a thrust or snap kick?
- How does the speed of a strike affect its force or power?
- How important is the contact time of a strike?
- Do you need to be grounded in order to be effective?




Debate and discussion is healthy. It invokes thought and deliberation over the topic of interest and prompts communication and exchange of views between individuals or groups. In many cases science can be used to help settle these debates or disputes. However, in some circumstances, science can also be misused and misquoted; which does not assist in finding the truth.

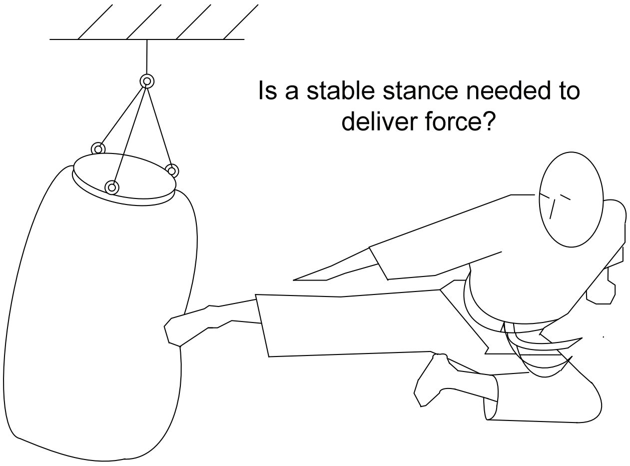
The problems associated with the application of science in the martial arts forum are numerous. In the past there has been limited formal research undertaken that produced reliable results to allow objective analysis and the formulation of clear conclusions. Despite the multitude of great books that have been written to help those dedicated to the pursuit of the martial arts, there are still only a limited number of authoritative texts that relate the art to the science.

Yet the fundamental principles of physics that apply in the martial arts are completely developed. Newtonian mechanics is sufficient to mathematically describe the forces in action. For example, the conservation of momentum and energy can provide the insight needed to understand what is happening when two bodies collide. After all, fighters are basically most concerned with what happens when two objects, such as a projectile and a target, collide. In our case the projectile may be a fist or foot and the target may be someone's stomach or head.

There appears to be a gap in the collective knowledge of the scientific principles that underpin the martial arts and for many fighters this leaves their understanding clouded. This book aims to show how known scientific principles apply to the martial arts; to provide the 'science behind the art' and thereby help part those clouds and fill that gap.

Prior to around the year 2000 there were relatively few numerical results from martial art orientated studies that had been undertaken in a rigorous scientific manner. In particular, the reliable and repeatable measurement of the force of a punch or kick was very limited. Simply put, the accurate measurement of force is difficult. Much of what we learn in training is based on anecdotal or subjective experience that provides qualitative (rather than quantitative) evidence. This book therefore attempts to explain the underpinning scientific principles, review some of the important available data and summarize the more useful results. The recent upsurge in the interest of fighting, due mainly to the popularity of the Mixed Martial Arts competitions, has prompted a renewed interest in the determination of how hard we can punch or kick. This has fuelled the production of television shows that are measuring 'who' can hit the hardest. The use of the internet allows easier access and review of these studies and insight can be gained by looking at the performance of expert fighters hitting a target.

A fighter does not need to be a physicist to be proficient at, or a Master of, their chosen art—far from it. For most practitioners the answer to the majority of questions can be found by simple examination of good practice. Indeed, many of the academic debates can be ignored by those who simply want to train under the guidance of a good instructor. However, the martial arts encourage contemplation and analysis and the serious fighters should have the opportunity to apply their minds to the numerous questions that emerge in training.




Frequently asked questions can often be answered by simple analysis of the techniques being practiced. This is mainly a contemplation over what 'feels' right, with time spent thinking about what it is that makes the difference between a technique that appears effective compared to one that seems weak or slow. As an illustration, during one post-training discussion I was asked if you really needed to be rooted in a good stance to be able to deliver power. The fairly high-ranking karate instructor that asked has a very impressive side thrust kick. It is even more impressive when you see this kick hit a bag as he 'hops' through the stance to strike, and better yet when the kick is delivered in mid air in a flying sidekick fashion. Anyone who witnessed his technique striking the bag saw the force of impact and power being delivered as the bag is blasted. So why would this person of intelligence have to ask if you need to be rooted to hit hard, given that he had seen and felt his own power being demonstrated when his feet were not even on the ground? If you need to be on the ground to be rooted, and only a technique delivered from a routed stance can provide power, then a flying kick can have no power. We know this is not true - and some of us may have even carried the bruises from such a kick.

Of course he used the floor to launch his attack and in so doing has found a way to 'lift-off' and get a massive push from the earth. The floor will have been the source of much of the power but when in the air you are in the air and no longer grounded. An arrow, cannonball or bullet has no connection to the ground when in flight but it carries immense energy and destructive power. Why then should anyone believe you can *only* be effective when *in* a solid stance? Why are the practical, every day, experiences ignored?

For good reason a beginner to the martial arts will be told to remain connected or even rooted to the ground when delivering a strike. This is good instruction but it can be stressed to the point where students become confused or conditioned into believing this is the *only* way to be forceful. This conditioning can be so ingrained that individuals will unwittingly 'bend' or misuse science to try and justify a belief that is actually inaccurate. In the following chapters I will therefore try to unravel some of these puzzles or 'mysteries'.

## Why Study the Science?

The book "Karate: The Art of "Empty Hand" Fighting, by Hidetaka Nishiyama and Richard C. Brown states: *"The remarkable strength manifested by many individual karate techniques, both offensive and defensive, is not the mysterious, esoteric thing many observers, as well as certain proponents of the art itself would have you believe. On the contrary, it is the inevitable result of the effective application of certain well known scientific principles to the movements of the body."*

Master Nishiyama was one the foremost experts on karate. He was taught by Master Nakayama and dedicated his life to Budo or 'the way of the warrior'. Those fortunate enough to have trained with this Master will attest to his immense knowledge, insight and unfailing enthusiasm in our art. In his book, published decades ago, Master Nishiyama is telling us that in karate the basic laws of science are used to attain the maximum benefit by the correct application of a technique.

To help explain these fundamentals of physics and the way they apply to fighting techniques this book will start at first principles and progress through to the advanced application of the science. Most of what follows, viewed with the right perspective, is 'only' a technical explanation for what is experienced in real life.

Why should a martial artist want to study the underlying scientific principles that underpin, explain and quantify the effectiveness of fighting techniques? The reasons are numerous and the following five suggestions are only a start; different people will have different focal points:

1. Knowledge of the related scientific principles provides a true understanding of the reasons why a technique should be performed or implemented a certain way.
2. Understanding the 'why' helps enormously with the study and improvement of the methods employed. This then assists with personal practice and the instruction of others.
3. With an understanding and proper application of science we can further develop and improve our art. Understanding is crucial to future development and progress.
4. The understanding of science will assist in the critical examination of all techniques, including any new innovations that may be promoted.
5. We are at a point where technology can be more easily used to measure the effectiveness of technique and thereby provide impartial judgment. Instructors may soon be able to start numerically measuring their student's abilities and progress.

***And yet . . .***

The martial arts allow a path of self-awareness where neither fighting ability nor technique is the ultimate goal. This path to self-awareness needs more than an understanding of the history of the chosen art or the study and practice of technique and forms - and it is certainly not restricted to fighting ability. This book is not intended to be a guide to an esoteric goal; it does not enter into philosophical discussion that may help a martial artist that is seeking to achieve the perfection of character. This book merely wants the readers to be better equipped to be able to understand their training and techniques.

