KARATE AND THE CENTER OF GRAVITY

by Jacques Chaurette

The center of gravity is a very important concept in karate. The forces that the body is subjected to while punching or kicking need to be related to the center of gravity (CG). We know that the lower our CG is, the greater our stability and also the easier it is to resist a horizontal push or strike. This short article seeks to explain what the CG is, where it is located depending on how the body's arms and legs are positioned and how this understanding can improve our karate abilities.

Definition : the center of gravity is that point at which if the body were suspended it would be perfectly balanced in all positions.

How is the location of the CG established? Figure 1 shows progressively more complex shapes and the location of their respective CG's. Imagine that all these shapes have a depth and therefore volume and weight. The location of the CG depends on the shape of the body or how far and heavy the various parts of the body are away from the CG. The mathematics of how this is determined are relatively simple, but we can do without the details for the purpose of this article.

The great usefulness of the concept of the CG is that it eliminates the problem of the complexity of the shape allowing us to concentrate on the interaction of the forces on the body and their position relative to the CG. In other words, the body can be seen as an empty shell with all its mass is concentrated at the CG. Figure 1 shows various shapes which all have the same mass. All the shapes have the same area as the square (Figure 1, Shape no.1) and therefore mass and volume. The difference we are interested in is how the variation in shape affects the position of the CG.

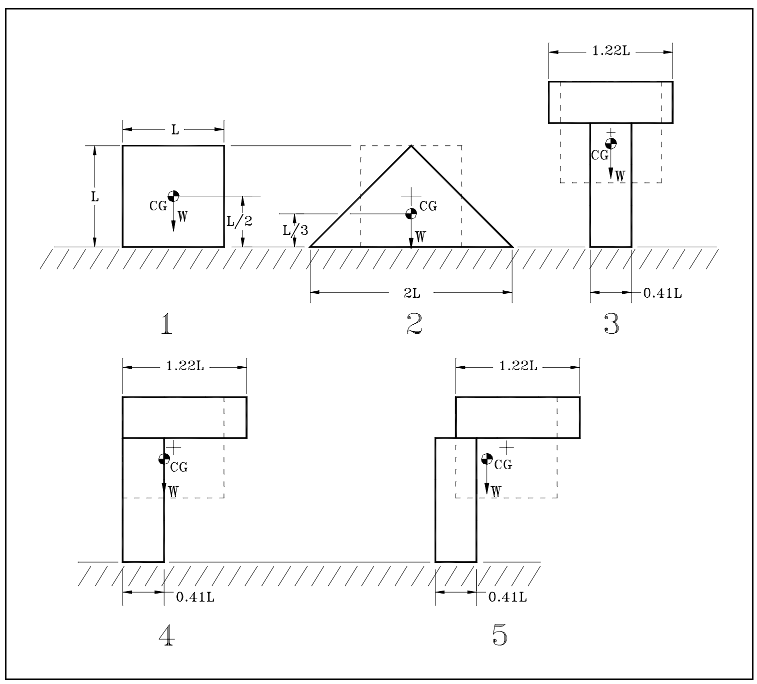

Figure 1 The position of the center of gravity for various shapes

For the triangle shape no. 2, the CG is low because more of the mass is closer to the ground compared to the square. This is similar to what happens when a karateka (karate student) assumes a low fighting stance (ex.: zen kutsu dachi). The tee shape no. 3 is exactly the opposite, and the CG is higher than the square's. Shape no. 5 is an example of a shape where the CG is located outside the body. This shape is similar to that of a human body bending forward with the arms out (more about this later).

It is a little more difficult to rationalize how the CG can be outside the volume of the body but it happens for certain non-symmetrical shapes such as shape 5. To convince yourself try this experiment, make cardboard cutouts of the shapes in Figure 1. Cut a straight piece of wire from a hanger and use it as a shaft around which you can rotate the shapes. Put the hanger through various parts of the shapes, you will notice that the only stable position is where the CG is located. For shape no.5 keep some of the cardboard around the CG point attached to the main part of the shape, this small piece of additional cardboard will not affect the results.

The high jump riddle

How is it possible for an athlete to get over a pole while his center of gravity does not (see Figure 2)?

