Hitting mechanics of "The Science of Hitting" from the Twisting Model

By Takeyuki Inohiza

The Science of Hitting by Ted Williams is an excellent book. Ted Williams wrote everything about hitting he obtained through his career in this book. However his explanation on hitting mechanics is vague for it is based on his personal perception.

Recently I surprisingly found that by applying the Twisting Model theory, his explanation on the hitting mechanics becomes a lot clear and helped for better understanding regarding movement and property of power produced.

In this article I would like to introduce the "Twisting Model" and by using physical approach I would like to show how the Twisting Model supports Williams.

1. The Twisting Model

1) Mechanism of power on the Twisting Model

The Twisting Model assumes that critical power for baseball is based on structure of body and the power has profile of a spring. It also assumes that such power from the structure is more important than the power from muscles in baseball. Interesting thing is the model theoretically predicts what kind of power is produced by which movement generally believed right in the field. One example is bat-swing.

It predicts bat-swing is one action with two processes, one is process of developing potential power and the other is process of releasing it. And by knowing it, a player will improve his performance swinging accordingly on purpose. First let me introduce Twisting Model and how it explains mechanism of power with baseball.

a) In pictures 1 and 2 (Picture 1, Picture 2), I am bending bristle grass to observe how power is accumulated in the grass. To accumulate power by bending, 2 different vectors of opposite directions are needed. We use our body in the same way when we hit (or throw) a ball. When hitting (or throwing), we produce power by using upper-body (above hip joints) and lower-body (below hip joints) with opposite force vectors at different timing. (Picture 3)
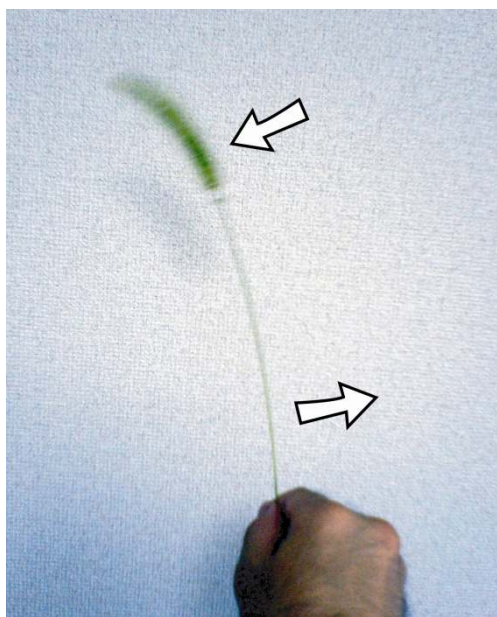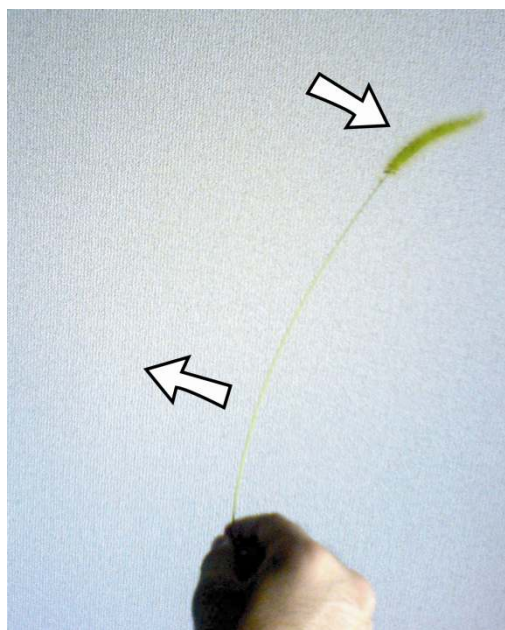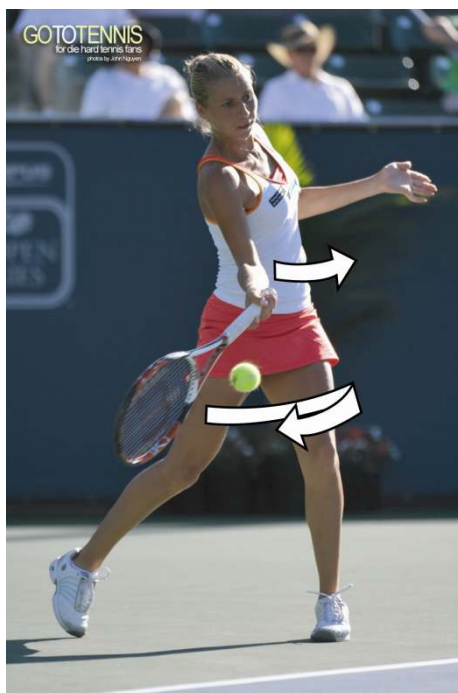
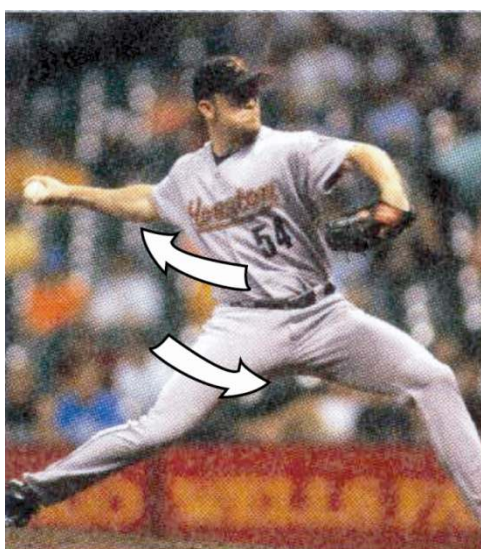Picture 1   Picture 2