## Summary

Understanding the scientific principles that underpin the martial arts can provide an insight into the reasons why we practice and apply techniques in a particular way. This can help fighters to fight, instructors to teach and advanced students to work things out for themselves. A lack of understanding of the theory and physical laws can cause difficulties for even the best instructors when trying to explain why a kick or punch is done a certain way. The use of 'loose' or inaccurate terminology by an instructor can cause a student to become confused. Many martial arts students are science graduates for whom force, power and energy are three completely different yet interconnected and well defined terms. An instructor may understand on a physiological level why a technique has to be done a particular way but can have difficulty putting that insight into words. Yet such instructors will typically strive to be accurate with both their strikes and their words.

This book explains the basic laws of physics and how they relate to the martial arts. It provides a summary of some of the key available data, including numerical values of the speed and force of kicks and punches. Chapters are devoted to the study of how to strike with maximum force, the penetration and timing of strikes, the determination of the energy needed to break boards, the pros and cons of different stances - and more. All this is aimed at promoting a true understanding of our art and helping people explain or even quantify some of the more subjective 'feelings' that they may have experienced in training or fighting.

*Don't worry about the math—just look at what's being told at a fundamental level.*

## 1.12 Summary

*Punching Statistics:*

- **Force:** The maximum peak force of the punch of an advanced martial artist has been measured at between **4500 to 5000 Newtons** (around 1000 pounds).
- **Speed:** With a standing reverse punch the maximum speed attained tends to be around **8 to 10 meters per second.** (Around 20 miles per hour.)

*Kicking Statistics:*

- **Force:** The peak force of a spinning back kick from an advanced martial artist has been measured at almost **7,000 Newtons** (more than 1,550 pounds force).
- **Speed:** With the more popular or classical kicks the range of speeds attained are as follows:

| Maneuver | Peak Speed (Meters / Second) |
|---|---|
| Front Kick | 10 – 14 |
| Roundhouse Kick | 13 – 16 |
| Side Kick | 9 – 14 |

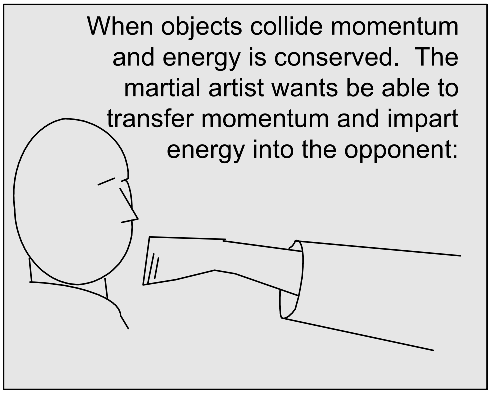
*Contact Duration:*

- A hammer strike used to break a concrete slab had a measured contact time of 5 milliseconds or 0.005 seconds (Feld et al. 1979).
- A roundhouse kick striking a chest protector was measured by Serina and Lieu (1991) as having a contact time of 10 milliseconds (0.01 sec.).
- A roundhouse kick striking a water filled bag had an average measured contact time of approximately 100 milliseconds or 0.1 seconds. (J. Pearson, 1997) This reference noted that such contact duration time is an order of magnitude greater than that experienced when kicking a football, due to the elasticity of the ball compared with that of a water filled bag. (A football, when kicked, is designed to immediately respond as a projectile.)
- With a fast strike to the head the peak force has been measured as being attained within 14 milliseconds of contact, in this instance with an impact velocity of 8.9 m/s. (Atha et al, 1985).

## 2.5 Summary

This chapter and the next are meant to serve as a reference of how physics can be applied to fighting; a reference that can supplement the insights gained through instruction and practice. Great fighting expertise is attainable without a full understanding of the associated science but to properly explain what is happening it helps if the related descriptive terms and definitions are appreciated. This assists with dialogue on subjects such as power, energy or force. Chapter 2 here provides the scientific definitions and explanations of important terms such as kinetic energy, momentum or power and thereby lays down a foundation for the work ahead.

The principles of conservation play an important role in explaining how things work. Put simply these principles say there is no magic, that material isn't mystically created or destroyed without trace and that mass, or matter, remains constant. After some mechanical collision or chemical reaction, individual objects may have changed but there is still an energy balance – no material is mysteriously lost or found. Energy that is no longer available or visible will have been converted into something less apparent, such as heat or sound. Energy and momentum remains constant after a collision. There is no such thing as a free lunch—you get what you give.




This chapter describes potential energy as stored energy that can be released, and kinetic energy as the energy that something has because of its motion. Reference is made to how a combination of both can increase the effectiveness of a strike. It covers the concept of inertia; something that needs to be overcome before we can move and engage in combat or defense. The relationship between force, pressure and area helps explain why the martial arts have developed techniques that use small area strikes and why boxing gloves reduce the risk of facial cuts.

This chapter has outlined how energy and momentum relationships influence the impact forces experienced when a strike hits a target. Chapter 3 next describes Newton's Laws and provides a fuller explanation of, and insight into, these forceful interactions.

# CHAPTER 3: NEWTON'S LAWS

'Do not forget the control of the dynamics, the elasticity and the speed'
*Master Funakoshi*

## 3.1 Introduction

The seventeenth century saw the publication of some of the greatest books ever written. Alongside the works of William Shakespeare and the King James Bible came the completion of *Principa Mathematica* by Sir Isaac Newton; a book that forever changed the world of science and mathematics. Newton's laws allowed scientists and engineers to predict with great certainty the behavior of machines that would be invented over the next few centuries; helping to create an industrial revolution and change the planet. These laws also allow fighters to understand the physics of the martial arts and are therefore described below.

## 3.2 Newton's First Law

**A body stays at rest or continues to move with unchanged velocity unless acted upon by an external force.**

In other words, nature lets sleeping dogs lie. This law has two major parts and states:

(1) That an object that is at rest or stopped will stay that way unless a force comes along to disturb it.

Secondly:

(2) An object that is moving in a straight line at a particular speed will continue along that path and at that speed unless something knocks it off its path, slows it down or speeds it up.

If the object were a car, then it may be another car that knocks it off its path, it could be friction of the road surface that slows it down or it could be a downward change in incline that would cause the car to go faster.

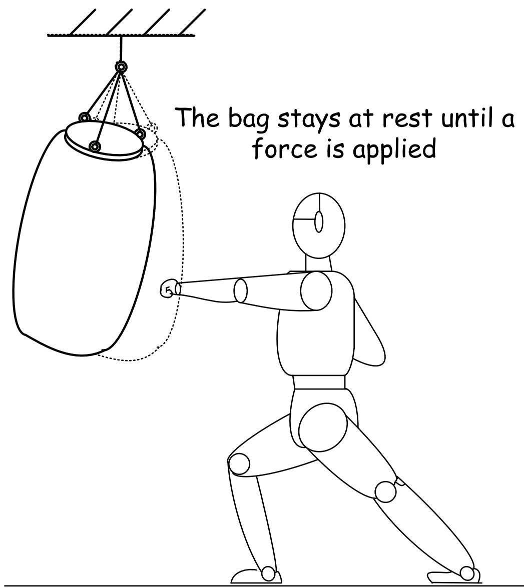



Figure 3.1: Newtons' $1^{st}$ Law - Punch a bag and it moves

In general, forces are associated with acceleration or deceleration. We know this from common experience; put you foot down on the