Prior to 1968, the high jump was done with the traditional scissor movement. During the 1968 Olympics, Dick Fosbury earned the gold medal by introducing a new way of jumping which consisted of approaching the bar straight on , jumping, and then turning his body so that his back was to the bar and curled around it, thereby greatly increasing the height of the jump. For the same height of the CG, the Fosbury jump allows the athlete clear the bar where the scissor jump does not. It's a brilliant idea, it almost seems like cheating. However, if you got over the bar, you got over the bar.

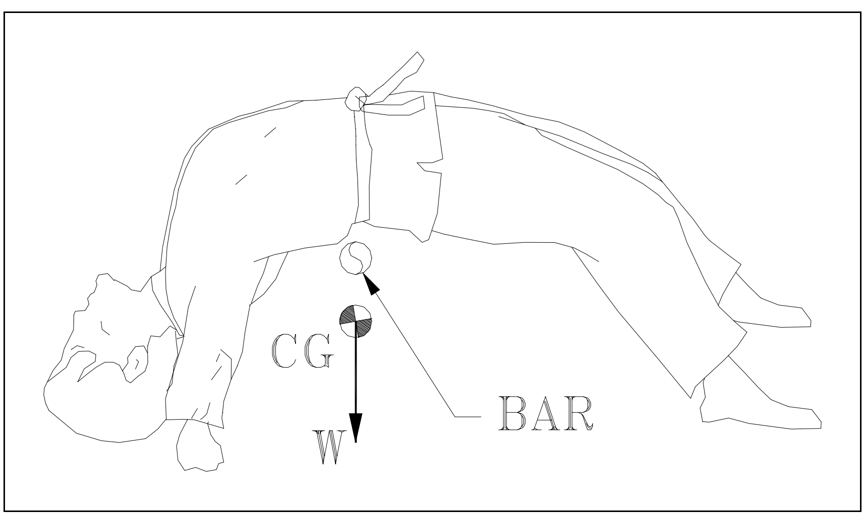

Figure 2 The Fosbury high jump

For a man standing or punching , the CG position is shown in Figure 3. The CG is normally located in the middle of the body at the hip level or approximately where the bellybutton is. However, since we have many joints throughout our body we can easily change the shape of our body and therefore the position of our CG.

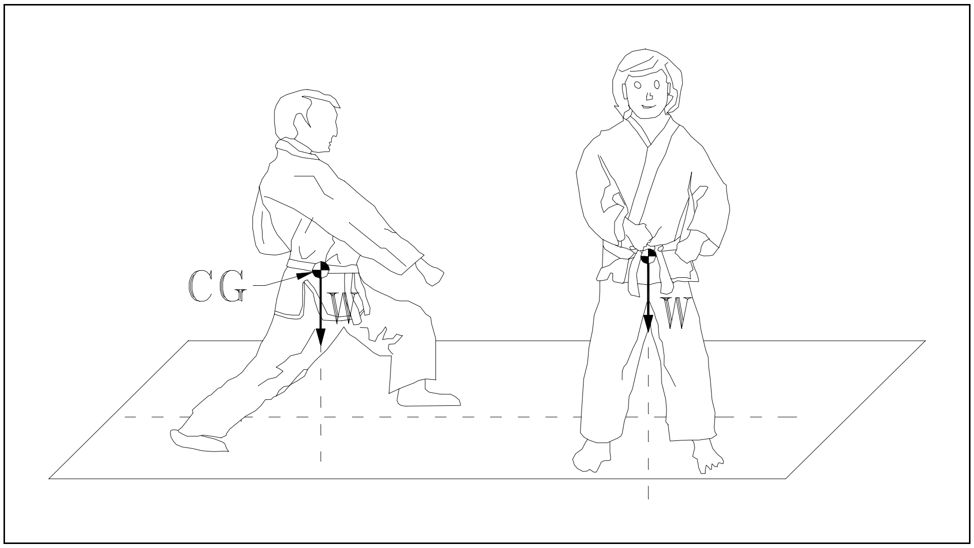

Figure 3 The position of the center of gravity for a man in a typical stances

Figure 4 shows a karateka in the various positions required to execute a front kick. In position A, he is standing, in B the knee comes up. In the B position, the location of the CG in the horizontal direction is the same as in A since if it wasn't then he would fall (if the CG is not above the foot, the karateka will fall). This means that the upper part of the body rotates back a to compensate for the weight of the right leg going forward. In position C, the body is moving forward by rotating on the left foot to strike the target. At position D, the body is fully forward and at the point of contact, the CG is now at its furthest position horizontally with respect with the heel. This forward movement of the CG is highly desirable. The further ahead it is, the larger the impact force F can be.