In picture 3 (Picture 3), a tennis player is hitting a ball using her upper-body and lower-body at different timing to generate opposite vectors to developing power. She twists in backward and moves forward but moves her lower body first. In the lower body, the twisted power naturally twists back by stepping the front leg, followed by another twist coming in the upper-body. You can see such twisting combination is accumulating/generating potential power in her body for hitting a ball.
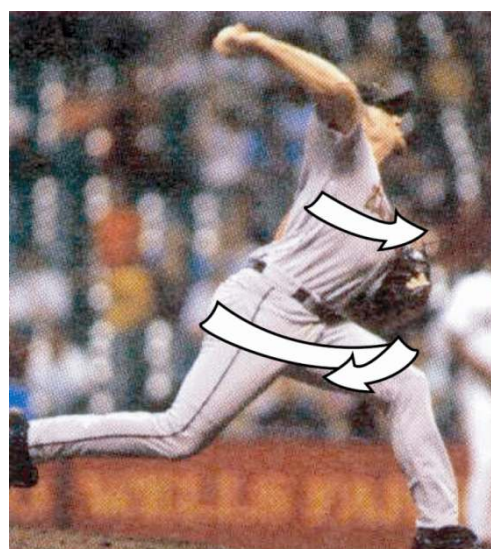
Picture 3

Pictures 4 and 5 are of pitching of MLB player Brad Lidge as he throws a fastball. (Picture 4, Picture 5)   He is also using his upper-body and lower-body twists in different timing. He twists his body in backward then steps forward to generate a twist-back in his lower-body that meets the upper-body twist at the right timing to generate power (vector) for throwing. Since both twist-back (after stepping forward) and twist-forward are centered on the hip joints, the more flexible around the hip joints, the more power will be generated in the body.

Copy right: Seibido Shuppan, Tokyo, Japan
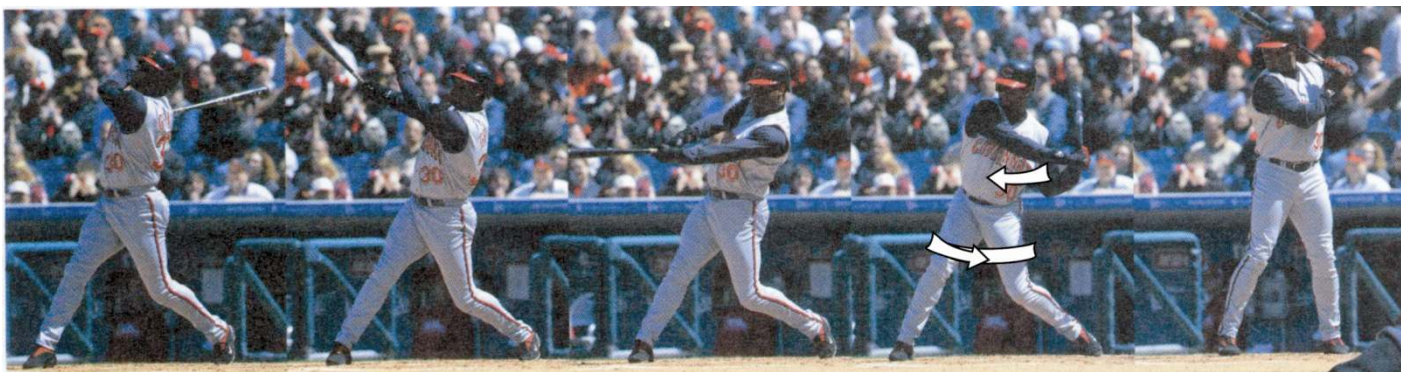
Picture 4

Copy right: Seibido Shuppan, Tokyo, Japan

Picture 5

Ken Griffey (Picture 6) is also producing power by twisting combination of his upper-body and lower-body in

different directions. He steps quite inside which causes strong twist-back in his lower-body. The only difference between Ken Griffey and the tennis player on Picture 3 is the angle of their wrists.

Picture 6

In this "Twisting model", since power is generated by "twisting", its property/profile can be described as "wave" like a spring. Illustration 1 shows that two power waves, one is the wave of upper-body and other is the wave of lower-body meeting/ interfering to generate a bigger wave. By this reason potential energy for hitting in the Twisting Model is described as elastic energy such as one in a compressed spring producing in it.

On Twisting Model, this process is important for both hitting and throwing. Twisting stress produced by lower body and upper-body develops a single/ bigger potential energy that throw/hit a ball forward.