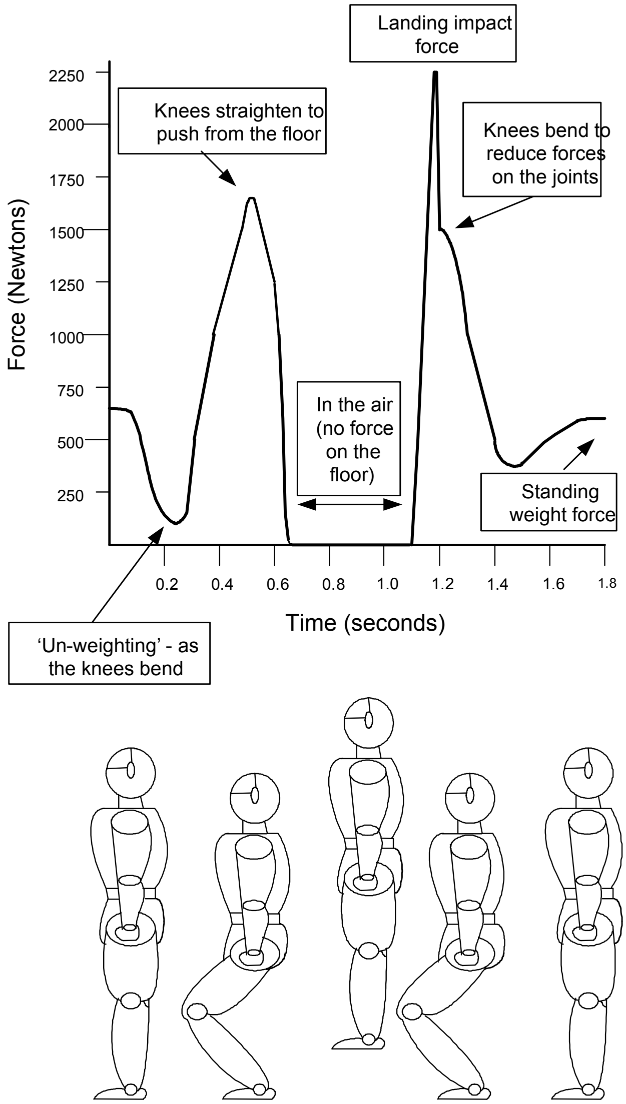



Figure 3.4: Ground reaction forces during a vertical jump

Martial Arts Demonstration:

When teaching, ask the class to jump up into the air. Now ask the students to do the same without bending their knees. Point out how this shows that they get their movement by pushing against the floor.

## 3.6 Summary

Things want to stay as they are. Objects will stay where they are until something forces them to change or move. Moving objects tend to continue traveling in the same direction unless something forces them to change their path. They stay at the same velocity unless additional forces make them speed up or slow down. For something to change you have to apply a force. To make a punch bag move push or hit it. This is Newton's First Law.

Apply a force to an object and you will make it accelerate at a rate that is directly proportional to that force and inversely proportional to the object's mass—the bigger the force then the bigger the acceleration. An object of lower mass will accelerate more than an object of larger mass, for the same force. A force applied against a moving object will cause deceleration. Deceleration is just negative acceleration. When you punch and hit a target your fist has a certain velocity at the point of impact. The target or opponent that is hit applies an opposing force which decelerates and stops the punching hand. The greater the punching speed the higher the consequential deceleration and the greater the resultant force. The greater the mass or weight behind the punch then the greater the required force to stop that punch, and the more pain felt. This is Newton's Second Law and if the target being hit cannot cope with the consequential forces then it will deform and may break.

To jump up and away from the floor you first need to push against the floor, to make it push back and allow you to go airborne. The pushing force just prior to a person lifting off can be two and half to three times the standing force due to that person's weight alone. Different people will display different results; an Olympian high jumper will use more muscle to create enormous pushing force just prior to lift-off. Fighters push against the floor to move forward to deliver a high force kick or punch.  And whatever you hit, hits back. This is Newton's Third Law in action, and reaction.

> **(Newton's) Facts for Fighters**
>
> Things stay as they are unless forces intervene: that moving object or fist should keep traveling if you don't get in its way.
>
> The more mass and speed behind a punch or kick the greater the energy it carries and hence the greater the force needed to stop it.
>
> Whatever you push—pushes back!

## 4.8 Summary

The implications of the principles associated with momentum and energy are of interest to fighters for they help to explain what happens when two objects collide. Two moving objects can have the same mommentum but vastly different energy levels. A lighter faster object can have more energy than a slower but more massive one yet the product of mass and velocity in both cases is the same. For example, if one such object is of half the mass of the other but twice the speed then its energy level is twice as high, despite the fact that their momentum levels are the same.

If we keep the mass the same and double the speed then:

- The momentum will have doubled—because we have twice the speed
- The energy will have increased fourfold
- Quadrupling the energy of an object provides four times the pentration potential—this increases the pain felt and damage done by such a strike.

On the other hand, if we double the mass but leave the speed unaltered then:

- The momentum has doubled—because we have twice the mass
- The kinetic energy has doubled—because we have twice the mass
- The penetration potential has doubled—because twice the energy exists.

Collisions can be elastic (bouncy) or inelastic (sticky), or somewhere in-between. A thust action technique tends to be more inelastic; with an extended contact time it's prolonged impact can be used to take a joint beyond its limit of flexibility. A snap action technique tends to be more of an ellastic colisions with an impact that is precisely targetted, having a short contact time and less penetration.

Punch a large cushion with a bare knuckle fist travelling at 10 m/s and there is no pain; great penetration and a long contact inelastic collision but no pain. Punch a stone wall in the same way and it's a totally different proposition. The pain felt will be severe, there will be virtually no penetration (of the wall at least), the contact time will be short and the collision is mainly elastic - as the fist virtually bounces off the stone surface. And the forces? In the first strike the peak force is low (no pain), in the second case the peak force will be so high that the person will be lucky to escape without broken bones of the hand.

## 5.6 Delivery of a Punch – the Practice

Where is all this leading? How does the theory and calculations help? What I am trying to provide are insights that will help martial artists to work out how best to achieve results. Let's try an example—what's the best way to deliver a punch? From the previous work this should be fairly clear (and the following is not meant to be an exhaustive study):

**(i) We want the punch to be fast.**

The striking hand velocity should be as high as possible. If the punch is a left jab, for example, *relaxing the body will help*—particularly the left side upper body, shoulder, elbow and wrist. You do *not* want muscles to be tightened before release of the jab, you *do* want to lower the resistance of joints or tendons or ligaments to the movement. When appropriate, try and use some of the opponents' speed or momentum against him. Try to catch him on the way in and moving towards your strike, this adds his available velocity into the equation.

**(ii) We want 'weight' behind the strike**

To create a larger mass in the equations quoted earlier, we want to hit with more than just the weight of the hand. Moving your bodyweight, your center of gravity, into the strike *simultaneous* with the strike landing will create a larger striking mass. 'Landing' at the moment of impact, or just after, will effectively increase the mass. Think of a stepping punch and the front foot hitting the floor at the same time as the fist lands, rather than landing and then striking. That can also work for a standing jab or cross strike; it is not restricted to a stepping punch action. With a jab, for example, try dropping the weight onto the front foot to coincide with the impact of the hand; 'stamping down' into the target, trying to shift the body's center of gravity towards and into the opponent at the point of impact. With a cross or reverse punch the core of the body (not just the punching hand and arm) should be moving toward the opponent, with the feeling of going into the target at impact.

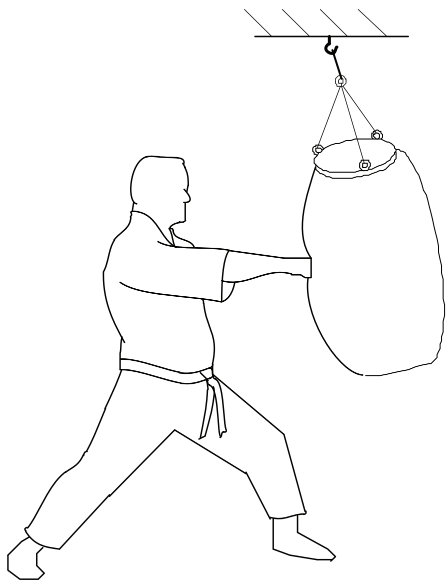


Figure 5.6: With a reverse punch move the core of the body into the target.

In each case the creation of high 'effective mass' and acceleration starts from the floor; the stance and leg

## 5.10 Summary

The penetration achieved by a weapon when it strikes a target is proportional to the energy the weapon has at impact; the more energy the more penetration. Penetration is also a function of the hardness of both the weapon and the target. A hard missile against a soft target results in maximum penetrative effects. That's a good reason to hit with the knuckles of a tight fist. If the strike bounced off rather than penetrated the target then the momentum exchange may result in the target being 'pushed away' or even over, but the internal (penetrative) damage will be minimal.

