

The Power of Karate Techniques Explained by Physics

Edward Marotta

I have heard the following training instructions from my Sensei and instructors at SKIF events and Zoom training sessions.

“Punch through the target”

“Add snap to your techniques”

“Apply Kime before making contact with the target” (bag or makiwara pad)

“Keep your center line when stepping or applying your technique”

I was always interested in the reason and science behind these instructions. I have since found that these instructions are all based in Physics, and all are methods for generating the maximum power for a technique and applies whether it is a block or a strike.

This paper researches the Physics of generating maximum power for blocks and strikes in Shotokan Karate and explains the reasons behind these instructions.

Punch through the target

The Physics behind this instruction is based on Newtonian Physics, 2nd law of motion.

$F=ma$ (Force equals mass times acceleration, Newton’s 2nd Law)

In this case for a Karateka, the mass (m) is their body weight, and the acceleration (a) is how quickly (or the change in velocity) they can strike, will determine the Force of a strike. The mass of the Karateka cannot be changed; however, we have control of the acceleration of the punch. The research shows that a karate reverse punch (*gyaku-zuki*), starting with the fist on the hip (*hikite* position) and then going out from the hip to the target has a certain acceleration or velocity pattern. The velocity from start to finish shows that the punching fist starts off at 0 m/s (zero meters per second), then the fist increases in speed, then finally goes back to 0 m/s at the end of the punch. Figure 1 shows the velocity pattern of the reverse punch fist from start to finish. At the 92% - 96% fist positions, the acceleration is at the maximum (represented as the ‘slope’ of the velocity). Based on the force equation, $F=ma$, the punch has the maximum force at these fist positions. For the rest of the fist’s journey, it is slowing down (de-accelerating) and coming to a stop.

The statement “Punch through the target” is a way to have the Karateka hit the target near the 92%-96% point to generate the maximum amount of force at the target. If the punch hits the target near the end of its journey (100% point) the force would be much less. For example, for an average human arm length of 28 inches (2.33 feet), the maximum force of the punch is at the following fist positions:

Fist Position %	Fist Position feet	Max Force before Target (inches)	Max Force before Target (cm)
92	2.1	2.2	5.7
96	2.2	1.1	2.8

Average Human Arm Length

2.33 feet (28 inches)

The maximum force will then be at the 2.1 to 2.2 feet position. Therefore, the target should be hit 1.1 – 2.2 inches (2.8 – 5.7 cm) before the fist comes to rest. Or put it another way, the punch should go beyond (“punch through”) the target for 1.1 – 2.2 inches (2.8 – 5.7 cm) to apply the maximum force on the target.