Often this process is misunderstood as "rotation". But power for hitting by rotation and by twisting are different things. I think this difference confuses baseball players. I would like to emphasis the Twisting Model is based on "twisting" as Illustration 2 (Illustration 2) but not "rotation" like a spinning top.

$$a = \frac{d^2X}{dt^2}$$

$$V = \frac{dX}{dt}$$

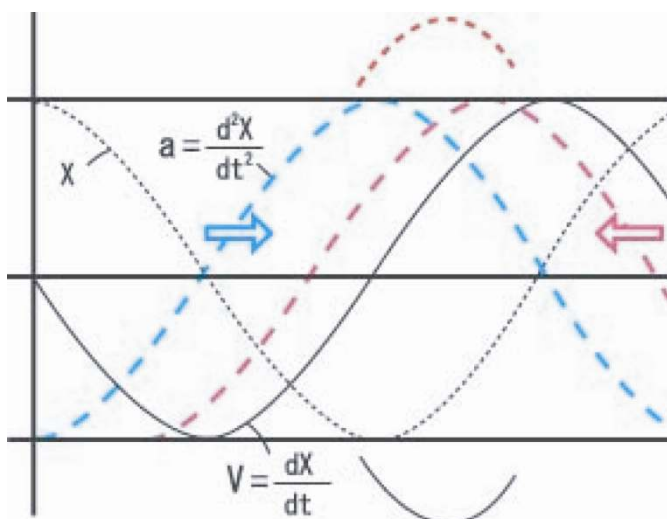Illustration 1
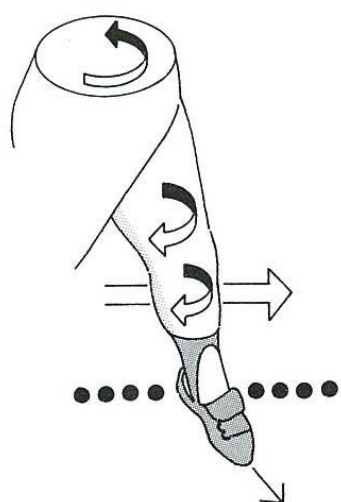

Illustration 2

How upper-body twist meets with lower body twist

2) Mechanism of power on The Science of Hitting

Williams wrote the most important he can think of is the cooking of the hips. Let me quote from The Science of Hitting.

"Now, with your weight evenly distributed, your hips starts out at level. You don't worry about hips until you actually begin the performance of the swing. The hips and hands cock as you move your lead foot to stride, the front knee turning in to help the hips rotate back. You are cooking your hips as you stride, and it's so important to get that right. It's pendulum action. A metronome-move and countermove. You might not have realized it, but you throw a ball that way. You go back, and then you come forward. You don't start back there. And you don't "start" your swing with your hips cocked."

What does Williams mean by the words "cocking of hips" or "pendulum action? Let me think Williams' explanation introducing Twisting Model. I added some arrows and lines into Williams' pictures in his book to show how potential energy of the Twisting Model is produced and released as below.

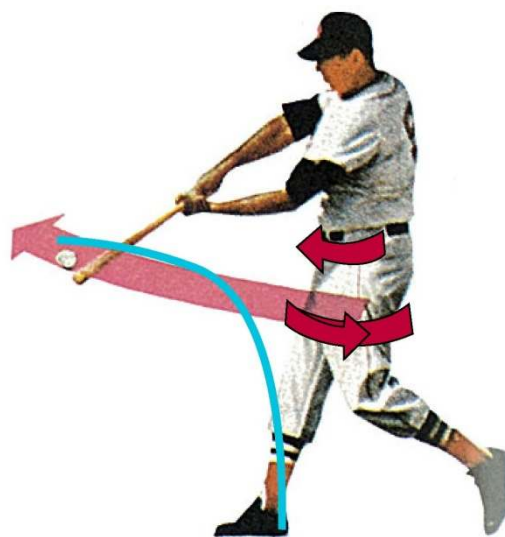Picture 7   Picture 8

In the picture 7 (Picture 7), I added an arrow of lower body twist. And in the Picture 8 to 10, I wrote two arrows at waist and lower body that are twisting combination, and also a line to indicate what kind of potential energy is produced by the combination. In the Picture 8 (Picture 8), original arrow at hands should be inertia force from a bat , that cocks his hands, and you can see the three arrows are producing potential energy such as like the bending bristle grass (Picture 1 to 2) which I drew with the line. This is exactly "pendulum motion" Williams explained. Twisting Model prediction and Williams' explanation both reasonably fit like putting missing parts of puzzle.

This process indicates that shifting most of weight on the front leg is needed to fix the end of the "plate spring" of

the potential energy of the line. Williams should have known that the hitting power is from combination of power, tensor because two arrows are already in the original Picture 9 (Picture 9).
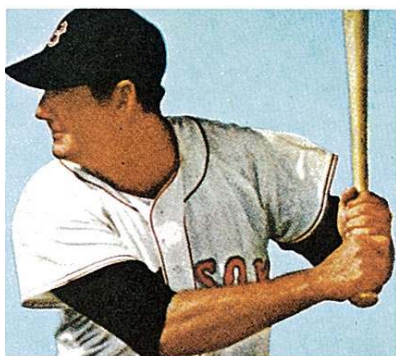

Picture 9   Picture 10
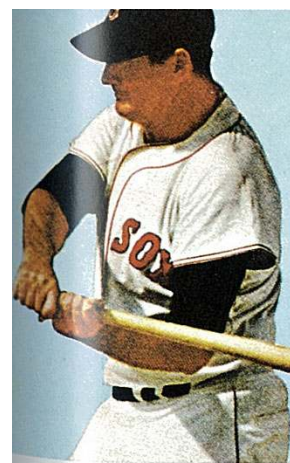
Looking into the line of potential energy, you will see that hitting is one action with two processes, accumulation of potential energy and its release. Below pictures (Picture 11-13) would be of process for accumulation of the potential energy, namely "compressing process".