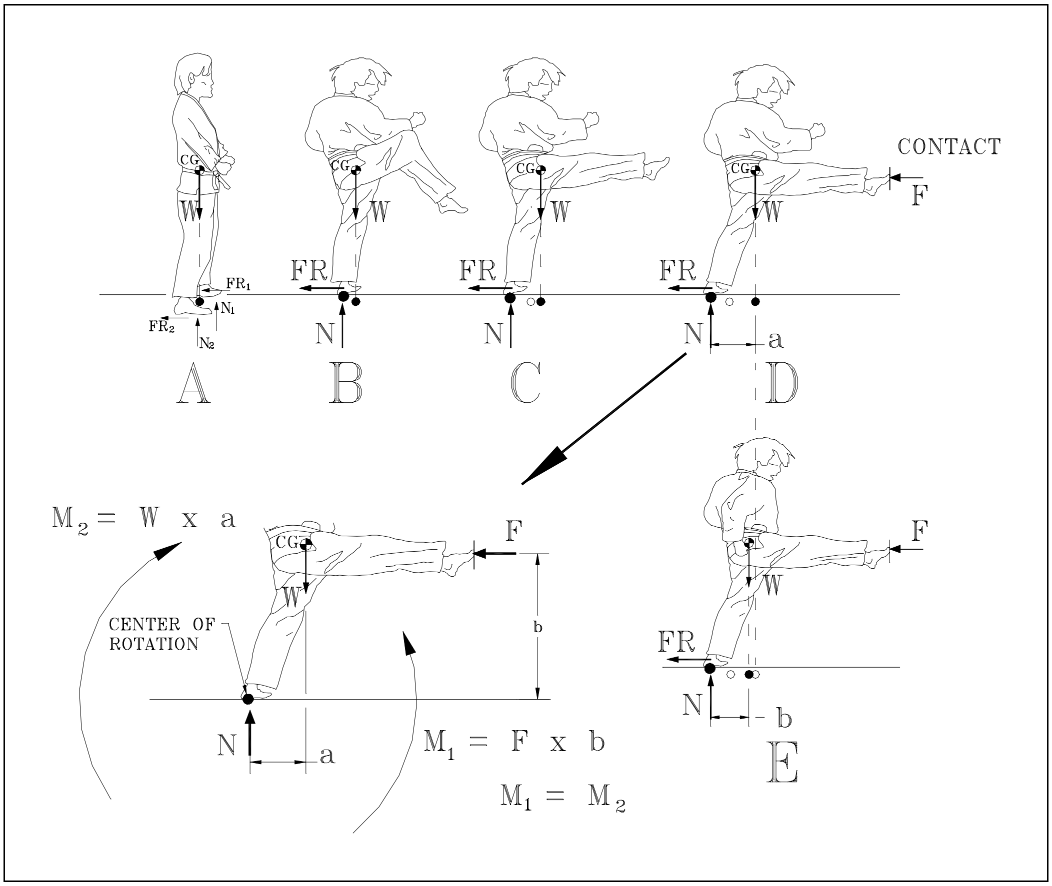

Figure 4 The position of the center of gravity while front kicking

Placing the arms forward, contributes to the forward movement of the CG. This has the added benefit of keeping your hands in a protective position. If the hands are low as in position E then the CG is moved backward, thereby reducing the magnitude of the force of impact F that can be withstood or delivered.

The contact force F produces a moment (M_1) which tends to rotate the body counter clockwise around the left heel. A moment is the rotational equivalent of a force.