Hit a hard target with speed and focus the strike inside the target, dispense the energy of the strike into the target and get out; the shorter the time taken to exchange energy the higher the peak forces(s). If the distance over which a strike is stopped is increased then the force felt is proportionally decreased. A bony target, such as a rib, has a short contact distance (and contact time) over which the force can be experienced—for it can only deflect so far without fracture.

There is an inherent difference between striking a hard object such as bone and striking a spongier, more compliant, material such as muscle, fat and tissue. One fundamental difference in striking hard rather than soft targets is that the contact time duration reduces and this shortening of the collision duration increases the peak force experienced. Fighters can choose to punch the head in a slightly different way than the stomach, concentrating more on speed rather than effective strike mass. Focus the power into a single strike that is fast and penetrative rather than a slow, protracted, pushing action.

Matching the weight of the strike with the weight of the target will help optimize the transfer of momentum *and* the transfer of energy into the target. Strike too heavy and you can over-commit and be off balance as the target is forced away. Strike a heavy object too lightly and you will effectively 'bounce off', with little penetration of that target. A head butt is one of the rare occasions where the weights of the missile and target are, naturally, approximately matched.

To become skillful in striking vulnerable points requires expert instruction, spending time to understand anatomy and knowing your own personal weak spots helps indicate where an opponent may be vulnerable.

If you need to do damage then use a solid high-speed strike and achieve target penetration within a short contact time. *Concentrate power into a strike that is fast and penetrative—not slow and protracted.*

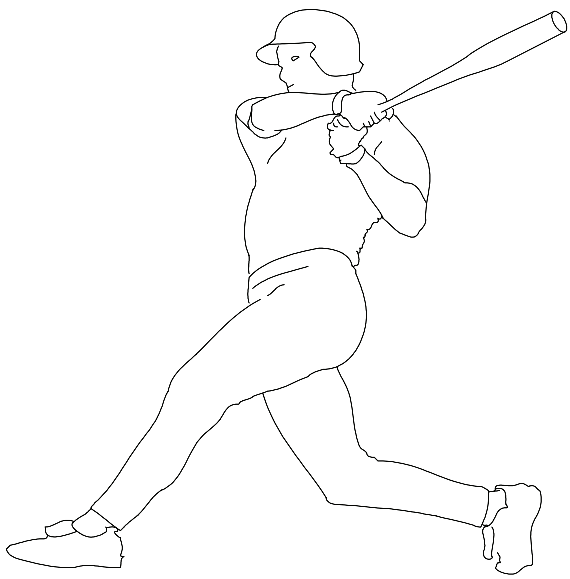
***Strike—don't push***

## Talking of Baseball (as a digression)

Think about a few facts and figures: A baseball weighs 5 to 5.25 ounces (150 grams), has a diameter of ~2.9 inches (7.4 centimeters) and a coefficient of restitution (COR) of between 0.51 and 0.58. This means that if a baseball is dropped onto a hard surface then the rebound speed would be just over 50 per cent of its striking speed. (The COR, or 'hardness' of a tennis ball is about 0.67 and the COR of a basketball is around 0.76, but a bouncy table tennis ball is around 0.94).

To hit a home run the velocity of the baseball after impact with the bat must be 100 mph [or 45 meters per second (m/s)] or more, at an upward angle of around 30 degrees to the horizontal. Assuming the air density is 0.07 pounds per cubic foot (1.14 kg / cubic meter) then the distance traveled before hitting the ground would be about 360 feet. Given that the pitch of a fast ball can be around 90 mph [or 40 m/s], ask one simple question: How does a batter manage to swing that bat so fast and furious that it will reverse the fast ball speed from over 40 m/s in one direction to over 45 m/s in the opposite direction; given that the ball would only bounce off a stationary hard object with little more than half its original speed?

The answer, predominately, is technique. Watch a good batter swing away and observe the hip action. The preparation and follow-through hip action, taking the force from the floor through the upper body, provides one of the best sporting demonstrations of the principles being taught throughout the world of the martial arts. (Look at the copy of a photograph of a batter at the end of his swing, ignore the fact that the front knee is almost straight but compare the hip action to a right handed reverse punch.) The hip action leads the way, from a baseball bat pull back position the hips rotate to meet the ball and the hands and bat follow—similar in principle to a golf swing. If the hips are restrained then so is the result. This has been tested, with batters fairing badly if they have their hips held and restricted by someone while they swing and hit a pitched ball.



## 6.8 Side Kick: Snap or Thrust Differentiator

Since the snap and thrust types of side kick have such notable differences there should be less confusion than that addressed with the front kick. The side thrust kick action is a direct thrusting line, whereas the side snap kick has the foot moving through an upward arc. A developing rule of thumb can be applied by asking the question: "Is the articulated joint of interest aiming to be locked at the moment of maximum impact and penetration?" In the side thrust kick the answer is usually that the knee has either straightened or that the reaction from hitting the target prevented this. With a side snap kick the answer is probably not, only a high target could temp the leg to be fully extended in this way. Even then the force line is *not* along the line of the leg, through the knee joint and into the target; the force is transmitted through the arcing path of the kick. There is another reason for striking the target before the leg has straightened: If the knee is no longer bent then the kicking movement is coming from a leg swinging up from the hip and the high speed action of the lower leg has ended.

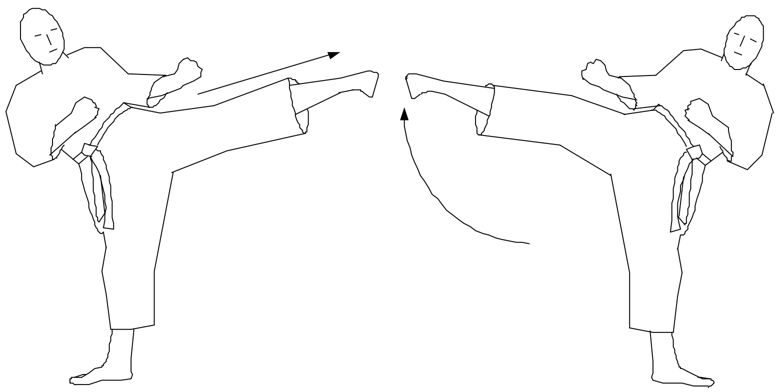


Figure 6.7: Side thrust and snap kicks - the end point may be similar but the techniques and trajectories are different.

## 6.9 Side Snap Kick Biomechanics

Figure 6.8 shows a simplified model of the skeletal action during a side snap kick. The leg is raised with the knee bent in this upward movement. The foot is simultaneously snapped up through the arc shown, using the hips and the upper leg muscles to drive the lower part of the kicking leg, through the knee joint connection. This is a complex movement that is a challenge to master. There is a three dimensional nature to this movement and the natural limits on the knee make it act as a restricted hinge in the plane of motion, particularly at or near the completion of a high kick. Instruction on this kick can vary. Some instructors teach that the knee should first point to the target, others emphasize that the hips should 'lead' the movement of the kick. Teaching beginners to point the knee to the target can cause them to initially confuse a side snap kick with a front snap kick that is delivered to the side. Such an error is often marked by the foot pointing upwards as the side snap kick is performed.