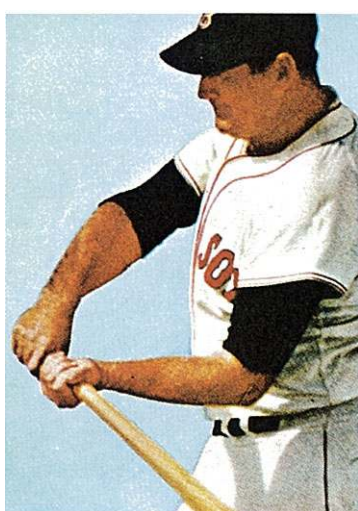Picture 11   Picture 12   Picture 13
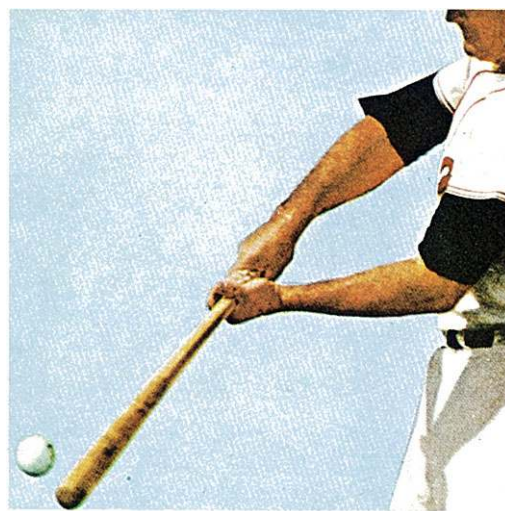
Process of potential energy development

And these pictures (Picture 14-16) would be of process for releasing the energy, let's say "releasing process".
So the Twisting Model predicts that optimally on the compressing process you should relax/being soft on your body is better for compressing and at the releasing process being hard is better for produce power for hitting.

| Picture 14 | `Picture 15 | Picture 16 |

Process of the potential energy release

This consideration indicates the more you produce potential energy the more you can produce power. Therefore in the Twisting Model it predicts that one of the critical differences between slugger and average hitter would attribute flexibility around hip joints at hitting motion. The more structurally flexible the more they produce potential energy. Therefore by introducing proper exercises for the flexibility at hip joints to young players, it will help for raising talented players. This is interesting topic but another discussion. If you are interested in please refer to "A new batting model for the Twisting Model".
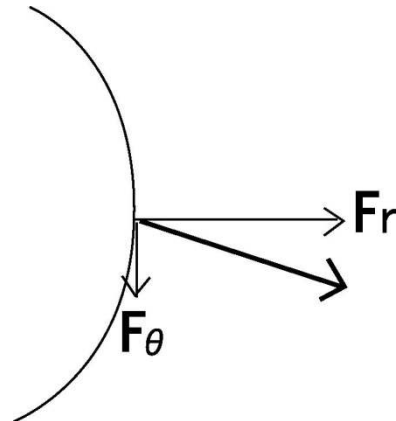
2. Property of power

Let me consider property of power produced by" rotation" and "twisting combination" that will help for supporting "push hitting" and "pull hitting" discussion between Ty Cobb and Williams in the Science of Hitting.

1) Property of power on the Twisting Model (Impulse toward r-direction)

At the contact by hitting a ball, power is added toward three directions based on polar coordinate. According to the Illustration 3, suppose they are r, theta and phi. To make matters simple I will use two dimensional polar coordinate r and theta for further consideration. (Illustration 4)
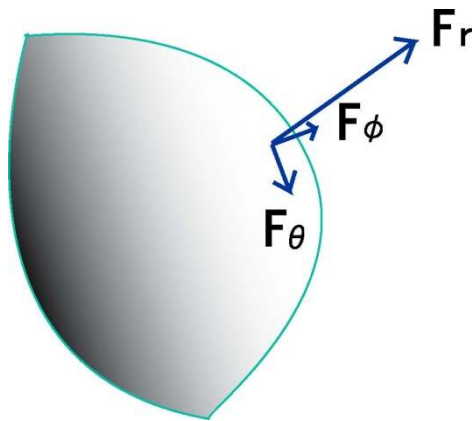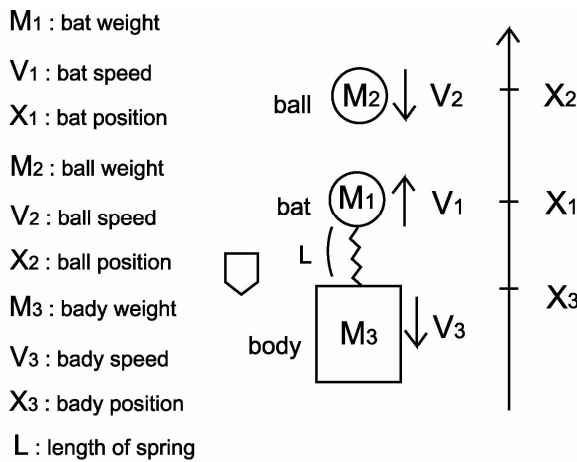
Polar coordinate (Illustration 3)　　　　　Two dimensional polar coordinate (Illustration 4)

On the Twisting Model it predicts critical power for hitting is produced toward r-direction (Illustration 3-4) because it comes from elastic energy like a spring (Picture 8) and its profile is liner. And the impulse of the r-direction will contain impulse from body itself.