It is at this point that the concept of center of gravity becomes very useful. Since all the body's weight can be thought of as being concentrated at the CG, we now know where to position the force W which represents the weight of the body. The direction of this force is of course always downward. The force W produces a moment (M_2) which rotates clockwise around the left heel. Both moments M_1 and M_2 have to be equal in order for stability to be achieved.

The counter clockwise moment M_1 produced by the impact force F is equal to the clockwise moment M_2 produced by the bodies weight.

$$M_1 = M_2 \qquad [1]$$

The moment M_1 due to the impact force F is:

$$M_1 = Fb \qquad [2]$$

The moment M_2 due to the body's weight W is:

$$M_2 = W a \quad [3]$$

The moment M_1 equals the moment M_2:

$$F b = W a \quad [4]$$

The magnitude of the force F:

$$F = \frac{W a}{b} \quad [5]$$

Equation [5] gives the terms which influence the magnitude of the force of impact F. To increase the force F, the weight W and distance a should be as large as possible and b as small as possible. The weight W is fixed, and of course the larger it is the better. The distance b depends on the target height. This height can be changed depending on the circumstances and target location, however if we are doing a traditional front kick aimed at the mid-section, this height is fixed. The only other dimension we can affect is the distance a, that is the distance between the left heel and the CG. The greater the distance a, the greater the impact force F can be.

Therefore, to achieve the maximum kicking efficiency, stretch the kicking leg forward as far as possible and keep your hands up to maximize the distance of your center of gravity from the forward heel.

The position of the center of gravity is of equal importance if not more when side kicking (see Figure 5). In position A, the karateka's upper body is downward and almost horizontal. Even before contact is made, this person's stability is very precarious. The CG must be at least located between lines 1 and 2 to avoid falling sideways. In position B, the karateka has improved his posture by lifting his upper body. Now the CG is to the left of line 1 and follows a vertical line that intersects the floor a distance **a** from point 0. The goal is to maximize the distance **a**. As the karateka continues to improve his posture, as in position C, the distance increases. Finally, in position D, we can get one more improvement by moving the arms sideways in the direction of the kick. This has the important added benefit of bringing the hands to a proper defensive/attack position. As the karateka moves from position D to E and makes contact, he will have maximized distance **a** which allows him to deliver a greater impact force. The same equations that were developed for front kicking also apply to side kicking.

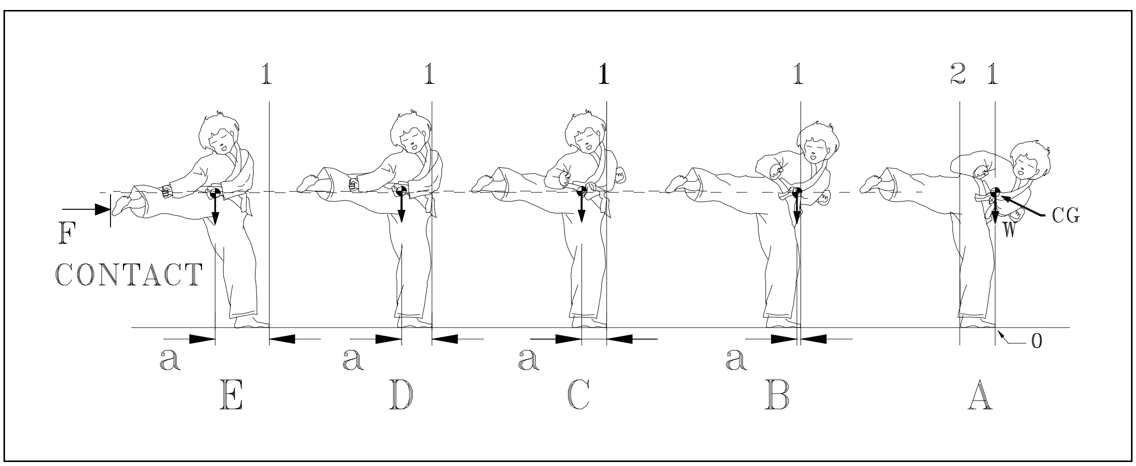

Figure 5 The position of the center of gravity while side kicking