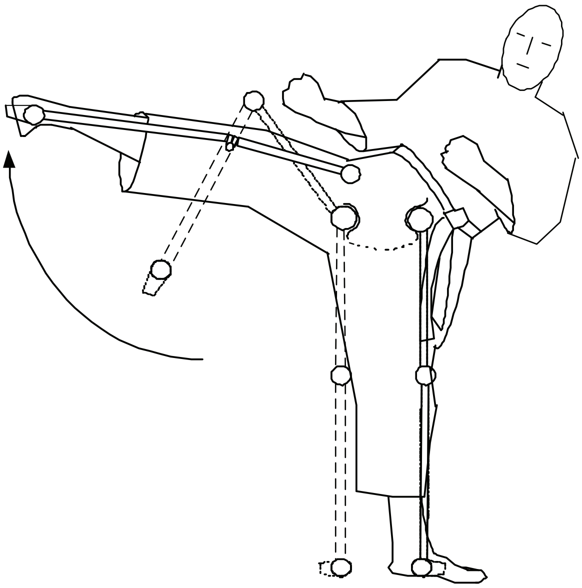
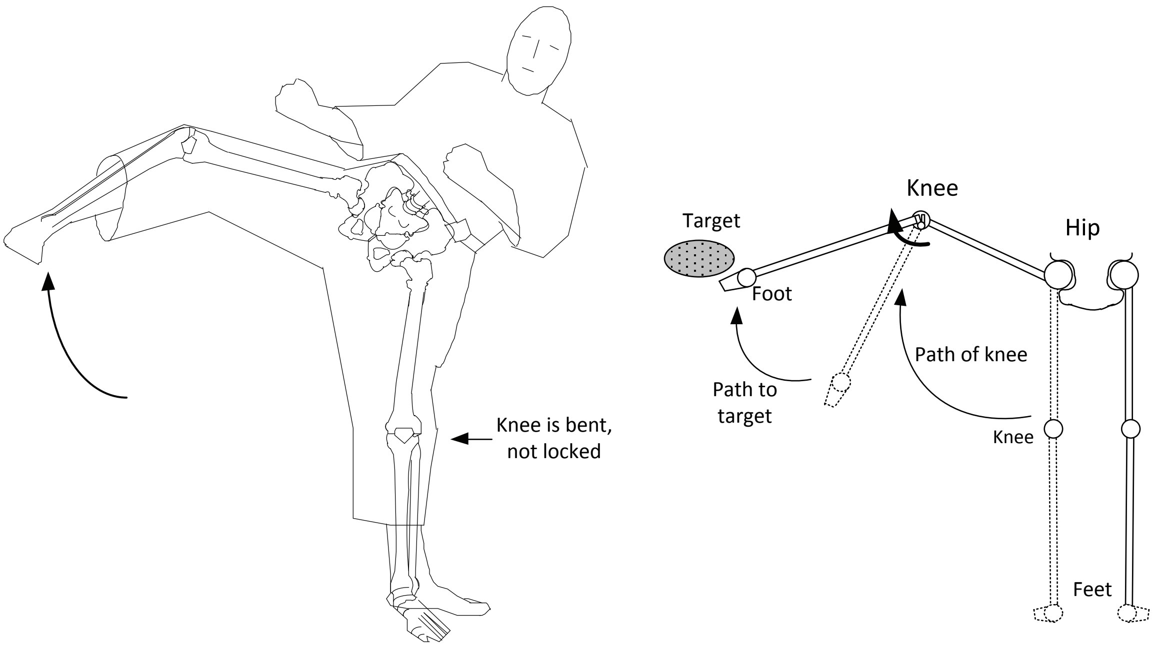


Figure 6.8: A schematic and skeletal representation of a side snap kick. The hip details are simplified for clarity.



## 6.14 Summary

Kicks have the potential for being the most forceful of unarmed strikes. Snap kicks and thrust kicks are different, although some techniques can become 'blurred' and the action 'merged' into a part snap, part thrust kick. Kicks and punches are not limited to either a snap action *or* a thrust action; a kick can be delivered in a snapping action manner with varying degrees of thrust at contact.

For a thrusting action to drive body weight into the opponent the limb should be straightening and driving directly into the target; a round house kick cannot be considered as a thrust kick.

Snap action techniques are generally of lower effective striking mass than thrusting actions, although the speed is high and the contact time is short. With a thrust kick or reverse punch more body weight can be put behind the strike, compared with a snap action strike.

Side thrust kicks have a very different biomechanical movement compared with side snap kicks. The side thrust kick has a straight line action and can be very forceful; delivered with significant speed and body mass it allows a lot of energy to be imparted into the target. The contact time may be deliberately sustained. The side snap kick is very fast and will impart a 'shock' into an opponent; being particularly effective against a vulnerable target. The contact time tends to be short.

Junior martial artists need to be taught and continually reminded of the proper technique that is to be attained. Practicing poor technique merely makes us good at kicking or punching badly.

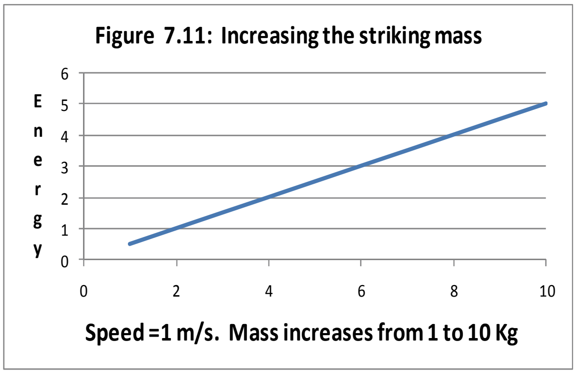
Fighters should be aware of how balance is affected when kicking and forcefully striking a target. A straight line horizontal kicking action has no upward direction component; it just goes into the target. A high kick can glance upwards off the target and it can also cause the kicker to be somewhat unbalanced, making him less stable, more prone to slip or being swept. Kicking high can carry risk, particularly in the difficult conditions that can be expected outside of the training hall. In a street fight it is usually safer to use low kicks.

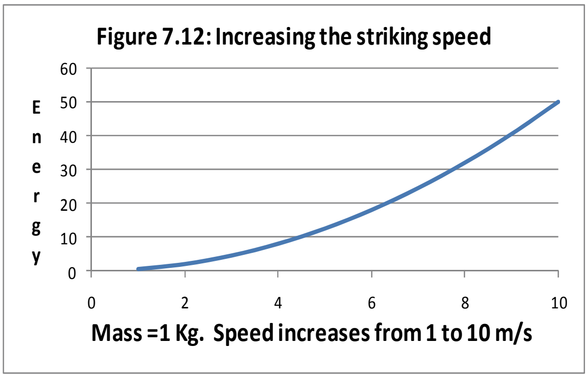
Hitting an object or opponent with a heavy thrusting action, for example using a side thrust kick, will create a reactive (push back) force that is not experienced when practicing in free space. This affects balance and influences the mechanics of the movement. Practicing in free space is excellent for improving form and speed, or for the development of combinations, but it is *not* the same as hitting an object.

## 7.10 Hitting with Maximum Energy; Maximum Force

The equation for deformation energy (7.2) can be studied to see the effect of fixing the strike speed and varying the striking mass and then fixing the strike mass and varying the striking speed. The results of such an analysis are shown graphically as figures 7.11 and 7.12. The graph in figure 7.11 is a straight line showing that increasing the striking mass proportionality increases the energy of the strike as a 'one for one' type of effect.

The graph in figure 7.12 is not a straight line, showing that increasing the velocity of the strike has a 'squared' effect which is significantly more than a 'one for one' type of effect. In mathematical terms the relationship is quadratic and the graphical display is parabolic in nature rather than a straight line—showing, once again, that hitting faster can give us comparatively more gain in force. Note that the vertical units of these two graphs are not the same: Not at all.




So what happens when we try to consider the best 'compromise' between the speed of a strike and the mass behind that strike? Academically, knowing that there is a tradeoff between speed and mass, we are looking for the optimal point where the speed and mass combination provides maximum energy. All else being equal (such as contact time and penetration) maximum energy will result in maximum force. We all acknowledge that a fighter needs to be both fast and strong. The lightning fast jab of a lightweight is admirable but it does not usually inflict the same degree of damage expected from the right cross of a well trained heavyweight. How do we try to look into this question of optimization between muscle mass and speed, so that a fighter can train to strike with maximum force?