Simplified Twisting Model (Illustration 5) is showing this r-direction momentum is kind of shooting a bat from a body by a spring. Point is that this model has an impulse term from body (∫ Fdt), not only impulse from a bat, in its momentum equation. Please be noted that in this model mostly power is produced to r-direction which is liner.

This model predicts while bat speed is slow, power (acceleration) from the body is high. This happens because bat speed and acceleration (power) from body are differential-integral relation and they cannot come up at the same time. They contradict so in this model you don't need to focus on swinging a bat as fast as you can.
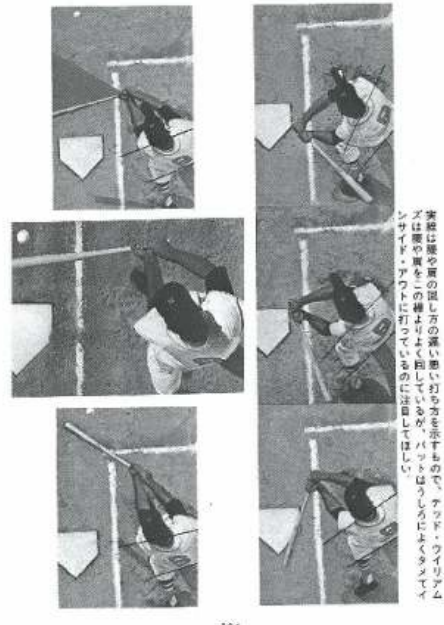

M_1 : bat weight
V_1 : bat speed
X_1 : bat position
M_2 : ball weight
V_2 : ball speed
X_2 : ball position
M_3 : bady weight
V_3 : bady speed
X_3 : bady position
L : length of spring

Conservation of momentum

$$M_1V_1 + M_2V_2 + k\Delta Ldt = M_1V_1 + M_2V_2 + \int Fdt = P \text{ (momentum)}$$
$$(V_3 = 0)$$

Simplified Twisting model (Illustration 5)　　　　　Picture 17

Rather you should focus on appropriate inside-out bat maneuver (Picture 7-10) for producing potential energy and contact a ball toward r-direction that will be more important than swinging a bat as fast as possible.

2) Property of Rotational Model (Impulse toward theta direction)

Then let me consider the conventional Rotational Model. (Illustration 6) This model assumes that only momentum from bat works but impulse from body is ignored. Optimally all the power needs to be consumed for speeding a bat before contact for this reason it takes only theta direction (rotational direction) impulse (Illustration 7) into consideration. And according to this model, conclusion is simple. You need to swing a bat as fast as possible for higher batted ball speed (BBS).

This model is widely accepted though in my opinion assuming only rotational impulse and momentum from bat speed does not fit to real baseball. It is not sufficient to describe activities/movement such as one in The Science of Hitting.

The reason why this mode ignores impulse from a body is that there are some objective tests results which conclude impulse from body does not contribute for the BBS. According to the tests by the time impact wave from a ball reaches on the body through a bat, the ball is leaving from the bat. However in my opinion it depends on the test condition. It depends on direction to which the impulse occurred. (Illustration 7)

ball (M_2) $\downarrow V_2$ theta-direction (rotational)

bat (M_1) $\uparrow V_1$ r-direction belly body
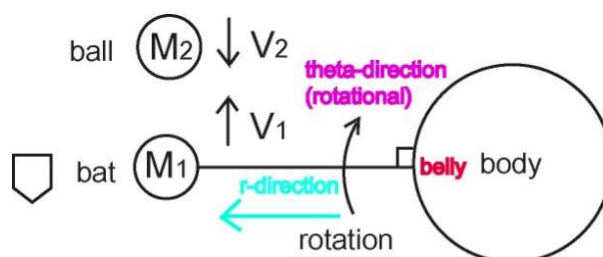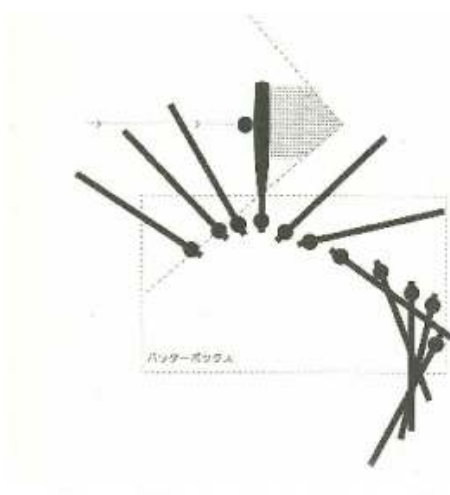
rotation

Conservation of momentum

$$M_1V_1 + M_2V_2 = P \text{ (momentum)}$$

Rotational model / The Physics of baseball (Illustration 6)   Simplified Rotational model (Illustration 7)

For example if the test is conducted under the Rotational Model condition as Illustration 6, impulse from body that works toward r-direction is square to the ball coming in (Illustration 7) therefore it should not work. There will be no record of impulse from the body with the test. So the test results will be only effective under the optimal Rotational Model condition.