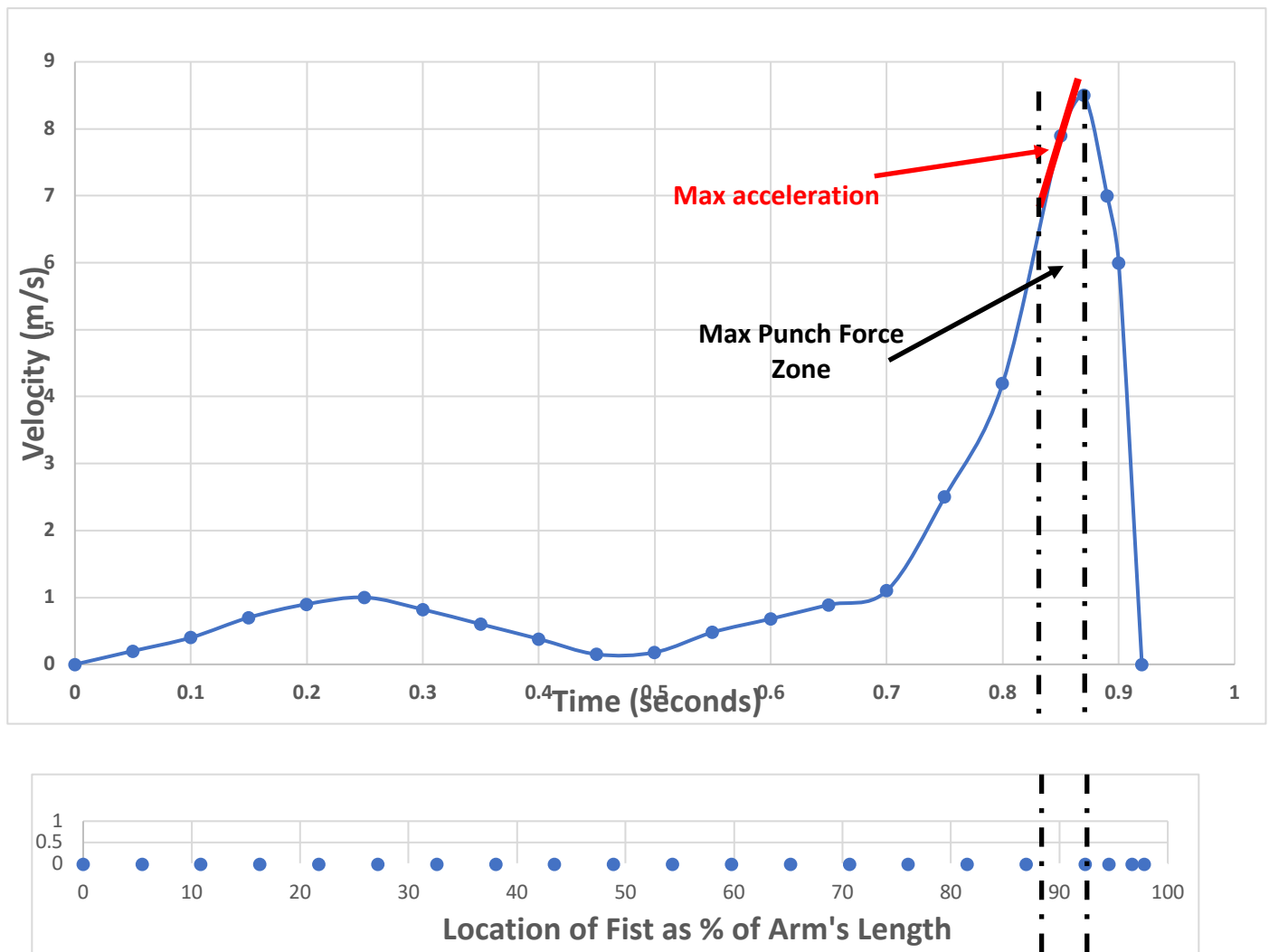


Figure 1: Maximum Force of Punch Fist Position

Conclusions

1. Punching Through the Target will generate the maximum amount of force on the target.
2. At the 92% to 96% of the arms length, a punch will generate the maximum amount of force. For a 28-inch arm length (average adult arm length) it means that a karateka should hit the target between 1.1 to 2.2 inches (2.8 to 5.7 cm) before the arm is fully extended.
3. Based on the Force equation, a karateka when faced with being hit, should move back and 'ride out' the punch to get out of the 'maximum punch force zone' to lessen the force of an opponent's punch.
4. Based on Physics, fear the opponent who has a large mass and has slow punches ($F=ma$, large **mass**, equals large Force).
5. Based on Physics, fear the opponent who has a small mass but is very fast ($F=ma$, large **acceleration**, equals large Force).
6. Blocks should be treated as a strike, and the same Physics apply to these techniques.

Add snap to your techniques

Does adding a quick snap at the end of a technique, whether it is a block or a strike, add any benefit to the technique? My research shows that a snap at the end of a technique (for example, *jun zuki*, *shuto uke*, *mai geri*) concentrates the applied force over a short amount of time. A pushing technique (for example, *yoko geri kekomi*, *ushiro geri*) as opposed to a snapping technique applies the same force but over a longer period of time.

The snap technique, also called contact time, or impact time, is generated by pulling back and relaxing the muscles after making contact with the target. Shorting the contact time produces a large force in a short amount of time. A short snap strike delivers the force in a short time. A pushing (thrust) strike takes longer to deliver the same force.

The Newtonian Physics that applies to a snap technique is Newton's 2nd law of motion ($F=ma$). This force equation, $F=ma$, can be written as,

$$F = m \frac{\Delta v}{\Delta t} \quad (\text{Force} = \text{mass} \times \text{Change in Velocity/Contact Time})$$

$$\text{Where, } a = \frac{\Delta v}{\Delta t} \quad (\text{Acceleration} = \text{Change in Velocity/Contact Time})$$

$$\Delta t \quad \text{Contact Time (also call impact time)}$$

In the above force equation, as the Δt gets smaller (faster) the force F gets larger. Figure 2 shows a plot of a typical Karateka exercising a snapping punch with different contact times. It can be seen from the plot, that as the contact time becomes smaller the force generated becomes larger.