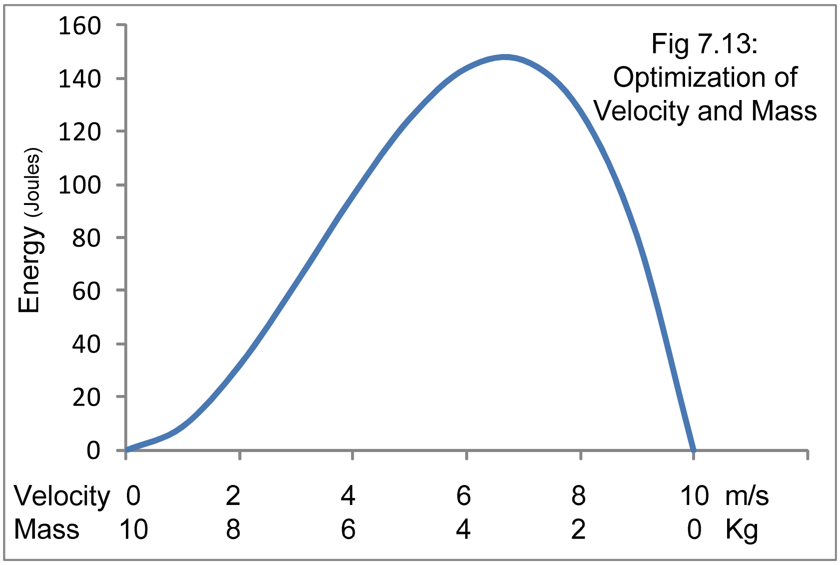



Figure 7.13 shows that if we increase the velocity of a punch from zero to 10 meters per second and simultaneously proportionally decrease the mass behind the strike, from 10 to zero kilograms, there is an optimal point where the energy level of the punch reaches a maximum. In this particular case that peak energy point is when the velocity is around 7 m/s and the mass is around 3 Kg. The actual values chosen to illustrate this concept can be adjusted – it's the concept that's important to understand. This illustration shows what happens if for every 10% increase in speed a fighter had to lose 10% of the striking mass; or by gaining 10% more mass behind his strike meant losing 10% of the striking speed. (Plotting the curve by increasing the mass while decreasing the velocity will simply produce a mirror image of figure 7.13.)

**A Fighter's Insight**

*If a fighter, by training, has increased his striking body mass to a point where his punching speed has dropped to less than 70% of its previous value then it's likely that by continuing to train in that way his punching force will start to reduce.*

To the best of my knowledge this concept has not previously been indicated graphically in the way shown here, and I have seen no published reports of studies along these lines. (That isn't to suggest there are none, but I cannot reference or credit any previous similar work.) The concept makes sense; many understand that the punching speed and body mass behind a strike are not independent variables; that a jab is typically a high speed, low mass, strike whereas the right cross tends to be a little slower but heavier. Figure 7.13 indicates that

## 7.11 Summary

All fighters need to practice hitting objects—punch bags, target pads or makiwara.

When hitting a hard object go for speed. To break a single board go for speed and punch through the wood. When striking a softer object—target pad or punch bag—practice elongating the contact time and penetration, allowing even more follow through type of action.

When breaking several objects or boards in a single strike, a higher degree of follow through is needed. The time taken will thereby increase, as the strike is continued to be driven through and beyond the first board to the second, third or even forth. In a breaking demonstration time is available for preparation and extended penetration. In self defense circumstances time will be at a premium and the luxury of preparation or very long contact times may not be an available option.

Boards that are spaced apart will be easier to break than boards resting on each other. Two one inch thick boards, spaced apart, are easier to break than one two inch thick board.

Do not strike a target at the end of the extension of the punching hand. As the hand approaches that final stopping point the speed reduces. Strike at about 75% of the extension limit—that's about the point of maximum speed—and punch through the target. The same principle applies to kicks.

By use of the equations in this chapter it is possible to estimate the energy needed to break wooden boards—and calculate the kinetic energy we can expect to achieve in a particular action.

Increasing the striking mass of a punch proportionality increases the energy of the strike in a 'one for one' manner, whereas increasing the velocity of the strike has a 'squared' effect on the energy level; which is significantly more than a 'one for one' type of effect.

For all fighters and all punches there is an optimal point of maximum energy, maximum force. This optimal point is the perfect combination of speed and body mass behind the punch. If, by targeted conditioning and training, a fighter has increased his striking body mass to a point where his punching speed has dropped to less than 70% of its previous value then it's likely that by continuing to train in that way his punching force will now start to reduce.

This all shows several points of significance:

- With a punch, strike the opponent at about 70 to 75 percent of the arms length.
- If your arm length, to a closed fist, is around 65 cm (~ 25 inches) and you are punching with the fist starting at the shoulder to hip line, then aim to strike the target at a distance of about 50 cm (~ 19 inches) or about 6 inches before full extension
- Punch through the target, don't aim at the surface.
- When punching from the hip, the speed achieved at around the thirty percent mark is only about twenty percent less than the maximum. If your peak speed is 8 meters per second then a strike with only a third of full extension could still be around 6 meters per second.
- About half the maximum speed can be achieved after only ten percent movement. [But remember that energy is proportional to the speed squared, so half the speed carries only one quarter of the energy of a full speed strike.]

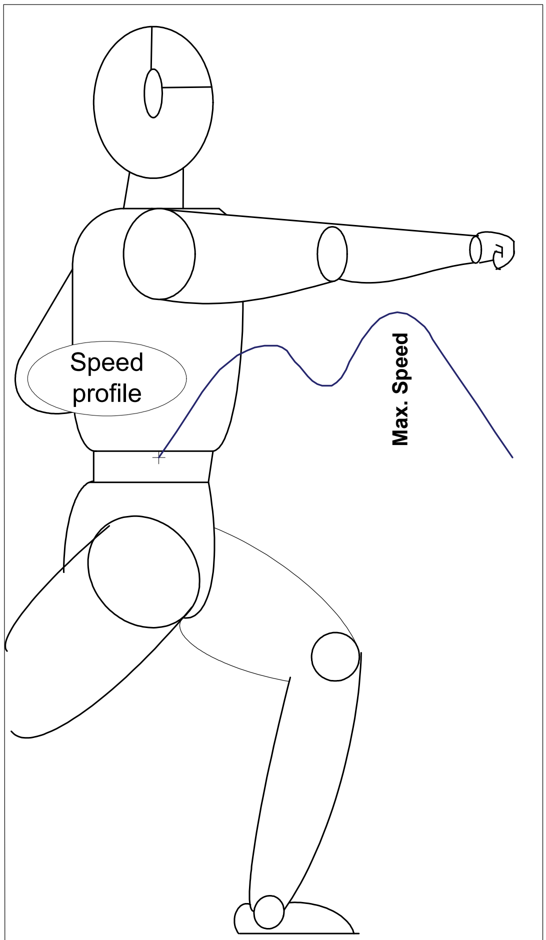



**Figure 8.3: A punch from the hip starts & ends with zero speed - the maximum velocity is at about 70 to 75 % of travel**

This study prompts a few questions to consider. For example, think about the effect of the length of arm: a longer arm can reach further but needs longer time to reach the opponent.

- If all else is equal, will the fist have more energy due to the extended distance traveled?
- What does this mean to the practice of 'shoulder extension' towards the end of the punch?

Another point to consider is that since the strike is at about 75% extension the fist will not by then have rotated to the normal finish position exhibited in free-space training, so:

*Why twist the fist?*

## 8.11 Summary

A basic reverse punch should hit and penetrate the opponent when the punching arm has reached around seventy-five percent of its full extension. Aim or focus to strike inside the opponent, beyond the target surface: Do not aim to impact at the end of the travel of the weapon for at that point the speed will be lower than the maximum. Do not aim at the surface of the target—aim to penetrate.