In my opinion even with the Rotational Model, impulse term from body should appear if it's done on r-direction to which the impulse works. An example is that hitting a ball in front gives a player powerful hitting than the side.

Apart from such discussion I think this model is helpful to understand what the impulse toward rotational (theta)

direction is. I think in reality both impulses toward r-direction and theta-direction work for deployment of potential power at impact.

3) Push hitting and pull hitting

Once Williams was having hard time learning to hit to left. And he had a lot of advice even from legendary Ty Cobb. Although he thought "Cobb was completely different animal" from him. He wrote "Cobb was more of a push hitter, a slap hitter. He choked up two inches apart. He stood close to the plate, his hands forward. ".He wrote like this but he overcame this problem by the push hitting. Let me quote.

"I did it by taking my stance a little farther from the plate, striding slightly more into the pitch-but concentrating on getting on top of the ball and pushing it. A push swing, an inside-out swing, fully extended, the hands ahead of the fat part of the bat."

If you apply the impulse of r-direction for the push hitting and impulse of theta-direction for the pull hitting, assuming for both pull hitting and push hitting the inside-out bat maneuver is necessary for producing potential energy of hitting (Picture 7-10), this hitting discussion will becomes reasonable.

Below Illustration 8 and 9 (Illustration 8-9) are for pull-hitting of Williams. I put arrows to show directions of impulse working. Suppose the impulse toward r-direction is for push-hitting and impulse by rotation is theta direction.

According to the Twisting Model, by inside-out swing initially r-directional energy is produced and it gradually split by theta rotational direction and r-direction. The reason for "pulling" a bat will be for increasing centripetal force that would produce torque for toward rotational direction to right. This is pull hitting but r-direction impulse is also important.(Illustration 9) Suppose you hit in the back while belly facing the side (Illustration 7), in such case only momentum of bat will work and in general "hitting power" is a lot reduced.
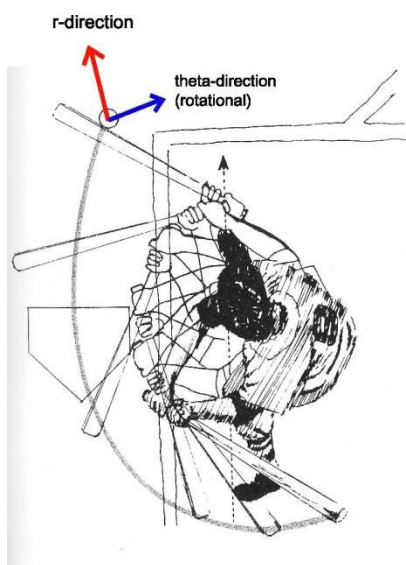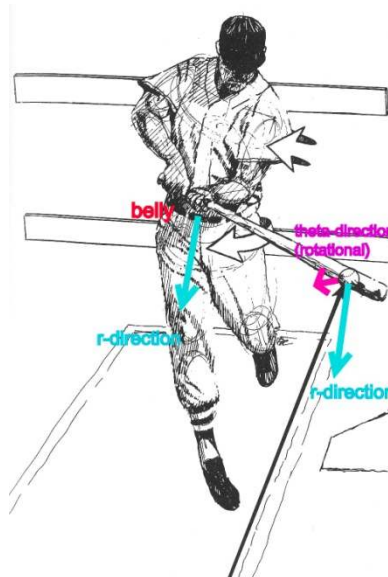

| Illustration 8 | Illustration 9 |

The Illustration 10 and 11 are for push-hitting. According to the Twisting Model, the arrow for rotational (theta) direction is pretty small. On the push-hitting r-direction impulse is dominant that is not based on bat speed but impulse from body. (Illustration 5: the term of ∫ Fdt on the equation is this.) In this case bat speed is not as fast as pull-hitting but an impulse from body toward r-direction is much bigger. So it works toward opposite direction, r-direction. (I think this is the technique Josh Hamilton hit a big homer on opposite direction too.)

And because the energy is stored by twisting combination of upper-body and lower-body (Picture 7 to 10), r-direction means roughly the direction the belly is facing. To this direction you can hit strongly. In any way unless the potential energy, you cannot hit strong according to the Twisting Model.
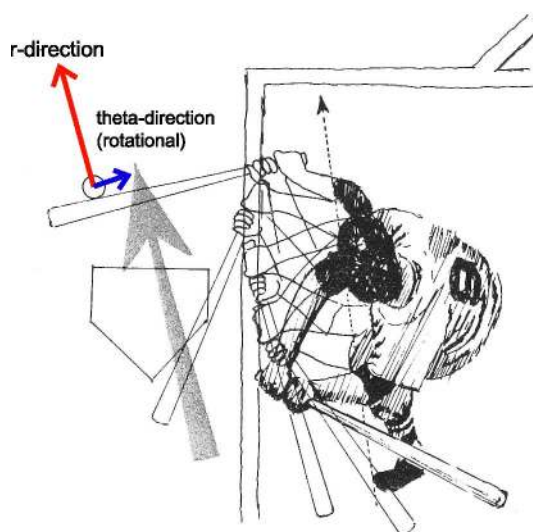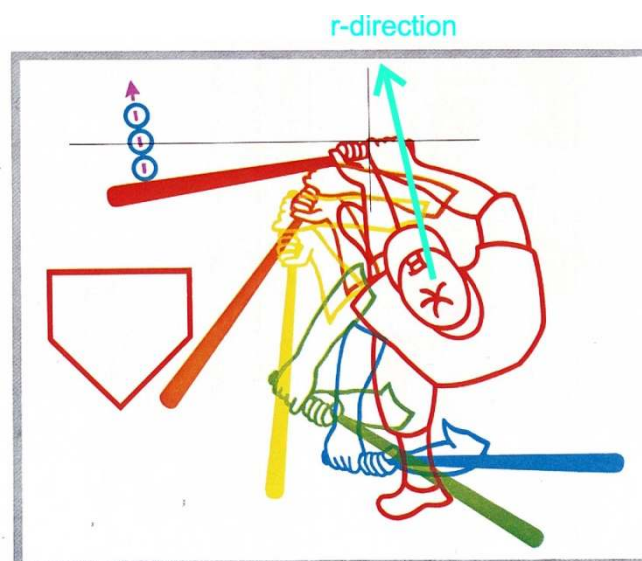