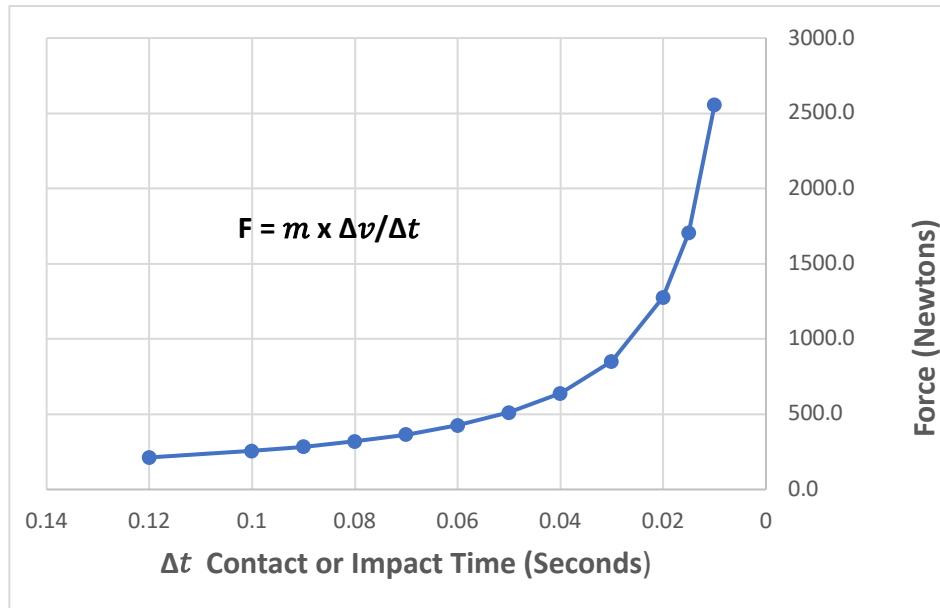


Figure 2: Smaller Contact Time Increases the Force of a Karate Strike or Block

Consider two points on the plot and are shown in the following table,

Arm Mass 5% of Body Mass (Kg)	Arm Velocity (m/s)	Contact or Impact Time (s)	Force Generated (Newtons)	Force Generated (Lbs Force)
3.65	7	0.01	2555	574
3.65	7	0.03	852	191

Average Human weight (US)	73 Kg (160 lbs)
Arm mass is about 5% of body mass	3.65 Kg
Arm Velocity	7 m/s

This shows that there is a big difference between the two different strikes. Hitting with a contact time of 0.01 seconds results in 574 lbs of force versus a contact time of 0.03 seconds results in 191 lbs force.

Conclusions

1. Snapping strikes will generate the maximum amount of force on the target in a short time.
2. Snapping actions that minimize the contact time can be applied to strikes and blocks to maximize the force.
3. The karateka should aim to shorten the contact time of a snapping technique to maximize the force imparted on the target.

4. To generate a snapping technique, pull back and relax the muscles after making contact with the target.

Keep your center line when stepping or applying your technique

The Physics involved in keeping your center line when applying a karate technique is Newton's 2nd law of motion ($F=ma$) applied with Force Vectors. Force Vectors show the orientation and direction of an applied force.

Consider a person trying to push a 100 pound box on the ground (Figure 3). If he pushes the box in a horizontal direction, he must apply a 100 lbs-force to move the box. However, if he pushes the box from above (at a 34-degree angle), then he must apply a 120 lbs-force to move the same box. He is wasting 20 lbs-force pushing in the down direction. This is not efficient movement, because 120 lbs-force is exerted to move a 100 lbs load (20% inefficiently in the applied force).

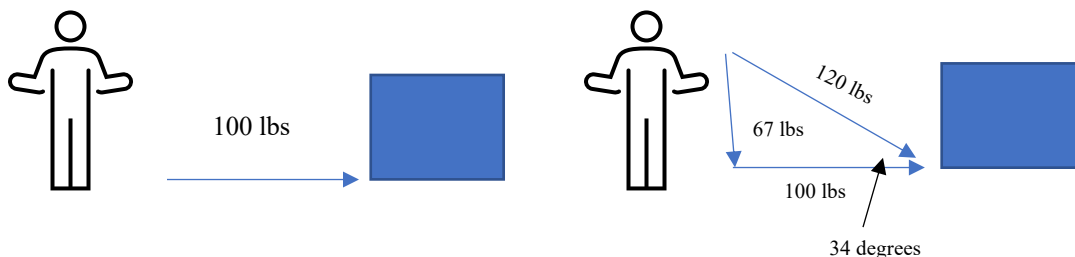


Figure 3: Force Needed to Push a Box Keeping a Center Line / Not Keeping a Center Line