It takes time to accelerate to a very high striking speed. Retraction or 'pull-back' of the fist before throwing a punch gives more distance to allow a higher speed to be reached—but when fighting such pull-back is usually an unaffordable luxury and unnecessary signal of intent. Close quarter combat does not have the long reach striking distances and a fighter can benefit here from the development of synchronized hip and body mechanics.

With a traditional punch we should teach students how to apply focus or tension approaching the full extension completion point, not at the impact point. At impact, rather than full extension, we should strike with maximum speed, aided by being relaxed rather than tense, with a center of gravity moving into the target and the strike driving through the opponent with a focused or 'hardening' attitude—all in a small fraction of a second.

The velocity profile of a punch can be very non-linear; in a classical reverse punch the fist accelerates from the hip and then the speed reduces before further acceleration reoccurs. An expert can, however, perform a roundhouse kick with almost complete linear acceleration of the foot; from the floor to the target it keeps on getting faster.

Expert fighters can develop their three inch punch to be about as half as forceful as their full reverse punch.

Non-contact competition and associated specialized coaching should be complemented by more traditional training and the striking of punch bags or similar.

Both by theoretical derivation and by looking at the available experimental evidence it can be shown that a kick can contain significantly more energy than a punch. All other parameters being equal (such as contact time and target characteristics) this means that the kick will be more forceful. Individuals should be able to develop their kicking abilities to be twenty-five to fifty percent more powerful than the best of their punches.

## 9.8 Summary

A body in motion has kinetic energy, regardless of whether that motion is straight or circular, and this energy can do damage when converted to an impact force. The linear relationships and equations used previously can be related to their rotational equivalents. All the insights gained through the study of the linear relationships can be applied to their circular cousins. The proportionality of kinetic energy to mass and the importance of speed and its square law all have direct bearing in the rotational analog.

The rotation of the body is shown to be important in everything we have examined. Trained fighters do not punch with just their hands and arms—they use their body to twist and move into the strike. Hooks and roundhouse types of punches require tuition and bag practice; once again the core of the body has to be employed for full effect. Control of these circular strikes is difficult, influencing their use in competitions. The swinging 'hay-maker' seen in a bar fight is used by so many because it can deliver a lot of force.

The rotation of the fist during a karate style of punch does not, in itself, carry significant extra energy. This action does, however, help the development of technique and a penetrative attitude. The calculated additional energy associated with a twisting arm block, compared to a block that does not use this swivel motion is, on its own, insufficient to explain the achievable increase in effectiveness by this means of blocking. Again this rotational action is considered to be for technique and attitude.

In close quarter hand-to-hand battles circular actions can become important and circular elbow techniques can be devastating. One of the important aims of the martial artist is to achieve more with less: Fighters want to be able to strike an opponent at very close range with a similar effect to that achieved with the luxury of distance and time. The science that we have worked through points out just how difficult this is, for with very little distance, and therefore time to accelerate to a high striking speed a fighter has to quickly 'impulse' into effectiveness. Some styles and instructors refer to this as a vibration like action; others use the one-inch punch type of test to aid development. All should picture this as an explosive action. Chapter 8 points out that with only a few inches of movement a punching energy can be achieved that is as high as 50% of the full range punch.

***Practice and training may be clean, even pure. Street violence is messy.***
***Excellence in the Martial Arts is achieved by understanding and applying the innumerable incremental improvements that accumulate to make the difference.***

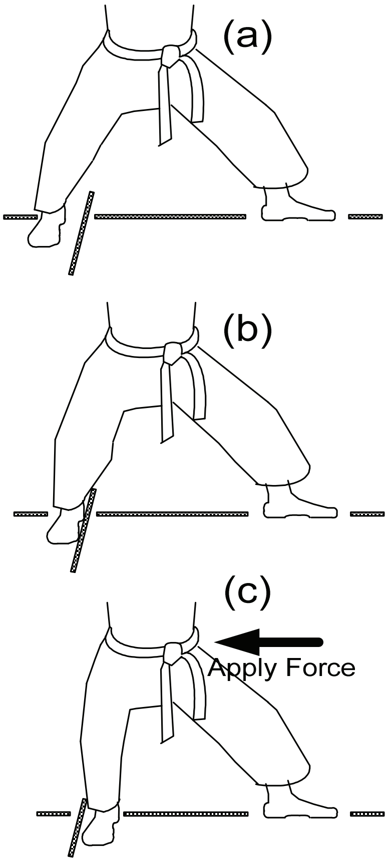



Figure 10.16:
Shortening of a back
stance.

Figure 10.16 shows how shortening a back stance & placing the back leg virtually under the body will allow easier kicking from the the front foot. However, there is now less resistance in the stance to an incoming force, less stability from which to deliver a strong penetrative punch.

### Fighter's Insights

Forward stance is a good offensive stance from which to deliver a strong punch.
Back stance is a good defensive stance from which to evade or absorb an attack and be posed to counter-attack; perhaps by converting to forward stance.
As fighters our options are not limited - we can step forward into back stance or step back into forward stance.

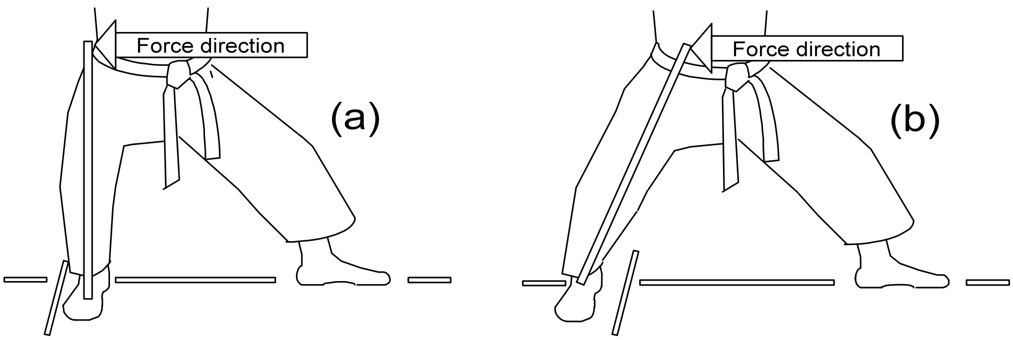



Figure 10.17: Varying the ability of a back stance to resist the reactive force from punching an opponent.

## 10.14 Summary

There are innumerable stances for a fighter to choose from. There is a stance or body position suited for any circumstances. In battle a warrior will not always be in an ideal stance or position but will fight on regardless. In battle a fighter will try to get the opponent(s) to a weakened position.

A solid 'forward' type of stance with a strong footing and connection to the earth is valuable when striking an incoming opponent. Martial artists often talk of how a stance has connectivity to the ground and train as though 'gripping' the floor. An onrushing opponent has an incoming momentum to contend with and facing him and striking him 'head-on' while in a weak stance probably won't allow an adequate transfer of power. Hence, even if the in-coming opponent is hit the strike may not stop him from 'running over' the defender. On the other hand, an opponent that is static and motionless has no such momentum while an opponent backing away can be considered to have negative momentum.

When striking an opponent that is static or moving away the stance adopted at the moment of impact does not need to have such a solid connection to the floor because there is no forward momentum of the target with which to contend. A solid base from which to launch the attack is more important than the connection to the ground at impact. Don't get confused with this distinction. If, at the striking point, the attack is moving into a *receding* target then there should be no argument that the back heel can be raised. In sparring and fighting there are great advantages in using techniques where the heel is raised. Recall that sprinters push forward from the floor through the ball, not the heel, of the foot.

The center of gravity (C of G) of a body is an important concept to understand. A typical human body will have a C of G point a little below and behind the navel. The lower the C of G of a body the more it is stable and more force is needed to upset it. Dropping an imaginary vertical line from the C of G of a body can indicate how much that body needs to be upset to topple to the ground. Move the C of G line outside the base area of a body (including your own) and, unless corrective forces are applied, the body will fall.