Illustration 10   Illustration 11

Interesting thing is that the rotational force toward theta direction and the force toward r-direction contradict that means the faster you swing a bat the more the r direction force is reduced by centripetal force.

For example often time you will see a player focus on getting fast bat speed at impact but because bat speed is obtained mostly toward rotational theta-direction that movement reduces impulse of r-direction. And sometimes it causes "slump" of players. In my opinion it happens because hitting only by momentum from bat speed would be less powerful than impulse from body that is contained in the impulse toward r-direction.

Suppose your weight is 80kg. Under right condition, it will work like 80kg hard concrete block hitting a ball with acceleration (power) that would be something. (again the term ∫ Fdt on the equation: Illustration 5) Therefore using r-directional impulse is important for hitting for the Twisting Model.

Williams wrote inside-out swing works for getting out of hitting slump in The Science of Hitting. My guess is that it was for producing potential energy for r-direction rather than producing bat speed that is theoretically reasonable from the Twisting Model point of view.

3. Tips of hitting for fieldwork

Discussion of hitting mechanics will continue. In this chapter I put my opinion of tips of hitting for a person who may try hitting by oneself to see how Twisting Model works.

1). Bat weight

Optimal bat weight depends on players. For producing potential energy, a heavy bat is preferable (Picture 11-13) on the other hand if it was too heavy it takes time for bat deployment for contact. (Picture 14-16) The time will depend on the potential energy stored too. So that optimal bat weight depends on player.
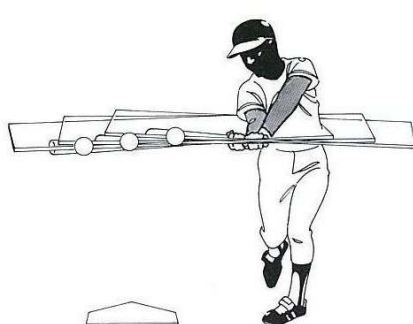
2) Power hand-which is it?

I support Williams' opinion. Forehand stroke is stronger than backhand. (Picture 3) Advantage of backhand is it naturally leads a bat toward r-direction. My opinion is that leading a bat by backhand and deliver power by forehand is reasonable (Illustration 9) whether it is pull-swing or push swing.
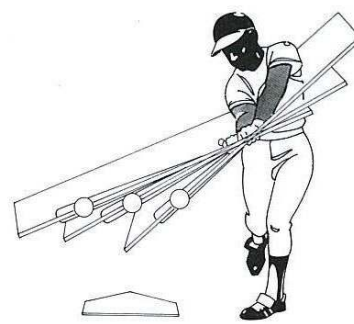
3) Swing level

Bat approach is also a discussion. Williams recommends up-swing whereas Hank Aaron supports down-swing. I support level-swing as Mr. Murakami wrote in his book Kagakusuru Yakyu (Baseball Science). According to Murakami, optimal approach of a bat is toward direction a ball is coming in thus level swing would be optimal. And he defined the level swing as bat approach is level with fictive surface toward ball height. (Illustration 12 to 14) I support these approach for they are direct toward a ball for r-direction impact.
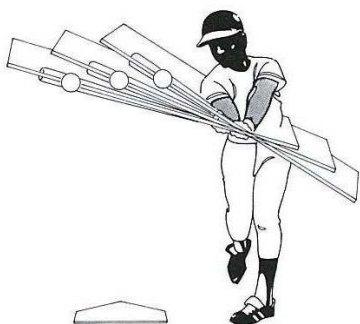
Level to high (Illustration 12)   Level to middle (Illustration 13)   Level to low (Illustration 14)

Most of strikes would be lower than waist so naturally most of optimal approach would be "Level to low" (Illustration 14). I think Williams' instruction is for this one. Aaron's down-swing should be the same thing for bat should go down to low.

And for high ball Illustration 12 is suitable especially for hitting a bean ball near head. This style may fit Ty Cobb's hitting a bean ball around his head. It's fun to imagine like that.

5) Angle of grip

Wrist position is also important for power delivery. I believe grip with a palm of bottom-hand up and palm of top-hand down to the ground at the impact point would be the right way. At least I recommend keeping palm of bottom-hand up, which is power hand that would convey power. Illustration 15 is a good example and Illustration 16 is a bad example.