This same Physics applies to karate techniques. For example, this occurs in the stance transition from back stance (*Kokutsu Dachi*) to front stance (*Zenkutsu Dachi*) in the Kata Heian Yondan (*Hidari Morate-Uki* in back stance to *Morate Kubi-Osae* in front stance). The stance transition also occurs in Khon and Khon-Ippon Kumite. If my left leg is forward and I shift from back stance to a front stance, the front left leg can first shift over to the left causing my center line to go to the left then forward. The Physics shows that this is not an efficient way to move. This shift in stance causes my body mass to be directed in two different directions. In this case my body mass represents the force generated by Physics: $F=ma$ (the moving body mass is the driver of this force). Referencing figure 4, the applied Force generated in the forward direction is reduced by not keeping the body in a center line. If I intend to apply 500 newtons of force, but I step over from my center line 30 degrees from the back stance before going into front stance, the actual

applied force to the target will be 433 newtons. About 67 newtons of force (500-433 newtons) would be wasted which is a 13% reduction in the applied force to the target.

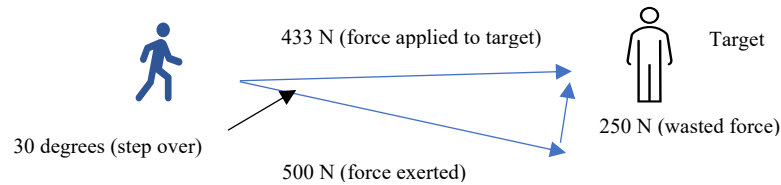


Figure 4: Force Vectors for Back to Front Stance Transition (not keeping body center line)

Conclusions

1. The Physics force vector analysis shows that the force applied to the target is wasted by not keeping a body center line when shifting stance.
2. A more efficient way to shift the body is to keep a center line directed at the target direction.
3. Stance transition from back to front stance (as performed in Shotokan kata and Kihon) should be performed with both legs shifting forward directly toward the direction of the target. This will keep the center line moving forward and maximize the force applied to the target.
4. In general, keeping a center line with the body when performing a karate technique will generate the most efficient transfer of force to the target. For example, when stepping forward, keep your body in a center line versus first stepping to one side then to the front.

Note: The step over angle alone from back stance to front stance will determine the loss in the applied Force. The percent loss in Force = $(1 - \cos \theta) \times 100$, where θ is the step over angle in degrees.

Apply Kime before making contact with the target

Kime in karate is translated as “to decide” in Japanese. My research into the meaning of *Kime* shows that there are many interpretations of what it is. However, the many interpretations all agree that the body should tense at the conclusion of a technique whether it is a strike or a block. Before and after the application of kime, the body should be relaxed so as to make the body movement faster. But what is the purpose of applying Kime? My research shows that applying Kime is based on Physics.

When punching and hitting an object like *makiwara* board, the fist must tense at the moment of impact with the board. Otherwise, the fist or wrist will bend and crumble due to the impact.

Newton's 3rd law says that "for every action, there is an equal and opposite reaction". This means that when I punch an object with 500 newtons of force, the object is hitting my fist with the same 500 newtons of force. If my closed fist is hitting a hard object, the object is hitting back, and I will feel this force. In order to brace for this impact, the body (fist, arm, whole body) should tense (apply Kime) for the collision with and through the target.

Conclusions

1. In Physics, Newton's 3rd law explains why we use Kime for karate techniques.
2. The body must relax while performing a technique and apply a brief kime just before hitting and through the target. And the body should relax after the completion of kime. This will brace for the impact and prevent injury to yourself according to Physics.
3. The Karateka should use Kime in Kihon, Kumite and Kata. Applying Kime is performed without hitting an object (in free space) during the 3K's. This will internalize the feeling and develop muscle memory of Kime.
4. There is no universal description for Kime. It is more of a feeling that one must internalize when performing karate techniques.

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Appendix 1: Newton's 3 Laws of Motion

1. Every object in a state of uniform motion tends to remain in that state of motion unless an external force is applied to it.
2. $F=ma$. *Force = mass x acceleration*.
3. For every action there is an equal and opposite reaction.