A sweep that catches an opponent when he is un-weighted requires very little force for it to be successful. An attempt to sweep an opponent who is 'rooted' in a strong stance will require significant force to be effective.

The principle of leverage is worth understanding for it demonstrates how a large localized force can be created by a much smaller one acting over a longer distance. It explains how joints can be dislocated, bones broken or opponents forced into submission.

## 11.9 Summary

On average, the hand speed of an experienced boxer will not be significantly different from the hand speed of a similarly experienced fighter, of the same body type, health and condition, but from another martial art. The speed of a good reverse punch or cross will be around 10 meters per second for each expert set of fighters, although there are always exceptional athletes that can break records. Boxers can deliver punches that are as forceful as those from any other martial art and more forceful than many.

Fighting whilst wearing large padded gloves, weighing 10 ounces or more, is different from battling in a bare-knuckled manner. Hands in large gloves have more weight and when in motion therefore have more momentum than an ungloved fist at the same speed, but to achieve this same speed demands more effort from the fighter, causing more exertion.

Large padded gloves prevent small area strikes (such as a single knuckle punch) and they spread the impact load over a wider area, reducing the peak force and the penetration that would otherwise be achieved.

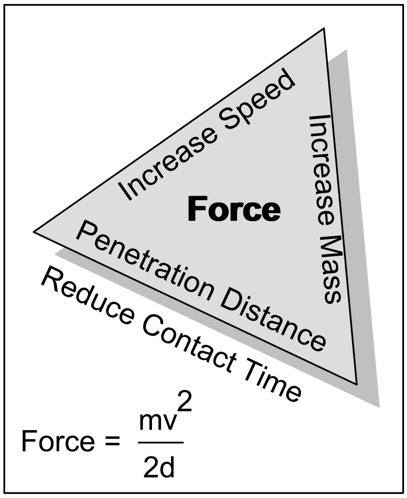
Lightweight mitts or hand pads make far less difference. Such a mitt, weighing from 1.5 to 3 ounces, is only a fractional increase in the weight of the punching hand, whereas a 10 ounce glove also increases the contact duration, flattening the impact force / time profile and reducing the peak force administered.

A lightweight mitt can help prevent cuts when the face is struck but a full contact strike can still cause extreme peak accelerations to the head, resulting in loss of consciousness. Lightweight gloves or mitts can make an undisciplined attacker even more dangerous, for he can lose any concerns over protecting his hands and may feel somehow 'licensed' to exhibit reduced control.

To win fights boxers want to knockout their opponents. A knockout or temporary loss of consciousness occurs when the head is impacted with enough force to cause the brain to be accelerated and stressed to such a degree that the brain effectively switches itself off. There are techniques and target points that are more likely to produce a knockout effect than others— with or without gloves.

Boxing is one of the best forms of self-defense but it can be supplemented by an appreciation of the basics associated with the use of, and defense against, kicks, sweeps, throws or grappling.

## 12.10 The Third Force Component: Penetration Distance




In previous chapters we have nominated the speed and the mass of the striking weapon as the two primary components to develop in order to increase the effectiveness of a strike. Repeatedly the importance of speed and mass has been stressed, relating both to the kinetic energy equation. From a force, rather than energy perspective, there are a couple of other considerations. First, let's consider the distance over which the impact occurs and the concepts developed in section 5.4.

Reviewing the theory again: since the product of force and distance is work, which equates to energy, we know that Force is equal to Energy divided by Distance (d):

$$\text{Force} = \frac{Energy}{d} \qquad \text{Energy} = \frac{mv^2}{2}$$

$$\text{Hence, force} = \frac{mv^2}{2d} \qquad \textit{Equation (10.1)}$$

So here we have our third component of interest, the distance 'd' in which the striking velocity is reduced to zero and energy transfers are complete. The above equation can also be derived from Newtons Law – see Appendix A. This shows that the ways to increase the peak force involved with a strike are:

- Increase the mass, 'm'.
- Increase the velocity, 'v'.
- Decrease the distance, 'd' over which the forces are expended

The distance referenced, for the transmission of the energy from the striker to the target is the distance over which the kinetic energy of the strike is absorbed by the target. Hence, the shorter the distance over which the energy is imparted into the target the greater the involved peak force(s). Here we have a scientific basis for so much of the material that we are taught during training and learn from our experiences.

How do we increase these peak forces, how can we reduce the distance over which the energy is absorbed? We know all the usual lessons about hitting perpendicular to the face of the target and this book has discussed the differences between hard and soft targets and has shown how a blow that is 'ridden' reduces the peak forces by elongating the time and distance of contact. This knowledge is critical to maximizing the force transmitted into a target but there is another way of increasing the peak force experienced; simply by reducing the "give" in the target. This has been noted elsewhere: Stull and Barnham (1988) said, "The force of the impact and therefore the potential damage done to an opponent or object struck can be increased by reducing the 'give' during the impact by either the karateka or the opponent or object being struck."

Allow me to illustrate by way of an example. Within the range of Shotokan kata there are repeated instances where the elbow of one arm strikes the palm of the other arm. In these examples at the instance of the strike the hips and body are turned in a classic synchronized manner so that the body is behind the blow and the stance is made strong.

What is happening here? One application is that, with a right arm elbow strike, the left hand has grasped and wrapped itself around the opponent's head or body, bringing the target to the strike point and allowing the target no escape—reducing the "give" or backward movement in the above force and distance equation. Simultaneously the shift of body and establishment of stance and focus ensures that there is minimal 'give' in the fighter that is doing the striking. Furthermore, hitting with the bony end of the elbow is a strike with one of the hardest points of the body, so again there is little 'give' in the attacking weapon. This is a technique which has the capacity to finish a confrontation. An elbow used with force will break a jaw or smash a cheekbone, rather than 'just' knock out the opposition. Note that in training or kata the hand that's struck is not passive; the strike should be timed to hit the hand as it is pulling the imaginary target onto the striking elbow.

**Figure 12.12 - Elbow Strike**

## 12.13 Summary

With any stance find where the strengths and weaknesses are, which muscles are in tension, and how the body is connected to the floor. Understand from where the forces are derived when punching or kicking. When stepping (forward or backward) or turning notice how the forces comes from the floor.

Optimize energy and momentum with fluid movements and know how and when to impart that energy into the opponent. Use any momentum gained, rather than squander such a valuable source of energy.

To increase speed of movement be relaxed. To increase the mass behind a strike synchronize the impact with the delivery of body weight and ensure that the technique and striking structure can transmit that body mass. A weak wrist, elbow or shoulder will result in a punch shedding energy because that joint cannot take the strain of impact.

Many fighters contemplate the ‘one strike’ concept; with a conflict ending in a single blow and moment. This one life, one strike idea is not just about technique—it is a philosophical attitude.

The usage of the hips in the martial arts is crucial. Ensure that the push from the floor and the movement of the hips contributes to the effectiveness of a technique or combination. Understand the different ways that the hips can be utilized, with the available choices in how we can apply both rotation and forward motion. Know where the center of gravity of your body is and how it can be moved into an attack.

For training purposes some styles teach the practice of becoming tense during the execution of a technique, such as at the completion of a punch. This can be taken to the extreme where the whole body aims to become virtually rigid, with connection from the floor through to the fist. Science shows that a high impact collision requires a missile (the fist) to have high speed and mass. Body tension from a fighter that will reduce the impact speed of the punch should be avoided. Tension can add mass to the strike but should not prevent the necessary penetration of the target. There is a difference between training and actually hitting something hard

There are numerous components to consider when striking, including four key variables: Speed of strike; the weight or mass behind the strike; the distance penetrated by the impact; the contact time of the strike.

In life-threatening conditions time may be of the highest priority, with no time for preparation, delay or recovery from over extension.

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