図24

図25
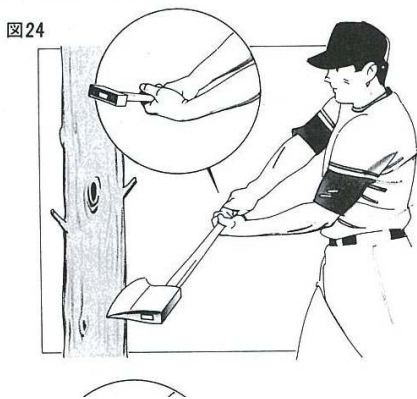
Squire grip (Illustration 15)   Bent with bottom hand (Illustration 16)

6) Direction of your step (Find appropriate step for your" r-direction")

For optimal hitting, from the Twisting Model point of view, stepping deep inside is preferable for producing power. However not everyone can swing like Ken Griffey by stepping so inside. (Picture 18) Because it depends on flexibility at hip joints of players that is vary by individual. So that position of step would be also vary by individual.
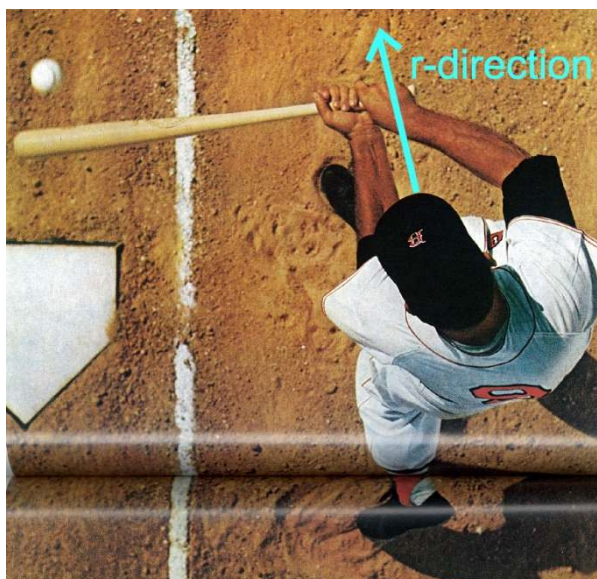
The more flexible at hip joints the more step inside. In contrast for the less flexibility the less inside step is recommended. Please find appropriate step for yourself at which your r-direction (belly) can freely face to the center field. (Illustration 17, Picture 19)
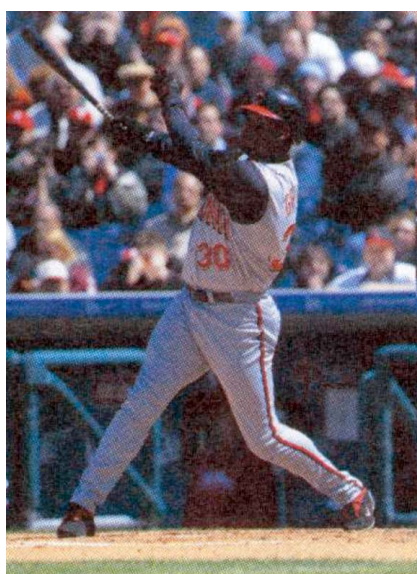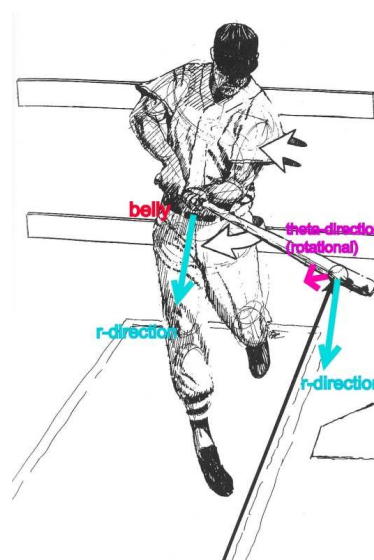
(Picture 18)   (Illustration 17)

(Picture 19)

Attached video (or You Tube "http://www.youtube.com/watch?v=6vL8K1B6ZLI&feature=youtu.be") is how I tested my position of step. Speed of the machine was 135km/h.

In the beginning of the video, I hit stepping deep inside but due to my low flexibility at hip joints, I could not convey r-direction impulse from my body to a ball and made poor results. Then I gradually stepped out-side and when I got right step, at which my r-direction (belly) can face to the front (Picture 19), I started hitting well.

Stepping out-side will cause less power and I had to give up hitting "out-side low" and real fastball thus how I found physical limitation of my capability.

Conclusion

This article is only an assessment of the Twisting Model by looking into explanation of The Science of Hitting by Ted Williams. However, according to my observation, Twisting Model well fit to a lot of professional player's movement.

Problem of the Twisting Model is it's still new and still regarded as experimental model in academic society than the conventional Rotational Model.

As for potential application of the Twisting Model, since it predicts critical point for producing potential energy is flexibility around hip joints at playing, introducing appropriate exercises for that purpose will

1) Raise talented athletes effectively rather than just hard work.

2) Prolong player's life-time.

3) Work for preventing injury.

4) Keep children/players away from using muscle enhancing drug for muscle is not critical issue for the Twisting Model.

Further study is awaited for developing these potential of the Twisting Model.

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